Community college students' plant biodiversity learning experience in an introductory biology course: exploring the value added by using a CD-ROM to develop inquiry lessons

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COMMUNITY COLLEGE STUDENTS’ PLANT BIODIVERSITY LEARNING EXPERIENCE IN AN INTRODUCTORY BIOLOGY COURSE: EXPLORING THE VALUE ADDED BY USING A CD-ROM TO DEVELOP INQUIRY LESSONS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Educational Theory, Policy, and Practice

by

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B.S., University of Puerto Rico, 1987
M.S., University of Puerto Rico, 1992
August 2007
DEDICATION

My grandmother, Margarita Perez Grajales (1907-1984), was one of eight sisters born to Canarian immigrants Margaro and Carmen. She grew up in her parents’ coffee plantation in Naguabo, Puerto Rico, where she developed her “nature sense of place”. Grandma moved to the city after getting married. A lady of hats, gloves, and embroidered dresses (and always a tight waistline!) for the social events, she kept her nature-connection in her house’s big backyard and garden.

She completed up to 6th grade in school. She knew something about everything. She could talk from sports to fixing radios, from medicine to sewing. Her knowledge of nature and accurate observations were the essence of an accomplished naturalist. We watched together when the first man set foot on the moon, and she would not miss any of NASA’s developments. In her late years, we would not miss an episode of Marty Stouffer’s “Wild America”. Grandma could predict a storm based on the avocado harvest, make tea from certain plants to treat fever or “tummy ache”, and notice how some insects and birds were not that common anymore.

Grandma was my first teacher. Before I went to kindergarten, I already knew about the benefits of composting as well as writing the numbers and letters. More than anything, she taught me, and my 10 cousins, about her love and respect for God and Nature.

To the memory of grandma

~ Abuelita Margot ~

...and to all, who like her, leave a legacy

of love, understanding, and conservation of our planet

through their teachings.
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As I am making the final revision of this work, a friend called from Puerto Rico. He reminded me about something I will be glad of not hearing anymore… “Are you done yet?”

Graduate school is a unique experience, a journey of dual discovery of knowledge and self. Reaching the goal of completing this degree has represented a journey of commitment and dedication for many years. My journey would not have been possible without a support team of family, academia mentors, and friends.

The help of my husband, Fermín Rodriguez, made the completion of my degree much easier. He has endured a wife in graduate school for most of his married life, being side-by-side riding the rollercoaster. He has done everything he could to help me finish. He has provided invaluable technical support with the computer as well as playing Mr. Mom. In the last year, he has not missed homework, swim and t-ball practice, birthday parties, or girl scouts camp to allow me some time to analyze and write. The light of our eyes, Erika and Alex, have been very patient and understanding even at their young age. Thanks for all your love.

My mom Maggie Grajales raised me with unconditional love. In spite of the many sacrifices of a divorced working mom, she was always there for me. She was by my bedside when I was sick, and always followed all my school activities. She encouraged me always to do my best. Her motto was the best thing she could provide me was a good education and the moral values to be a responsible citizen. Mom...I think you did it! I look forward to pass this lesson on to my children. Mom, along with my aunt Minerva, and my mother-in-law Edith helped us by traveling whenever possible from Puerto Rico. They not only provided additional hands to help with the kids but also lots of prayers and emotional support throughout the journey. There are no words to express my gratitude to each one of them, as well as to the family and friends abroad.
for the phone calls, e-mails, chats, and occasional visits always encouraging us to keep going to
make the goal a reality.

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ABSTRACT

This study examined the value added to standard textbook-based instruction of plant biodiversity by the use of the exemplary interactive CD-ROM, *Conserving Earth’s Biodiversity*. This CD-ROM features renowned conservation figure E.O. Wilson. The setting of the research was an introductory biology course in a rural public community college in the Deep South. Six participants were purposively selected to represent three levels of achievement and two groups, the CD-ROM group (exposed to CD-ROM in addition to the textbook) and the textbook group (only course textbook). Students experienced lecture-based, textual, virtual, and real experiences, and examined their ability to understand biodiversity-related concepts and to pursue guided-inquiry questions about local plant biodiversity. Their performance was assessed through activities, quizzes, concept maps, interviews, surveys, and students’ presentations.

This study led to three main findings. First, use of the CD-ROM, in addition to the textbook, allowed students to form a well-rounded grasp of plant biodiversity. Second, use of the CD-ROM enhanced the development of inquiries on local plant biodiversity and the metacognitive phase of assigning roles for local plant diversity. Third, the *Plant Biodiversity Literacy Rubric* [PBLR] was developed, based upon the history of the concept of biodiversity and was used to evaluate students’ progress by assigning them to various levels of understanding during the study.

The students in the CD-ROM group gained a broader perspective of plant biodiversity-related concepts, such as levels of biodiversity, hot spots, genetic diversity, food plant diversity, and threats to biodiversity. The CD-ROM was never detrimental to the learning process. They were more self-directed in their development of inquiries, felt more confident about their presentations, and were more metacognitive during their inquiries. Performance on specific
activities such as the essay and The Golden List of Species suggested an enhanced cognitive-behavioral/affective experience for students in the CD-ROM group.

The PBLR is an exportable instrument, which may allow ecology educators at all levels to assess student’s levels of understanding in a sensitive way. At this time, it is critical to gauge effective understanding of plant biodiversity and ecology education, as it is vital to the survival and well-being of life on Earth.
CHAPTER 1
INTRODUCTION

“Science education can play a role in helping the current generation of students understand the importance of collective global environmental problems that all students should be aware of and understand in spite of their personal experiences with the problems” (French, 1994)

Rationale

As we enter the new millennium, science education faces new challenges. Perhaps one of the most important challenges is bringing the human race to an understanding of the critical situation of life on our planet, specifically the loss of biodiversity and the profound consequences this may have for the survival of the human race itself. The LSU 15° Laboratory, directed by Dr. J. Wandersee, is committed to improving and increasing emphasis on formal and informal science education about plants. Dr. Wandersee and the work of E.O. Wilson, The Future of Life (2002) have served as inspiration and motivation for me. I explored whether some of the best technological tools and instructional practices in biology education can promote better student learning about plant biodiversity and contribute to putting forward an effective biology education agenda for college-level students. This represents an important part of the major educational goal of the American Association for the Advancement of Science’s (AAAS) Project 2061 that it established in 1989 to improve scientific literacy for all Americans by or before the year Halley’s Comet returns.

For decades, we scientists have studied life on this planet, describing it and trying to understand its intricacies. We have explored and exploited life. Towards the end of the last century, our awareness of the state and fragility of life on Earth has increased, especially after the celebration of the first Earth Day in 1970. Despite this increased awareness, three and a half decades have not been enough to shift the direction of our self-destructive behavior as we push flora and fauna to extinction. Why? If the information is there, why it is not reaching us? If it is
reaching us, why are we not responding to it? It may be the case that the right tools and/or teaching practices have not been employed to convey the message. In other words, while the scientific knowledge is there, we may have not established a bridge between the concepts (i.e., biodiversity, extinction) and a real understanding of these ideas. Students must be exposed to and experience formal biology education so that conservation of biodiversity can be promoted. Students cannot be expected to protect or conserve something they do not understand.

The biodiversity concept is one of the most fundamental concepts in biology, especially in the field of ecology. As such, it has been identified as a key topic by the science education reform movement and is included in the National Science Education Standards (NSES) for grades 5 -12 (National Research Council, NRC, 1996). In addition, it should be a topic of study for 2-year college and 4-year college courses (Biological Science Curriculum Study [BSCS], 1993; Haury, 1998). The scope of biodiversity is not clearly addressed in the national standards. Biodiversity is more than an ecological concept; it integrates different areas of knowledge, including environmental concerns that affect the quality of human life (Haury, 1998). As a strategy to help advance the understanding and importance of biodiversity, in 2001, the American Institute of Biological Sciences (AIBS) coined the term “biocomplexity”. This new term stresses the need to appreciate the scientific-socio-cultural aspects that are linked to it, in order to fully understand biodiversity itself. Education about biodiversity is therefore fundamental to understanding the more cross-disciplinary term, biocomplexity (Colwell, 2001).

This need became very evident to me when I attended the AIBS meeting From Biodiversity to Biocomplexity in 2001 in Washington, DC and presented a poster based on my research on ecology education at LSU (Guzman & Wandersee, 2001a). During a panel discussion I was invited by the moderator, Dr. Alan Covich, to share my findings on the status of ecology education with the audience and the panel members. He invited the audience to see our poster
later at the poster session. Our poster was the only one addressing the importance of ecology education. Panel members, such prominent ecologists as Dr. N. Rabalais, Dr. J. Lubchenco, and Dr. S. Levin, stated that they strongly agreed with my comment on the “need to bring ecology and specifically biodiversity to the center stage in biology education for non-majors, because it is there that we can reach our future economists, teachers, and policy makers” (Guzman, personal communication). Our challenge was to get these students interested in learning about it. I realized then, that research in science education addressing this issue would be of great value for science educators, scientists, and policy makers in the future.

Biocomplexity is a novel idea, which was identified by the National Science Foundation (NSF) as a priority area for research and education (Greenler & Greenler, 2002). Defining it has been challenging because of the magnitude and intricacy it entails (Greenler & Greenler, 2002). Learning about it and what it includes might unveil opportunities for science educators where they can play an important role benefitting teachers, scientists, and most importantly the students.

One of the dimensions of biodiversity, and in turn, part of the biocomplexity, is plant biodiversity. This particular area has become a center of attention for the Botanical Society of America (BSA) and the Ecological Society of America (ESA), which have both set improving instruction about plant biodiversity as one of the goals for the new millennium (BSA, 1999; ESA, 2005a).

With education about biodiversity, specifically plant biodiversity, at the center stage, how this concept is taught is pivotally important if meaningful learning is to occur. Three areas need to be considered: (a) instructional practices, (b) tools to be used, and (c) assessment of students’ understanding. When considering instructional practices, educators need to realize that science is
an active process. The best way to learn about science is by doing science. This involves not only
the concepts but also the critical thinking skills necessary to build and reflect upon those
concepts.

In the specific case of teaching/learning about biodiversity, a traditional lecture where the
students are mere receivers of information is not optimally beneficial. However, Suter (1996,
cited in Nelson, 1997) indicates this is what students in most high school science classes do:
listen to the teacher and take notes. To make the situation worse, about 50% of all high school
science teachers consider basic scientific terms and formulas more relevant than the underlying
concepts and principles, and the most commonly used classroom resource is the textbook. How
can students experience meaningful learning in situations like this?

Such “traditional” practices must be improved if students (and the general public) are to
achieve a meaningful understanding of biodiversity and ecological science. Drawing attention to
the roots of the problem of loss of biodiversity, Grant (1997), pinpoints the “collective
ignorance…of ecological realities” and asserts,

the only solution lies in devising and implementing a pedagogy of ecological literacy that
defines what people need to know about how the natural world functions, and how we
affect it, in order for them to be empowered problem solvers in biological conservation (in
the broadest sense including us, too). (p.89)

The National Science Education Standards emphasize that an inquiry approach for teaching
and learning will be more effective in promoting the appropriate science (NRC, 1996). One
interesting pedagogical practice that follows this recommendation is the use of scaffolded,
thought-provoking inquiry activities in middle elementary school grades 5-8 (Songer, 2003).
Another teaching practice is the laboratory and field-based Project GLOBE, designed for K-12
environmental science-inquiry (Penuel & Means, 2004). Perhaps elements of these approaches
could also benefit college-level students, but studies or data to support these conjectures are lacking at the current time.

To meet the challenge and achieving the goals of improving ecological literacy, in particular instruction about plant biodiversity, it is imperative that we employ not only effective teaching strategies, but also effective tools. According to Hurd (2000) we need to “invent new curricula” where students are prepared for life-long learning. They must “learn how to learn” in an era when we have an immense flow of information and rapid technology change facing them. According to the NRC (2000), the real science experience must include how it is aided and limited by the available technology. Computer technology, if properly used by well-prepared teachers, has the potential to positively affect the classroom learning experience. In fact, Good and Berger (1998) not only identify the computer as one of the critical resources from which science education may benefit, but also state that “…visualizing science can take on a whole new meaning” (p. 214) with the effective use of computers. Now, bear in mind that a great portion of our brain is dedicated to visual processing, so it seems reasonable that our learning experiences can be improved when permeated with visual aids!

The development of new technologies and the availability of the Internet, has allowed for incorporating the use of computer technology in many instructional resources for teaching biodiversity. One such computer tool of common use today is the interactive CD-ROM. Traditionally, many early CD-ROMs were simulation, drill-and-practice, or tutorial lessons that accompanied the textbooks, along the lines of computer-assisted instruction (CAI). However, newer products incorporate hypermedia (i.e., video, sound, interactivity, virtual reality, and text) and are “designed to teach higher-order thinking and problem-solving skills by supporting student-initiated inquiries” (Rumberger, 2003).
Nevertheless, it is surprising that research addressing the effectiveness of computer technology and computer-based education on student learning of science-related concepts is very limited or has not been properly designed (Good & Berger, 1998; Haertel & Means, 2003). Results of studies in high school biology classes where students used simulations addressing topics such as predator-prey, plant growth, osmosis, evolution, genetic crosses, and water pollution, indicated that simulations may improve the ability of students to make inferences and interpret data (Good & Berger, 1998).

In another study researchers found that a CD-ROM version of a laboratory manual was not a successful substitute for the traditional text-based material (Brickman, Ketter, & Pereira, 2005). These materials were tested in a non-science major students course at a large four-year public university. The students using the text-based manual and those using the CD-ROM did not differ in their performance as assessed using quizzes. However, overall laboratory grades were better for students who used the text-based manual. In looking at their attitudes, students strongly favored use of text-based material and traditional studying (i.e., reading and highlighting) over the electronic source and the use of animations.

Brickman and associates (2005) recognized their study lacked assessment for the additional material included in the CD-ROM, as compared to the text-based material. This shortcoming in their study probably contributed to student bias. They offered an important recommendation on the quality of course materials, stating that the electronic media should not be intended to substitute for text-based material but rather

…should emphasize interactivity by including meaningful graphics, animations, and curricular materials that challenge the students to use deep-process cognitive skills, and faculty should test for this knowledge. (Brickman, et al., 2005, p. 29)
In addition, they suggested that when implementing the use of electronic media, the students should be provided with support materials that will specifically help them to learn when using electronic sources.

It is important that the use of the electronic media in the classroom is well-planned. This allows making the most of the learning experience for the students and the most effective use of class time by the instructors. Previous research has demonstrated that students’ perceptions of the learning environment can affect the learning outcomes (Fraser & Fisher, 1982). It has also been demonstrated that the use of a selection of curriculum materials and instructional strategies may affect the student’s perceptions of the learning environment in a positive manner. A correlation between learning environment and understanding the subject, and with the student’s attitude towards science as the subject has also been demonstrated (Fraser, 1981, cited in Fraser & Fisher, 1982). Moreover, a study of middle school students emphasized the connection between students’ preferred individualization level and their achievement (Fraser & Fisher, 1983). The researchers actually recommended that teachers should guide their classroom practice according to profiles generated by their students.

Careful selection and examination of the electronic material used, as well as careful planning of the lessons, are important aspects needed in the present study. To help achieving this, I have created a detailed guide for the Conserving Earth’s Biodiversity (CEB) CD-ROM (Wilson & Perlman, 2000) based upon careful examination of the program and consideration of comments made by my students who have previously explored the program. This guide served as a starting point for the selection of activities. It describes main concepts discussed in each section of the program. In addition, I paired each section of the program to the American Society of Plant Biologists’ (ASPB) principles (2005a; Appendix A), the NRC science education standards
(NRC, 1996), and the pertinent chapters of the course textbook used in the course (Audesirk, Audesirk, & Byers, 2002) (See also Methods and Appendix B). My guide also provided a framework from which to prepare sets of instructions on how to access different sections of the program, to help guide students as they worked on the activities. Regarding the learning environment, fortunately the class size in the community college setting where this CD-ROM was tested allowed considering the student-environment fit and its potential influence on student learning gains from using the CD-ROM.

Limited research has been done on effective teaching and student learning of biodiversity when technology is used. The only science education research available was on learning through an inquiry-based curriculum and using a technology-focus on animal diversity through the Animal Web and the BIOKIDS project, which are designed for college and K-12 levels respectively (Jones, 2005; Songer & Lee, 2003). After an extensive literature review and after searching various data bases on the Internet, I consider it prudent to say there is only one peer-reviewed exploratory study addressing college-level student learning of plant biodiversity and technology issues (Wandersee & Guzman, 2002). More about this study will be introduced later.

Last, but not least, it is important we use proper means for assessing student learning. Teaching using an inquiry approach involves activities that extend for a prolonged period of time. Thus the teachers’ judgment on the progress of the students in understanding the concepts is very important (NRC, 2001). Therefore, standardized tests that are designed to be machine-scored, or any “one-time test” type of assessment are not an adequate way to evaluate educational practices that involve inquiry and the incorporation of educational technology in a constructivist learning environment (NRC, 2001; Rumberger, 2003). The NRC sees assessment and learning as intricately associated and interdependent, like “two sides of the same coin.” The NRC favors ongoing assessment, where the teachers choose and organize students’ tasks, collect
information from the students while they are engaged in the activities, and promote students’ discussions. These discussions, in fact, can help teachers observe the levels of learning and improve the development of skills, such as understanding, reasoning, and applying the learning. The discussions can also influence the development of rubrics (progress-level-oriented checklists), an informed ongoing assessment process that benefits not only from the observations and perceptions of the teacher, but also from the self-evaluation by the students. Both the teacher and the students must take an active role in establishing the guidelines for high quality work (NRC, 2001, chap. 3). They experience learning-reasoning-assessing-adjusting-improving, which, together, is conducive to meaningful understanding (NRC, 2001).

According to Haertel and Means (2003), one of the five areas in need of contributions in educational research is improving the evaluations of technology-supported innovations. Such evaluations need to be conducted within the context in which the technology innovation is implemented. There is a consensus that this type of research will benefit from the collection of both qualitative and quantitative data (Haertel & Means, 2003). The availability of a CD-ROM like *Conserving Earth’s Biodiversity* (Wilson & Perlman, 2000) placed in our hands a tool that helped us discover some insights about student learning when an inquiry approach is used, and helped us develop better assessments of this learning within the context of plant biodiversity.

The CD-ROM *Conserving Earth’s Biodiversity* (Wilson & Perlman, 2000) was selected from other related media for several reasons: (a) it was designed as hypermedia, so it exposes the student to text, images, videos, interactive activities; (b) it is comprehensive -including information at the global scale and allowing the design of activities that exposed the students to the local (close, known) and the global scales; and (c) one of the co-authors is Harvard University’s E.O. Wilson, a leading ecologist in the area of biodiversity, and the co-creator of the concept of biodiversity.
We are at the moment in time when it is critical that we establish strong bridges between the life sciences and “the science education” arenas. In addition, we must develop means to evaluate both: (a) *IF* the supplementary use of computer technology is effective in promoting student learning of biodiversity and (b) *HOW* to effectively evaluate the learning processes of students with respect to biodiversity.

**Research Goal**

My objective with this research was to examine how the use of interactive CD-ROM technology may affect the inquiry learning experience of the introductory biology students in a rural public community college. Specifically, I implemented the use of an interactive, biodiversity-focused CD-ROM—especially the aspects related to plant biodiversity. I examined how students understand the concept of biodiversity, and what, if any, conceptual change occurred when a CD-ROM is used in addition to the standard textbook-based instruction. In other words: What is the value-added? By involving students in lecture-based, textual, virtual, and real experiences, and helping them consider data about plant biodiversity, I examined the students’ ability to pursue inquiries about biodiversity-related concepts and assessed their performance on representative tasks. I developed an appropriate rubric, based on the actual history of the concept of biodiversity, that evaluated students’ progress by assigning them to levels of understanding at critical junctures in the study.

**Research Questions**

The principal research question driving this study was: What is the value added to community college students’ understanding of biodiversity via supplementary use of an interactive biology CD-ROM in a non-majors introductory biology course?

The sub questions that guided the detailed exploration of this topic were:

1. What, if any, is the “value added” incrementally to these college students’
baseline understanding of biodiversity by supplementary, sequenced use of an exemplary interactive CD-ROM on biodiversity, “Conserving Earth’s Biodiversity” (CEB) (Wilson & Perlman, 2000)?

2. Does the use of the CEB CD-ROM enhance student ability to develop and pursue selected guided-inquiry questions about local plant biodiversity, with respect to threats to biodiversity?

3. Can a rubric be developed and validated, based on the history of the biodiversity concept, that differentiates college students’ progress and levels of understanding of biodiversity?

Research Vee Diagram

The elements that represent the interaction of the conceptual and methodological aspects of this study are graphically illustrated and summarized using a Vee diagram (Gowin, 1981; see Figure 1).

Research Plan

A flow chart organizer was constructed to illustrate graphically the main events, procedures, and associated timeline that guided this study (Appendix C). I started exploring the CD-ROM as an instructional tool in 2002 by doing exploratory inquiry activities with the students. This led me to create a comprehensive guide that helped me to explore several factors: concepts, science standards, and ASPB principles in relation to the textbook used in the class. I acquired a site license for the CD-ROM instructional tool through a grant, and made it available to the institution where the research took place. After completion of the research phase, I completed analysis, results and discussion, and implications for future study sections to defend my dissertation in Summer 2007.
CONCEPTUAL

WORLD VIEW
It is of critical importance that college students develop proper understanding of the importance of plant biodiversity and its relation to biocomplexity if we are to achieve goals of life-long learning that lead to conserving biodiversity.

THEORIES
Human Constructivism – (Novak, 1998a)
* Conceptual change (Mintzes & Wandersee, 1998)
* Meaningful learning – Ausubel (1968)
Social construction of knowledge
* Zone of proximal development (Vygotsky 1978)
* Use of everyday tools
- Computers as tools (Papert 1993)
Expert-Novice learning (Newell & Simon, 1972)
Technology-Mediated learning (Tapscott, 1998)
Biodiversity/Biocomplexity (Wilson, 1988/AIBS, 2001)

CONCEPTS
Plant diversity, number of species, distribution of species, exotic species, habitat, anthropogenic effects, evolution of plants, values of plants, population growth, resources, deforestation genetic diversity, biocomplexity, inquiry learning, conservation construction of knowledge, ecosystems, threats, specialization, ecology, ecological literacy, metacognition, concept maps, rubrics, meaningful learning, effectiveness, value added

RESEARCH QUESTIONS

Principal Question:
What is the value added to community college student’s understanding of biodiversity via supplementary use of an interactive biology CD-ROM in a non-majors introductory biology course?

Subquestions:
1. What, if any, is the “value added” incrementally to these college students’ baseline understanding of biodiversity by supplementary, sequenced use of an exemplary interactive CD-ROM on biodiversity, “Conserving Earth’s Biodiversity” (CEB)?
2. Does the use of the CEB CD-ROM enhance the student’s ability to develop and pursue selected guided-inquiry questions about local plant biodiversity with respect to threats to biodiversity?
3. Can a rubric be developed and validated, based on the history of the biodiversity concept, that differentiates college students’ progress and levels of understanding of biodiversity

VALUE CLAIMS
Effective implementation of CD-ROM enhances student understanding of plant biodiversity concepts and supports and stimulates development of inquiries, as well as positively influenced attitude towards conserving plant biodiversity. A biodiversity history-based PBLR helps evaluate student understanding of plant biodiversity based on open and close-ended assessments. Its value for assessing guided inquiries is limited. Study represents first of its kind assessing how the CD-ROM may enhance learning of plant biodiversity in a college biology course. It also represents the most comprehensive collection of history of the biodiversity concept with a focus on plant biodiversity.

KNOWLEDGE CLAIMS
CEB CD-ROM both strengthened and complemented the information presented in the textbook by providing additional information and examples (i.e., numbers of species, plant structure, species-genetic-ecosystem levels of biodiversity, goods & services of plants, threats to plant diversity, ecosystem diversity). The CD-ROM offered new learning experiences not possible with the textbook, i.e. comparison maps, food plant diversity, diversity of flowering plants, hot spots. Students that experienced the CD-ROM were able to negotiate many misconceptions with a positive outcome. In-depth exploration of the plant biodiversity concept through inquiry -constructivist approach allowed for students to establish meaningful connections with the local plant diversity, regardless of the instructional tool. It also allowed for novice-expert interactions.

TRANSFORMATIONS
Transcription & analysis of students’ interviews. Calculation of changes in rubric levels, paired pre-post activity. Descriptive statistics for activity sheets quizzes, and concept maps, t-tests, concept maps Pre-post assessment of learning gains Content analysis of activity sheets

EVENTS
Develop Plant Biodiversity Literacy Rubric (PBLR) based on ecological history and the standards of the NSES
Develop study’s lesson plans, including textbook-based lectures and CEB CD-ROM based activities
Modify SENCER-SALG instrument; deliver instrument pre- and post-instruction
Identify participants and fill out research participation consent forms
Expose participants to study’s lessons. Construct pre-lesson and post-lesson concept map
Conduct individual interviews (pre- and post-chapters and activities, with concept map co-construction post-chapter)
Require participants to develop an inquiry about student-selected LA plants and construct plant diversity as a class concept.

RECORDS
Videotapes of interviews. Pre- and post-instructional assessment of student’s gains. Concept maps, field notes, quizzes, activity sheets, Student-prepared presentation on an LA plant

Figure 1. Research Vee Diagram
Theoretical Framework

Various cognitive and learning theories influenced this study to different extents. These include human constructivism, conceptual change, meaningful learning and social construction of knowledge, “technology-mediated interactive learning”, and finally, novice-expert studies.

Human Constructivism

Human constructivism is the foundation of modern science educators. It is perhaps the most influential epistemology of science educators primarily concerned with student understanding of scientific concepts. Its origin is traced to the last part of the 20th century, circa 1978 (Mintzes & Wandersee, 1998). This development in the history of science education provided a new way to look at the learning enterprise, moving away from rote to meaningful learning, and encouraging active building of understanding and integrated knowledge. Research in science education was changed and now questions can be answered properly. As an epistemology and learning theory, Novak’s Human constructivism has set the stage for curriculum reform, triggering change in how natural sciences are taught and learned in the classrooms. Human constructivism claims the most important ideas affecting the learning process are those the learner already has. Knowledge construction allows the students to build upon their existent ideas, change them and create new understanding, and learn new and meaningful knowledge. Human constructivism rejects the notion of minds being “empty vessels” or “blank slates” (Mintzes, Wandersee, & Novak, 1998).

Conceptual Change – Human constructivism emphasizes three ideas: (a) humans are meaning makers, (b) the goal of education is to construct shared meanings, and (c) guides (i.e., well-prepared teachers) facilitate this process (Mintzes & Wandersee, 1998). The first two ideas are part of the construct of conceptual change. According to the notion of conceptual change, during the process of learning the learner first recognizes his/her own views, evaluates them, and
then decides whether to reconstruct not only his/her understanding of a particular concept, but also of other related ones (Gunstone & Mitchell, 1998). In other words, two initial steps are part of the teaching practice: (a) probing students knowledge frameworks for their ideas, and (b) encouraging them to reconstruct these ideas in different contexts, as necessary to learn contemporary science. In its earlier stages conceptual change is unstable, gaining stability as the learners understand the generality of the concept and develop the ability to apply it to novel situations, until it ultimately becomes part of the long-term memory (Tao, 1996, cited in Gunstone & Mitchell, 1998). A third step in the practice of teaching for conceptual change is assessment, which should properly gauge and reward student engagement and learning.

Human constructivism also considers important the presence of guides during the process of knowledge construction. These guides can be teachers/experts who play a negotiators’ role and share the responsibility of helping learners establish connections between old and new ideas within a “zone of modifiability” (analogous to Vygotsky’s zone of proximal development discussed later on here) (Mintzes & Wandersee, 1998, p. 50; Kearsley, 2006). As guides, teachers also confront the challenge of creating a trusting environment. When exposed to the teaching practices associated with conceptual change, the students need to believe that they will learn, that confusions will be resolved, and that they can trust in the support of other students (Gunstone & Mitchell, 1998).

Both of these issues, the process of knowledge construction and the teacher’s role in it, are critical for the development of curriculum. When the human constructivist model is used, fewer topics that are carefully selected and sequenced can be addressed in the classroom. However the learning curve associated with these is parabolic rather than linear (Gunstone & Mitchell, 1998). The instructional methods (i.e., graphic organizers, microcomputers, hypermedia technology) employed to present these topics and the assessment methods (i.e., essays, portfolios) not only
need to be carefully selected, but they must also encourage active participation, social interaction, and reflection. The ultimate goal of the education process under the light of human constructivism is to supporting the development of “adaptive learners” by empowering them to be able to make meaning and build knowledge, in any novel situation.

**Meaningful Learning** – Novak’s work was influenced by Ausubel’s assimilation theory of meaningful learning and brings a middle ground between two positions that have been in conflict for a long time: radical and social constructivism (Mintzes, et al, 1998). In Ausubel’s understanding, meaningful learning occurs when the learner is actively and voluntarily involved in building new ideas based upon pre-existing ones and not just literally memorizing and repeating concepts (Mintzes & Wandersee, 1998). Meaningful learning is the mechanism through which knowledge is built. The process of building meaning involves elaborating upon and clarifying concepts, while establishing differences and similarities among them. The learner can be engaged in this process by self-motivation and/or aided by a guide. The value of meaningful learning is that it allows the possibility of retaining long-term knowledge that can be retrieved and applied in novel scenarios.

Human constructivism offered the perfect foundation for this study. When examining the meaningful-rote learning versus reception-autonomous instruction continuum, this study serves as an illustration of instruction through guided discovery to promote meaningful learning (Novak, 1998a, p. 11). Human constructivism also offered the right scenario, where concepts coming from many different areas of expertise (i.e., biology, chemistry, geology, economics, and education) can be meaningfully connected to bring about an emergent understanding of plant biodiversity. It provided a way to establish proper instructional practices, focusing in-depth on a specific topic by implementing use of CD-ROM- and inquiry-based activities, and through the assessment of student understanding to evaluate if the practices and tools were effective. It
offered a way in which students’ knowledge gain related to biodiversity was explored as they were exposed to different learning scenarios. It also offered a process to connect meaningful understanding of concepts to real world problems, and a way to guide the student’s understanding to effect solutions. Using a human constructivist approach for this study allowed moving away from the "mile-wide, inch-deep" science curriculum problem in the U.S. (Schmidt, McKnight, & Raizen, 1997) to a more meaningful and focused approach for ecology education.

Constructivist Learning: Social Interaction, Zone of Proximal Development, and Collaborative Learning

Some notions of Vygotsky’s social development theory served as context for this study. This constructivist idea advocates that the development of skills and higher mental thinking depend on the social interaction of the children (Jones & Carter, 1998; Kearlsey, 2006). The social interaction is a needed part and critical process of the learning experience. Learning is viewed as a process of scaffolding, where previous ideas or conceptions are critiqued, re-evaluated, modified, and finally comprehended in a social environment. This environment includes peers and experts/teachers as participants who guide the process, and it also requires mediators like language, teachers, or tools which can help convey the learning experience.

Learning takes place on an “interpsychological plane” before it is transformed via individual learning, on the “intrapsychological plane” (Cole & Wertsch, 1996; Wertsch, 1991 in Jones & Carter, 1998). The level of social interaction is important because it determines the “zone of proximal development” (ZPD), which represents the extent to which the students can develop skills beyond what they can achieve by themselves. In these social groups, participants who are less capable (i.e., novices) can benefit from their interaction with more capable participants, that is, more experienced peers, specialists, or experts (Cole & Wertsch, 1996; Kearsley, 2006). Peers are part of the process of “scaffolding", or gradual reduction of support during the construction
of knowledge, and can have any of three roles: (a) mediators for knowledge, (b) masters of knowledge, or (c) co-builders of knowledge (Jones & Carter, 1998). It is this student-student discourse that allows the students to engage in meaningful learning and improve cognition, in a “non-arbitrary, nonverbatim way” (Mintzes & Wandersee, 1998). In essence, the “knowledge gain” itself is an emergent property of the interaction among the participants of the learning experience.

The “socially constructed meaning” that, according to the human constructivist epistemology results from sharing the ideas with peers, serves as a base for building models of teaching, learning, and curriculum. An example of an instructional practice is collaborative or cooperative learning. This practice involves students at various performance levels who work together in small groups.

Vygotsky (1978) argued that students perform better in collaborative situations than individually. When students are presented with different interpretations, their problem-solving skills are improved. In addition, such an active exchange of ideas is beneficial to the student for three reasons: (a) it increases interest, (b) promotes critical thinking, and (c) the student can retain information for longer periods of time in long term memory (Johnson & Johnson, 1986).

Collaborative learning is central to Osborne and Wittrock’s Generative Learning Model (1983, in Jones & Carter, 1998). Participation in groups allows the students to exchange, compare, and challenge ideas and potentially reach those “A-HA” instants that result in knowledge construction, suddenly connecting their previously isolated concepts. If teachers want to achieve conceptual change, it is important that they assess the students (probe their ideas) prior to formation of the collaborative groups. To do so they can use concept maps, open-ended questions, interviews, as well as evaluate student performance when using tools (Jones & Carter, 1998). The effectiveness of the groups should be assessed by using rubrics.
Learning Tools: Technology Mediated Interactive Learning

The use of computers as a tool in the process of knowledge construction unifies several venues into what can be called “technology- mediated interactive learning”. These include the principles of Novak’s human constructivism, Vygotsky’s use of tools in the process of social interaction, and the era of technological revolution.

A particular role in which the expertise of peers is of great importance is in the use of tools for the process of knowledge construction in science. According to Cole and Wertsch (1996) knowledge construction is mediated and influenced by the type of tools used, “artifacts clearly do not serve simply to facilitate mental processes that would otherwise exist. Instead, they fundamentally shape and transform them”. They help make sense of the world. There are two basic kinds of tools: (a) everyday tools (used to construct intuitive knowledge) and (b) analogous–to-school tools (used to construct formal knowledge). Vygotsky considers both of these to be needed for building knowledge. The students’ previous experience with these tools, especially in the science classroom, is important for the process of knowledge construction (Jones & Carter, 1998). In this study the “tool” that crosses the everyday/school boundary is the computer. For some of the student population, this is an everyday tool. The textbook and CD-ROM used may be considered “school tools” which the students used to construct formal knowledge.

According to Bruner (1983) the availability of instruments and technologies nowadays gives students the ability to access information that was not available to them before. Therefore, this technology contributes to the process of building new ideas or learning. Interestingly, statistics from the U.S. Department of Education (USDE) indicate that the technological revolution of the last century has reached most classrooms, and in 1997 69% of students in Pre-K through college used computers in schools (USDE, 2002a). However, no figures are available
that can tell us about the extent of actual *learning* with this technology, and in many states, standardized tests are telling the sad story that many students are not showing the grade-level-expected competency. So, the question remains, *Is the technology helping students learn?*

Papert, the creator of the LOGO software for children, an early computer program used by students to simulate objects and events, says that computers and computer-based media may become “tools” which the students can use to take charge of their own learning, express themselves, and demonstrate their knowledge (Papert, 1993). The essence of constructivism is connecting new ideas and adding new meaning to those that already are part of the individual’s knowledge framework. Papert’s program supports this belief and he sees children as active participants of the process, because their natural curiosity drives their meaning construction. In his view, it is the structured educational system that we have submitted them to in the past that actually drives the students in the opposite direction, turning them into passive learners. In order for computers to become part of the active construction of children’s knowledge, computers need to offer both an environment the learner can interact with and a means to create metacognitive (reflective) learning. Computers can thus represent a learning tool for both the teacher and student. Teachers have the potential of creating engaging learning environments that promote mindful learning;” one way to do so is by incorporating appropriate technological resources to each student.

The idea of a new era of “technology-mediated interactive learning” comes from the role current technology can play in the classroom. According to Tapscott (1998) we are at the cusp of a “paradigm shift”, entering what he calls the “digital era of learning”. In this new era, learning is changing from what he calls "broadcast" to "interactive" learning. The new media tools available today promise and promote a time for active/discovery learning,
The Net generation children using GlobaLearn [a web site], are beginning to process information and learn differently than the boomers before them. (Tapscott, 1998, p.127).

In Tapscott’s view we are at the point where if the digital media available are exploited, students can become motivated learners, critical thinkers, problem-solvers, and metacognitionists, as foreseen by Papert’s use of the computer as an educational tool. Along with the principles of human constructivism, Tapscott (1998) views teachers as facilitators, not transmitters, helping students discover/rediscover in a learner-centered environment. Their learning experience is customized, fun, and lifelong rather than structured, homogeneous, and limited to school-time. What Tapscott’s theory adds to the discourse of constructivism is the role of computer technology as an explicit mediator of the construction of knowledge in an interactive environment. According to him, the current tools can shift education from a linear mode to exploit the benefits of hypermedia, where students learn how to navigate and learn, rather than to absorb prescribed material.

Novice-Expert Learning

The field of cognitive psychology has made significant contributions to the research in learning and science education. One such contribution comes from Newell and Simon’s novice-expert theory of learning (Newell & Simon, 1972). According to this theory, novices and experts use the same mental processes to solve problems, but their levels of expertise affect where they gather the information to solve them. While experts gather information in information-rich chunks, novices only harvest bits of information from which to gather solutions. These chunks, or schemas, represent how knowledge is organized in the long-term memory. As learners become more familiar with the material, they are able to access and manipulate the information more efficiently. In the evolution from novices to experts, cognitive performance changes from
awkward, forced, and problematic to effortless and easy (Sweller, 1988). In Bruer’s view, learning is this process of change (Bruer, 1993).

The work of Chi, Glaser, and Farr (1988) explored these novice-expert differences of knowledge structure in scientific domains. It suggests that in science learning, experts: (a) excel in their own domain of knowledge, but have limited transfer to other domains; (b) can solve problems easily because they can see large meaningful patterns within their own knowledge domain; (c) possess deeper knowledge organized as a hierarchical framework of related concepts; and (d) have well developed metacognitive skills and thus can identify and correct errors in their own comprehension.

In the context of the theories of human constructivism and social learning, both peers and/or teachers can play the role of the experts. From the teacher-expert perspective, their role is to illustrate the learners, so later on they will be able to create expert representations on their own (Resnick, 1983). Teachers need to be aware that they will find and locate the “expertise” level of their students somewhere along a continuum. Therefore the teacher’s challenge is to find ways to “meet” the students where they are standing (Tinkler, 2000). In the light of collaborative groups, we can assume groups may represent a diversity of both expertise levels and areas of expertise. In these groups some students /peers may play the role of “quasi-experts”, stimulating and helping others becoming “quasi-experts”.

**Significance of This Study**

This study addressed three important areas of research in science education in the context of learning about plant biodiversity: (a) intervention practices, (b) conceptual change (including critical junctures), and (c) comparative knowledge structures (novice-expert).

Throughout my college and professional years I have struggled with the idea of how important ecological literacy should be for everyone, and I have noticed that, most often, ecology
is a neglected topic in formal biology education. This led me to explore the teaching practices associated with teaching ecology at the college level. I explored this issue with a survey on ecology education at Louisiana State University, a large research university (Guzman & Wandersee, 2001b). Some findings of this study regarding course content indicated that over half of the university’s courses that teach ecology reach only a small percentage of the student population, and in courses where ecology is taught as a separate topic, teaching of it does not take place until the later portion of the semester. In addition, when we looked at the instructional practices, most of the discussions concerning the specific topic of biodiversity came from the concepts presented in textbooks. The great majority of the faculty and graduate student participants of this survey (88%) agreed classroom activities needed to be enlarged and improved. They suggested the incorporation of more demonstrations, taking a more global perspective, introducing interactive computer-based exercises and simulations, and learning by field trips. The participants of the survey also suggested limiting class size to insure greater instructor-student interaction.

This survey also provided information about the use of computer technology in the ecology-related classrooms as an instructional tool. Despite the abundance of computer assisted instruction (CAI) currently available related to biology, it has been rather slowly incorporated in teaching biology concepts across the various instructional units at LSU; only about 5% of the courses in 2000 were using this technology. This figure included computers used to present graphics and short animations as part of lecture and laboratory courses (Guzman & Wandersee, 2001b). This also needs to be reconsidered in light of the new generations of students entering college. A great number, already 90% of high school students in 1997, have used computers in their classrooms and/or at home (USDE, 2002a). Furthermore, a report on teachers’ use of technology indicates that even most K-12 teachers in low poverty schools assign information
research using the Internet, and use either computer applications or CD-ROMs in their classrooms (USDE, 2000).

At present, the development and enhancement of multimedia tools is happening at a faster rate than the corresponding knowledge of how people actually learn from these sources. In a study done by Mayer (1997), a significant attribute by treatment interaction was obtained indicating that multimedia and contiguity (verbal and visual representations) affected learning of students with high spatial ability and who had little prior scientific knowledge. In this research, the scenarios used were a computer program presenting images that explained a specific concept, and a textbook with figures. Therefore, students were exposed to text (written or narrated) and a visual aid. Mayer (1997) advised that more research is necessary to investigate how people learn with multimedia. From his point of view, the current emphasis should not be on the effectiveness of one medium over another, but rather on the effects of multimedia in developing sound scientific explanations. This involves analyzing the underlying cognitive theory of verbal and visual knowledge construction and its role on the learner's development of knowledge.

The teaching practices implemented in college science classrooms must appeal to the senses of this “technology generation” of students. We are in an era of computer revolution. In this framework we must bring together the goals of both the science education and the scientific communities and stimulate students to learn.

The setting where this study was conducted is a small-class environment in a public community college. Therefore, it offered an optimal scenario wherein questions related to instructional practice were examined. A well-designed research plan used to explore these questions helped gaining insights into the value-added by CAI (e.g., a high quality, interactive biology CD-ROM) to a standard textbook-based biology course.
The study addressed the use of a common computer-based educational technology, the interactive CD-ROM, as well as the use of proper assessment tools such as rubrics and projects. It was important to explore if this teaching strategy and use of these tools could lead to increased learning and understanding of a concept of critical importance, plant biodiversity, thus improving science literacy among the non-biology-major students. Finally, the study represents a contribution to the growing epistemology of human constructivism and gauges if/how student learning can be affected in this era of the interactive technology.

The study also represented a valuable active and collaborative learning activity for community college students. Exposing students to collaborative learning experiences allowed me to examine knowledge structures and document the pathways of conceptual change as potential novices and quasi-experts (which in this case can be teachers, other students, or the scientist in the field) exchange ideas. To document these pathways, I used in the investigation selected metacognitive tools which were taught to the participants. It is of interest to add here that according to the Community College Survey of Student Engagement (2003), only 48% of community college students across the nation have collaborated on projects during class “often or very often” and only 21% collaborated in projects outside of class, and only 27% have made a class presentation very often. These figures include all courses taught in community colleges. It is apparent to me from these statistics that if we are to prepare our students to be active and creative professionals in the workforce of this nation, as well as to become scientific literate, we need to increase these percentages. The outcome of this study could provide a resource for community college biology instructors to use to introduce more collaborative, inquiry-based activities that incorporate the use of technology into their classrooms.
Previous Research With *Conserving Earth’s Biodiversity (CEB)*

Two exploratory studies completed earlier have involved the use of CEB (Wilson & Perlman, 2000) as an instructional tool in the setting of a small community college. The first study (Wandersee & Guzman, 2002) presented to the National Association for Research in Science Teaching at its annual meeting looked at the advantages of learning about biodiversity with a 3-D knowledge representation combining two interactive learning tools: the CEB CD-ROM and the Explorer™ interactive globe. The second was a grounded theory project (Guzman, 2002). The purpose of this second study was to understand how students develop an understanding of biodiversity through a collaborative learning experience and student’s perceptions about this commercial biology CD-ROM (CEB) used to build their knowledge.

The first study, the 3-D knowledge representation, was designed as a multiple case study (N = 3) and was conducted for a period of 2 weeks (T = 15 hrs.) at a rural community college. Some findings of this study suggest the interaction of both teaching tools sparked curiosity and stimulated scientific inquiry. It also suggested that students might remain on task for longer periods of time when the instructional technology is humanized through the synergy of learning objects (the talking globe) and computer visualization. Students expressed a desire to learn more about local plant biodiversity and enjoyed using both tools to learn about plant biodiversity.

The 3-D knowledge representation study also offered some information based in Bandura’s (1977) self-efficacy theory. It suggested that the use of technology made it less stressful and easier for the students to learn; and technology increased the confidence of the students in learning about plant biodiversity.

For the grounded theory project, I used the CEB CD-ROM as the sole instructional tool, meaning that the students were not exposed to textbook instruction when using the CD-ROM to learn about biodiversity. This particular study is limited by a very brief exposure (1.5 hrs) of the
participants (N = 6) to the CEB CD. This study was also conducted at a rural community college. The data were collected from audio taped interviews, which were transcribed and coded manually, followed by axial and selective coding.

In this second study I identified the learning situations to which the participants were exposed (group vs. collaborative) as the phenomena of interest. These might determine or shape the outcome of preference or avoidance of the instructional tool in the future. The group approach was supported by most of the participants. For example, one participant commented in the interview “When I worked with X we read more of the longer text. Before I did not read much.”. Another example of a student comment was “The group helped me see stuff that I wasn’t discovering in the disc, and actually I liked it with the group”. In contrast, one of the participants opposed the pattern, by preferring the individual approach, and commented “…individual works best for me.”

The group interaction promoted more active and focused learning. One participant stated, “I think discussing helps to keep focus and get a better idea, probably just stay in one thing of the CD, I mean, before, by myself I was all over, then, with the group …well, yeah, we discuss stuff and kept in one theme…”. The group interaction also stimulated comparisons and prolonged engagement “It has stuff we have in our book, but you can see it better here, you know, like the little movies. I can sit at a computer longer than with a book, it’s more fun.”. However, the data collected in this study were not enough to establish a definite trend: group-active, group-passive, individual-active, or individual–passive. These strategies were affected by the feelings or attitudes the participants had, and, in general, if they had a positive attitude towards both group and individual interactions, they tend to prefer the group situation, and that gained/resulted in “consensus” and prolonged engagement. In only one situation, a negative attitude toward the group went along with a positive attitude to the individual experience.

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The phenomena of focus occurred in the context of the themes developed by the students, which included learning about topics such as: “humans” [effects of humans on biodiversity], “corridors” [a way of conserving habitat, therefore preservation of diversity], and “animals and plants” [describing Earth’s biodiversity]. Although I describe the topics as the “context”, potentially these topics can be “consequences” as well. If, for example, I analyzed the data creating a family and a network that focused on the types of inquiries developed using the program, there is no pattern present in the types of inquiries that the participants conducted. I think this reflects the “broadness” of possibilities that the CEB (Wilson & Perlman, 2000) computer program has to offer.

The visual appeal of the CEB program (Wilson & Perlman, 2000) was definitely a pattern observed in this prior study, and I included it here as part of the context. I think this is very important because the visual images affected the strategies (active versus passive) and the consequences (prolonged engagement). I would say that visual appeal, in a sense, sparks curiosity and inquiry. This visual appeal was prevalent among most of the participants, for example, “I really liked the pictures and reading the pictures.” and “I need pictures and stuff to look at, I did not like reading the text, but you see, when we were in the group I did more of that because Y read it to us.”. The visual component of this program makes a difference and represents a contrast to their attitudes to the amount of text.

This visual text contradiction is something that could be further explored using an Atlas.ti.com research net. The length of computer text led to sharing (a positive group interaction), but also to a loner strategy, in a single case, where the participant preferred reading by himself. This also makes me think that it was the longer text –and his interest in reading it that made him prefer the individual approach. But the majority of participants preferred visual over text, and group over individual, learning experiences.
Some leads or insights about how and what the participants learned were, for example, “it was visual. I learn better in that way.”; “…if you have corridors, they help the species to travel and survive, otherwise they die, you know, if there is just a little space they don't.”; and “…at least I know more now, before I did not want to learn about all the animals and plants and microbes.” These statements were the outcome of the participants’ active manipulation of information while working with interactive activities for about 4 weeks before the interview. This finding also lends support to the idea of human constructivism and conceptual change presented in Mintzes, et al. (1998).

The data collected also supported the role of logical argumentation in constructing knowledge as suggested by Johnson and Lawson (1998). Two participants claimed that working in a group and discussing with a group helped them understand the science and reach consensus.

A general positive feeling or approval of this kind of tool was observed, some participants stated “I really liked it.”; “I liked that I could see and listen to new stuff. We could do group activities, but using this stuff.”, and “I liked that I can go to the Internet and look for related information”. This may reflect the variety of stimuli presented in this educational tool (CEB). Different stimuli may support different learning styles as proposed by Kolb (Svinicki & Dixon, 1987), and potentially help to individualize instruction.

The findings of this exploratory study were somewhat hindered by the way the grounded-theory study was done. When I performed this project I did not include specific tasks or a way of actually assessing how much learning took place in the students. In addition, a more prolonged exposure to the program and/or more extensive interviews may be necessary to see what patterns emerge from the type of science inquiries developed by the participants. This approach, along with focusing more upon a theme (i.e., plant biodiversity), may provide an idea on whether or
not there are learning gains when the CEB CD-ROM is used in addition to the textbook. It may also provide an insight about how group versus individual approaches in using the computer can affect the overall learning experience.

Limitations

The design of this research limits its applicability to inquiry based biology courses at community colleges in the Deep South. The instructor incorporates the use of interactive CD-ROM technology as a means to develop inquiry learning experiences in an introductory biology course for non-major students. The human constructivist approach was used.

Definition of Terms

**Biocomplexity** – a multidisciplinary approach to the study of ecology that takes into account behavioral, social, chemical, and physical interactions that affect, sustain, or are modified by living organisms, including humans. All systems from cells to global ecosystems are associated (adapted from AIBS, 2001; ESA, 2002).

**Biodiversity** – diversity of life. The variation of different species found among microorganisms, plants, fungi, and animals. It represents the richness (number and relative abundance) of species of living organisms. It is a measure of vigor, health, productivity, and beauty of an ecosystem. (ESA, 1997; Golley, 1998; Molles, 1999).

There are three aspects of biodiversity: (a) genetic diversity within species that enables organisms to evolve and adapt to new conditions, (b) species diversity that refers to the number and kind of organisms distributed within an ecosystem, and (c) ecosystem diversity that refers to the variety of habitats and communities interacting in complex relationships (ESA, 1997; Haury, 1998).
CAI – refers to instructional material to be used in a computer, incorporating text, graphics, sound, animation, simulation, and videos. The CAI tool for this study consists of *Conserving Earth’s Biodiversity* (CEB).


Collaborative/Cooperative learning – instructional techniques that requires positive exchange of ideas or interdependence between the learners in order for learning to occur (Funderstanding, 2001; Gokhale, 1995; Linn & Burbules, 1993). In this study students will be required to work in small groups to develop and solve their own inquiries.

Concept map – a two-dimensional graphic organizer developed by Novak and his research group, which presents a hierarchical organization of main concepts and how these are linked, among them and to examples of the real world, forming propositions. The network of linked concepts represents the structure of knowledge in a given domain. One use of this technique is as an assessment tool of student understanding in science-related fields (Mintzes & Wandersee, 1998).

Instructional technology – refers to the use of computers, CD-ROMs, interactive media, modems, satellites, teleconferencing, and other educational means to support media (Funderstanding, 2001). See also CAI.

Scientific literacy – awareness and understanding of basic scientific concepts and the process of science, how these inform personal decision making and impact the participation and contribution to civic, cultural affairs, and economic productivity (Rutherford & Ahlgren, 1990).

Vee diagram – is a graphic technique designed by Gowin (1981) and consisting of 12 elements that helps trace the route and plan of the researcher from the start of the study to conclusion. It allows the researcher to identify the different interactive elements of a research study by
depicting the processes of seeking understanding and building knowledge associated to the study. The questions and subquestions of interest are presented as a central focal point in the diagram, pointing to the events and objects (bottom of diagram) that will help to answer the questions. The left side of the Vee presents the conceptual framework including world-view, philosophy, theory, principles, constructs, and main concepts. The right side presents the methods and includes records and transformations. In addition the right side includes a set of value and knowledge claims resulting from evaluation and interpretation of this plan. These inform the Conclusion section of the study (Mintzes, et al., 1998).
CHAPTER 2
LITERATURE REVIEW

*It is another property of the human mind that whenever men can form no idea of distant and unknown things, they judge them by what is familiar and at hand.*

(Giambattista Vico, 1744)

In this literature review, I start by providing an overview of the theoretical framework upon which this research is founded, as it applies to the field of science education. In addition, I examine the body of literature related to developing science as inquiry, and the use of computer technology in the classroom for improving learning. Computer assisted instruction (CAI) has played a major role in the education arena for at least a decade. Limited information, however, is available on how students actually learn with it in an inquiry science-teaching practice and what additional value to the traditional textbook science-teaching practice it may offer.

Then, in considering and providing background information on the biology content of this research, I provide a brief overview on ecology and environmental science as the conceptual framework for biodiversity. After addressing the contributions of science education to this area, I discuss biodiversity, and in specific, plant biodiversity. The most relevant concepts in this area are developed, ending with the concept of biocomplexity.

Science Literacy: A Basic Need to Move Forward

One of the challenges faced by science educators in the new century is facilitating the achievement of scientific literacy by their students. The idea of literacy is not a new issue; in fact, it has been a concern ever since science appeared for the first time in the American college curriculum in the late 1800’s (Mintzes & Wandersee, 1998). The idea grew more than ever when the Soviets launched the Sputnik in 1957, and years later as the document *A Nation at Risk* was published (National Commission on Excellence in Education, 1983). Indeed, what is challenging is achieving literacy in face of the wealth of information in science. Some researchers estimate
that by the year 2020 the amount of scientific knowledge will be doubling every 73 days (Costa & Liebman, 1995). This figure, although alarming, is probably a good estimate. We can take for example the field of biology. The last half of the 20th century was marked by remarkable advances following the discovery of the structure of the DNA molecule, having knowledge repercussions from the molecular to the organismal levels. *Science for All Americans* (Rutherford & Ahlgren, 1990) calls it a “knowledge explosion” (Morse, 2003). It seems that to achieve science literacy, today’s citizens will need both, knowledge and the training necessary to keep adding more knowledge to their conceptual knowledge base. Educators thus need to prepare students for lifelong learning (National Research Council [NRC], 1996). Several questions come to mind when considering this situation, such as: What are we doing for science education? In which direction are we moving? How much do students need to know if they are to be scientifically literate? The answers to these questions are not easy ones.

**Breaking the Ground for Change: Project 2061**

Project 2061 is an initiative of the American Association for the Advancement of Science, a project which started in 1985 and recently celebrated its 20th anniversary. This initiative provided a visionary plan to reach the goal of literacy: targeting where students entering school in 1985 and thereafter should stand in science, mathematics and technology education as they enter the work force and society moves toward year 2061, the year when Halley’s Comet returns to earth view (AAAS, 2006).

This initiative is a comprehensive effort offering a plan and a compromise to move forward the state of science education through a thorough, thoughtful, and sustained effort of reform. In fact, it is considered “the single and most visible attempt at science education reform in American history”, including “curriculum, instruction, and assessment” (Organization of Economic Cooperation and Development, 1996, cited in AAAS, 2006, para. 1). It continually
focuses the K-12 science curriculum on what is essential to develop science literacy and looks for effective teaching practices to convey the project’s message. Rather than continuing to teach it all, the project recommends a “common core of learning” which is limited to the “ideas and skills” that have the greatest “impact and significance for science literacy” (Rutherford & Ahlgren, 1990, Introduction, para. 19).

In a celebration of the project’s 20th anniversary on Capitol Hill, Washington D.C., Jo Ellen Roseman, current director of Project 2061, recognized that there is actually no due date for this project. The 2061 date is a metaphor which marks the date when children that entered school in 1985, when Comet Halley was observed, will again see the comet. For the AAAS, it indicates working toward the future, continuing to promote science literacy goals, and developing tools that educators can use to help them reach those goals. A reflection on the accomplishments of Project 2061 revealed that although there have been significant strides and contributions towards the goal of literacy, still US schools need to improve their performance which is currently below satisfactory level (AAAS, 2006). In fact, the job should be considered an ongoing process to meet the current needs of society.

Among other accomplishments of Project 2061 there are several publications, Science for All Americans (Rutherford & Ahlgren, 1990), Benchmarks for Science Literacy (AAAS, 1993), and the derivative National Research Council's National Science Education Standards (1996). These represent a strong national consensus among educators and scientists on what all K–12 students should know and be able to do in science. For example, Benchmarks for Science Literacy is a set of learning goals or benchmarks for grades K-12, based on the science literacy goals stated in Science for All Americans. These benchmarks form the basis of various state and national standards. In addition, Project 2061 has taken on the role of evaluating middle-school
and high school textbooks. One of the more recent publications, *Designs for Science Literacy* (AAAS, 2001), proposes how educators can reform the curriculum.

**Science for All Americans**

This report was first published in 1989 and established the science literacy goals: what American students should know and which skills they should have in science, mathematics, and technology, at a minimum.

The *Science for All Americans* report defines scientific literacy. In doing so, it recognizes that science, mathematics, and technology are human activities that are co-dependent and have their “strengths and limitations” (Rutherford & Ahlgren, 1990, Introduction, para. 18). According to the report, a science literate person is capable of understanding basic and important concepts and principles of science; can recognize the diversity and unity of the natural world, and uses scientific knowledge and scientific ways of thinking for individual and social purposes (Rutherford & Ahlgren, 1990).

The report establishes that past attempts of an education reform have not been successful in creating a scientifically literate American society, as measured by student achievement. Based on the results of international studies of educational performance, the Third International Mathematics and Science Study the US students have placed below the average international level in science and mathematics (Rutherford & Ahlgren, 1990). These findings suggest the educational system in the US is in a critical state.

Several factors have contributed to the circumstances that have prevailed in the US educational system. Some of these include: type of teacher preparation, traditional teaching methods, and an ambitious curriculum. In the past, the US higher education system has failed to provide adequate teacher preparation. According to Rutherford and Ahlgren (1990), the lack of an adequate science background stretches from elementary to high school teachers. Only a few
elementary teachers have a basic background in science, and many of those teaching junior and senior high school do not meet the reasonable standards of teacher preparation. Furthermore, in many instances teachers receive unreasonable assignments that don’t match their science credentials.

Another part of the problem is the teaching practices. Over many years, methods have been predominantly didactic. There has been a lack of emphasis on a hands-on approach, where exploration, critical thinking, group work, and contextual understanding among other things are valued. To make matters worst, the science curriculum is too comprehensive.

The amount of information added to the science field has increased extensively over years, and it will just keep growing. Morse (2003) states “Biology research is on a roll.”, as he points out the enormous strides of biological research in the last 50 years. Not only has it contributed a lot of information, but new windows are continually being opened to keep asking new questions and add more information. The problem on one hand is trying to cover all of this information in the science classrooms. We end up with the metaphorical descriptions of the current curriculum “overstuffed and undernourished” or “mile long, inch deep” (Fratt, 2002, para. 3; Rutherford & Ahlgren, 1990; Schmidt, McKnight, & Raizen, 1997). In an attempt to address all that content, teachers and students are faced with textbooks that exhibit information overflow. In the classroom, this translates into instruction that focuses on “covering” facts and on memorization, rather than promoting deep understanding, cultivating learning skills, and seeking knowledge applications. Also, while some topics are repeatedly covered over the years, others are absent or left for only some students. We have lost the whole point of teaching science by limiting it to teaching a long list of facts, sometimes no longer relevant, and many times we do it without considering how these ideas connect with each other (Rutherford & Ahlgren, 1990). Giest and Lompscher (2003) also echo this important problem of the science classroom when they say,
Science education suffers – among other shortcomings- from the dominant orientation toward isolated, nonsituated facts, which are seldom applied to real life situations. This approach leads to difficulties in understanding and a loss of sense and motivation in many students (p. 267)

In the other hand, the educational system has suffered from low expectations of the students, who on many occasions plan to avoid science and math education. It is necessary that all students, regardless of what their career paths will be, leave school with a basic understanding of science and math.

These issues are even more significant when considered in light of the rethinking of education that the report offers. The report raises awareness about the meaning of education in our time, by establishing that education is no longer considered just a means of personal satisfaction or the way by which our nation remains the most powerful. Instead, science education, and as a corollary, science literacy, has become essential for everyone’s work and personal needs.

Rutherford and Ahlgren (1990) assert science education is what will prepare humans to deal with and develop solutions for the distressing global issues that we now face such as,

…unchecked population growth in many parts of the world, acid rain, the shrinking of tropical rain forests and other great sources of species diversity, the pollution of the environment, disease, social strife, the extreme inequities in the distribution of the earth's wealth, the huge investment of human intellect and scarce resources in preparing for and conducting war, the ominous shadow of nuclear holocaust… (Rutherford & Ahlgren, 1990, Introduction, para. 3)

The AAAS makes several recommendations to what should be the foundation of scientific literacy based on the following criteria: (a) utility, (b) social responsibility, (c) intrinsic value of knowledge, (d) philosophical value, and (e) childhood enrichment. These recommendations seek to promote science understanding that is worth now and in the future. They included five areas of knowledge: biological and health sciences; mathematics; physical and information sciences; and technology.
Living World Literacy – Among all the recommendations presented throughout the AAAS document, of special relevance for this study is *Chapter Five of the Science for All Americans* (1990) report, “The Living Environment”. This chapter lays out a conceptual framework and basic understanding of topics about the living world that students and people in general should gain and use throughout their lives as they acquire new science knowledge.

the diversity of life, as reflected in the biological characteristics of the earth's organisms…the interdependence of all organisms and their environment…and how biological evolution explains the similarity and diversity of life. (Rutherford & Ahlgren, 1990, Chapter 5, para. 3).

That chapter delineates the basic science knowledge that should remain within our memory after the details of various concepts have faded from memory. In the paragraphs that follow I summarize references made in the chapter to concepts related to plant biodiversity.

**Diversity of Life**: Ability to distinguish between plants and animals based on the way these acquire energy and the variety of their body plans. Recognizing the importance for humans to preserve diversity of species, basically because the complex interdependence among species is what stabilizes the food webs, both marine and terrestrial, that provide our energy and material needs. Both kinds of webs begin with plants. These food webs can be disrupted. Depending upon the magnitude of the disruption, the systems maybe restored, or in other situations, may exhibit irreversible changes. “Maintaining diversity increases the likelihood that some varieties will have characteristics suitable to survival under changed conditions.” (Rutherford & Ahlgren, 1990, para. 8).

**Heredity**: Most modern fruits and grains are the result of people breeding plants to select desirable characteristics. In grains, for example, the changes are sometimes so far-reaching as to result in new species.

**Interdependence of Life**: All species have a direct or indirect link with many other species in an ecosystem. Plants depend upon other organisms for reproduction (e.g., pollination) and for
nutrients that they receive as animal waste. Plants supply other organisms with food, shelter, and nesting sites. Food webs include plants and animals. Some species depend exclusively on each other, as in the case of certain species of plants that are the sole food source for some animals, for example koalas and pandas feeding on eucalyptus and bamboo leaves, respectively, or a co-dependency where the animal is also the sole pollinator (e.g., the fig wasp-fig tree mutualism). In an ecosystem other relationships will likely include parasites, scavengers, as well as decomposers, which feed only on dead animals and plants. There are other mutually beneficial relationships, like bees that pick up pollen from flowers as they obtain nectar, and bacteria that live in our intestines and synthesize some vitamins we need.

**Flow of Matter and Energy:** The source of energy for plants, animals, and decomposers is ultimately the sun's energy, captured by plants and converted to energy-rich molecules using carbon dioxide and water via photosynthesis. In both terrestrial and marine food webs, plant-consumers get energy and materials from breaking down the plant’s own molecules, and use them to synthesize their own life structures. In turn, they are themselves consumed by other organisms. Across the different trophic levels, some energy is stored in newly synthesized structures and some is released as heat produced by the energy-harvesting processes in cells. A similar energy cycle begins in the oceans with the capture of the sun's energy by tiny, plant-like organisms. Each successive consumer stage in a food web captures only a small fraction of the energy content of the organisms it feeds on.

Millions of years ago, the growth of land plants and marine organisms exceeded the ability of decomposers to recycle them. This resulted in an accumulation of layers of energy-rich organic material, which eventually turned into coal and petroleum under the pressure of the overlying earth. Sustained productivity of an ecosystem requires sufficient energy for new
products that are photosynthesized (such as trees and grasses) and for recycling completely the remains of life (dead leaves, human waste, etc.).

**Evolution:** This is the unifying ecological principle “for understanding the history of life on earth, relationships among all living things, and the dependence of life on the physical environment” (Rutherford & Ahlgren, 1990, Chapter 5, last para.).

**Future Changes to the Science Curriculum: Designs for Science Literacy**

Published in 2001, *Designs for Science Literacy* represents a tool for educators to use to be able to design curricula according to the local needs and in harmony with science education reform. It is a comprehensive look at curriculum design. While keeping literacy goals in mind, it encourages designing curricula that are tailored to suit the needs of individual schools, communities, and students (AAAS, 2001). Curriculum design should be an ongoing process that engages the stakeholders, and should “evaluate risks, benefits, and tradeoffs” (AAAS, 2001, para. 6).

One of the ideas developed in *Designs* is reducing the amount of material, or content, of the curriculum. It also encourages teacher educators to include curriculum analysis and design as part of a pre-service education program.

**The No Child Left Behind Act**

The No Child Left Behind Act (NCLB) was signed four years ago, in January 2002, by President G.W. Bush. This act ordered a transformation of the Department of Education of the United States. It attempted to change the culture of the US public education system into one of achievement (United States Department of Education [USDE], 2002b). This was not an easily accomplishable task. The NCLB act continues to affect all areas of education, including science, plus research in science education.
With the NCLB act, the US Government has taken a more active role in promoting science literacy. The Department of Education moved to the center stage many of the premises and ideas that have been in discussion in the mathematics and science education discourse since Project 2061 was established back in 1985. The NCLB Act is based on four main principles: (a) Increasing the responsibility of the US states and school districts to perform better in education and reporting the progress to the parents; (b) Increasing the freedom of local control for federal funds to benefit the schools; (c) Improving the quality of teaching and learning through the application of research-based educational methods; and (d) Increasing the options parents have to move their children to another school if the one they attend doesn’t meet the NCLB Act standards.

The Act addresses the need to improve the performance of all students. It gives special attention to the students of African American and Latino ethnicities, as well as all low-income and special education students. According to the National Assessment of Educational Progress in Science in 2000, elementary and middle school students’ proficiency was far below the international level (O’Sullivan, Lauko, Gregg, Qian, & Zhang, 2003: USDE 2004). A high percentage of students, do not even master pre-requisite knowledge and skills, in the specific case of African American 12th graders testing below the basic level. One of the goals of the NCLB Act is 100% student proficiency by year 2014. Many meetings, documents, and summits have followed the signing of the NCLB Act as school systems attempted to comply.

Strategic Plan – In working towards the 100% proficiency goal, a Strategic Plan 2002-2007 of the United States Department of Education was released in March 2002. The plan specifically addressed the need of “improving mathematic and science achievement for all students” and laid out the approach to follow for science, based on the four principles stated earlier (USDE, 2000c, p. 27). This approach included developing mathematics and science
partnerships. Together with the support of the National Science Foundation, the Department of Education encourages partnerships among school districts, higher education institutions, research centers, and scientific institutions. The Department is also encouraging rigorous course-taking in elementary and secondary school. In fact, a recent bill has been submitted to the United States House for a project that will provide additional scholarships to “low-income college freshmen and sophomores who have completed "a rigorous secondary school program of study" and “to juniors and seniors majoring in math, science and other critical fields” (Dillon, 2006). However, if passed, this project is likely to start some controversies because of feared control of the federal government over the local schools, and because the project bill, as written, excludes a high number of students who either attend private schools or are home-schooled.

**Mathematics and Science Initiative (MSI)** – As part of the Strategic Plan and supporting the goals of the NCLB Act, the Department of Education established, in February of 2003, the Mathematics and Science Initiative (MSI) (USDE, 2003). This five-year initiative seeks improving math and science instruction by addressing three main objectives. First, involve the general public in recognizing the need for better science and math education. Second, making a commitment to recruit, prepare, and retain teachers with a strong science and mathematics background. Third, developing a research base which will expand professional understanding of what enhances student learning in science and mathematics. The MSI involves several departments and agencies in collaborating to promote and improve United States science education: The Office of Science and Technology, the United States Department of Education and Department of Energy, the National Science Foundation, National Institute of Health, and National Aeronautics and Space Administration.

As an approach to develop the MSI, the US Department of Education held the Science Summit in March of 2004 (USDE, 2004). This meeting brought together many experts in
different areas of science and education. The state of science education and the future trends were discussed by panelists with the aim of strengthening two goal areas of the NCLB Act: finding better approaches to learning science, and bridging the gap between formal and informal science education.

A presenter at this summit was Dr. Grover Whitehurst, director of the Institute of Education Sciences (Whitehurst, 2004). He established an interesting comparison between the curriculum of the US and other countries that out-performed the US in the Third International Mathematics and Science Study conducted in 1995 (Schmidt, et.al., 1997). This study investigated the mathematics and science curricula of the participating countries through an analysis of curriculum guides, textbooks, and other curricular materials.

Whitehurst indicated there were striking differences in the way we teach science in the US and the way other countries do (Whitehurst, 2004). For example, in some of the countries, science is not introduced until 3rd grade, and science topics are addressed in a hierarchical fashion through 8th grade. This is different from the way the US does it, where concepts “spiral” and are taught all the way from 1st through 8th grade leading to the experts’ critique of the “mile wide, inch deep” US science curriculum.

The data cited and shared during this meeting were based on the 1995 TIMSS study and presented the pitiful status of scientific literacy in the US. However, after I examined the results of the 2003 TIMSS study released by the National Center of Education Statistics (NCES), I find these two studies painted a mixed picture of the future of our students (NCES, 2004). While overall fourth graders in the US had no improvement in science performance between 1995 and 2003, this research indicated that the proficiency gaps between white and black students, and boy and girl students had narrowed, and in addition, the science performance of black students had improved (NCES, 2004). Furthermore, the TIMSS results for 8th graders show a significant
improvement in average science performance between 1995 and 2003. Still, in this category, the US placed below the performance levels of other countries such as Singapore, Chinese Taipei, Republic of Korea, Hong Kong SAR, Japan, Estonia, and Hungary (NCES, 2004). Overall the science performance of all boys and girls, blacks and Hispanics too, improved and achievement gaps among these groups narrowed. We will continue to receive information on the status of the K-12 children’s literacy through future testing. The TIMSS study will be repeated in 2007 and NCLB Act mandates that state-wide science assessments will be conducted during 2007-2008.

It would be interesting to know the state of science literacy of two other sectors: college students and the general public. In my opinion, the more recent study about US K-12 science performance (NCES, 2004) indicates our education system seems to be moving in the right direction. However, more work is needed to improve our students’ science literacy. There is plenty of room for improvement, especially in the elementary school.

**Curriculum and Tools** – The science curriculum is a central issue, not only discussed at the Science Summit, but also in other discourses of science education (Morse, 2003; Rutherford & Ahlgren, 1990; Whitehurst. 2004). According to former Secretary of Education Rod Paige,

,…for the most part, we're still blindfolded and trying to find our way through a cluttered room. Much more high-quality research is needed to determine what methods, resources and curricula are best for educating students at all grade levels.
(Paige, 2004, para. 17)

Dr. George Nelson of Western Washington University, speaking at the Science Summit of the Department of Education, made two interesting points about the science curriculum. First, extending his views to the first two years of college, he pointed out the K-14 education is considered mostly ineffective. Second, in Nelson’s opinion “Most curriculum materials don’t have potential for helping teachers teach or students learn” (Nelson, 2004; slide 3). He specifically noted that a majority of the material produced by major publishers or by the informal education community has not been researched. It is important to establish which are the best
resources and tools available for teachers to employ while using the best teaching practices; but it is also important that students be exposed to the highest quality and most effective materials available. Drawing together the advances of educational research along with the advances in science is an important bridge that needs to be established. Nelson’s viewpoints support the development of the research I conducted.

A point of particular interest for my study is the goal of the MSI mentioned earlier, namely, improving the research of mathematics and science education. The MSI is interested in research that can help improve the educational practices and instructional approaches leading to science literacy. There is interest in the light that can be shed by research on better learning about the way people gain, develop, and apply science and mathematics knowledge. In addition, research can provide information on teaching methods and curriculum materials that can help science instruction become more effective. This goal may not only have an impact in higher education, but also could have an impact on the future design of curricula.

A major limitation on the quality of educational research has been the use of “weak and inappropriate evaluation tools” (Novak, 1998a, p. 16). Most researchers limit their studies by using traditional evaluation tools, like questionnaires, multiple-choice tests, and true-and-false tests to evaluate attitudes, knowledge, and aptitudes (see Novak, 1998a for multiple examples). Novak (1998a) claims that this approach only exploits about 10% of the human abilities. Therefore we are missing information about the other 90%, and any light that may shed about the level of human knowledge. It is not possible to improve practice based upon research if we are “missing the point” because our assessment tools fall short of what they need to measure.

A Direct Call for Reforming College Science Education

Although the US science education reform efforts address most explicitly the K-12 classrooms and teacher’s education, many ideas and premises are also relevant to the higher
education sector. One of the challenges faced by science educators in higher education is bringing together the knowledge contributed by the recent advances in science research and applying to their teaching practice the best educational research on how students learn science.

According to Alberts (2003), the major improvements at the K-12 level can only be maintained by improving science education in the first years of college. This idea is not surprising when we think that college science most likely has a direct impact upon the quality of the science background future science teachers will have. Already the K-12 science reform has identified teacher preparation in science as one of the weakest links in the chain that needs to be changed. In addition, research institutions are also calling for better-prepared students that are trained to bring interdisciplinary knowledge to bear on problems to meet the current needs of biological research (American Cancer Society, Burroughs Welcome Fund, and Howard Hughes Medical Institute, 2000; National Research Council (NRC), 2000).

To attend to this matter, the National Academies Press (NAP) has published several reports, like Science Teaching Reconsidered (NRC, 1997); Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology (NRC, 1999a); Bio 2010: Transforming Undergraduate Education for Future Research Biologists (NRC, 2003), and others. These reports expose the problems that exists in the college situation – specifically, the way science is taught at most colleges and universities is far from optimal if it is to prepare both future scientists and college graduates who are scientifically literate. The objective of many of these reports was improving the introductory science courses offered at the college level.

The NRC recognizes two main problems that should be addressed and calls upon colleges and universities to work on these: instructional practices employed by university science faculty and outdated/inappropriate science curriculum content. These problems are not new, as they have been recognized to some extent in earlier reports,
In the early 1990s, a network of professional societies in biology set out to increase the attention paid to undergraduate education. Efforts by the Coalition for Education in the Life Sciences (CELS) led to the publication of a curricular framework for introductory biology. *Issues-Based Framework for Bio 101* (Coalition for Education in the Life Sciences, 1992) called for all students to receive an education in overarching issues in biology in the belief that this education is necessary to prepare them to participate fully in society. The group also published a monograph entitled *Professional Societies and the Faculty Scholar: Promoting Scholarship and Learning in the Life Sciences* (Coalition for Education in the Life Sciences, 1998). This monograph addresses issues of faculty development, including the way that “faculty finds both cooperation and competition from many sources in their commitment to teaching.” (NRC, 2003, p. 21)

**Approaching College Faculty** – According to the NRC *Bio 2010: Transforming Undergraduate Education for Future Research Biologists* report (2003), most college faculty follow a didactic approach, teaching just like they had been taught. However, educational research indicates these are no longer the best practices conducive to learning (NRC, 1999a). According to the *Bio 2010 report* (2003), to engage undergraduates and also to prepare them for graduate studies, students must experience the empowering of active learning through inquiry. In an effort to move education practices in this direction, the *Bio 2010* report approached university faculty who cared about education and who had received no training in how to teach (NRC 2003). It offered them suggestions to improve their teaching and provided helpful examples, such as case studies. *Bio 2010* also called on the administrators of colleges and universities to support “faculty who want to devote energy to improving teaching and to producing new teaching materials.” (NRC, 2003, p. 22). Administrators were encouraged to revise their policies and provide incentives for faculty who dedicate time to improving quality education for undergraduates, and provide professional development time. These activities are not commonly rewarded by the university or college administration, compared to time devoted to research, grants, and publications.

**A New Look at College Biology Curriculum** – *Bio 2010* (2003) also looks into transforming the biology curriculum to make it relevant to the needs of the new century (NRC,
2003). Undergraduate biology education and biological research have moved at a different pace in the past 20 years. Current educational practice corresponds to “the biology of the past, rather than to the biology of the present or future.” (NRC, 2003, p. 1).

Bio 2010 (2003) recommends an interdisciplinary approach for life sciences majors, including a stronger foundation in physics, chemistry, and mathematics. Although the Bio 2010 report is focused on better preparing students for biomedical research, interestingly, it also considers establishing connections between different biological fields to be important. It recognizes the power and relevance of population biology, plant biology [emphasis added], evolutionary biology, and behavior and cognitive science. Furthermore, the report favors a comprehensive, well-integrated curriculum, rather than one that tends to compartmentalize,

The connections between biomedical research and other sciences will become more intimate and mutually reinforcing …the fundamental unity of biology speaks strongly against the desirability of compartmentalization too early in one’s education. (NRC, 2003, p. 24).

The report suggests strengthening the existing courses by bringing in examples, (i.e. modules), with related concepts into the courses rather than creating and adding new courses. In addition, courses can benefit from team teaching. The report provides several references, such as the National Science Digital Library, the BioQUEST Curriculum Consortium, the National Center for Case Study Teaching in Science at SUNY-Buffalo, and the University of Delaware’s Clearinghouse as sources of modules and case studies that can be integrated into courses. (cited in NRC, 2003: http://www.smete.org/; http://www.udel.edu/pbl/; http://ublib.buffalo.edu/libraries/projects/cases/case.html).

Another problem with curriculum that the NRC recognizes is teaching to the test. Students (and biology curricula) had focused on those courses needed for medical school admission and for preparing to take the Medical College Admissions Test (MCAT) (NRC, 2003). In fact, the report recommends that medical school and MCAT requirements should be reexamined (NRC,
2003). In light of the recognition of the need for a more comprehensive education in biology, and the use of the best teaching practices, then research studies like the one I conducted, focused upon learning gains in biodiversity education become relevant, not only for the non-major student, but also for major students who may not even be interested in following the organismal biology approach.

Scientific Societies

Three scientific societies are intimately related to the progress and quality of science education, ecology and botany in particular. Namely these are the Ecological Society of America (ESA), the Botanical Society of America (BSA), and the American Society of Plant Biologists (ASPB). In the paragraphs below I briefly describe the role of each one of these. The scope of this review was limited to the associations of interest for the research proposed here. In the following paragraphs I summarize their roles in contributing to science education reform and helping improve science literacy.

Ecological Society of America (ESA) – The Ecological Society of America has created an education program with the goals of engaging the public in a dialogue on ecological research and issues, and improving the quality of ecology education at all levels (ESA, 2005a). The ESA encourages the members to take a leadership role in bringing together the best science, research, and practice to present the content, extent and challenges of ecology education” (ESA, 2005b). The ESA is providing support for faculty professional development in the area of ecology and working on stimulating interest in ecology. In working towards these goals it has made several resources available to the educators and students including the Ecology Education Network (EcoEdNet), Teaching Issues and Experiments in Ecology (TIEE), and Strategies for Ecology Education Development and Sustainability (SEEDS).
TIEE offers resources that faculty can use in the classroom. It also offers support for higher education faculty establishing a bridge between science content and pedagogy to deliver it effectively. An example of this is a paper by D’Avanzo (2000) wherein she describes the differences between assessment and evaluation, and between summative and formative evaluation. As an ecologist with a profound interest in education, in this paper she provides some examples and how these can be used in different scenarios. She also directs faculty to many other resources that can further help them teach ecology better. In addition, ESA continues working on helping to reform biology education. Last year (2005) the organization started a project to evaluate the effectiveness of TIEE materials. This project, which involves ecology faculty of universities and community colleges, will last until 2006. It will use resources from TIEE and evaluation tools to study the effects on student learning. The study will focus on students’ misconceptions in ecology and the development of critical thinking (ESA, 2005c).

**Botanical Society of America (BSA)** – The primary objective of the Botanical Society of America is to provide formal and informal education about plants. It provides educational support through different tools and resources made available for K-16 educators. One such example is the report *Botany for the Next Millennium* (BSA, 1999). This report is a visionary outlook to the 21st century, portraying the research and educational goals of botany. It focuses on two main ideas, integration and education. BSA recognizes the need of integrating different levels of plant biology research and increasing education and communication about plants at all levels of society. The latter is addressed by revealing to non-botanists the role of plants in evolution and diversity, their value as models for studying organismal development, and their important role in ecosystem structure and function. It also makes plants more relevant to the general public by describing their practical used for humans as food, fiber, fuel, and pharmaceuticals.
Other examples of educational support provided by the BSA include articles and support on educational practices. Educators teaching about plants at any level can find resources such as an article on plant misconceptions which can be used to teach (correctly) many difficult plant-related concepts (Hershey, 2005). Hershey’s work on explaining students’ misconceptions is important in light of research that indicates upper elementary children are capable of changing their misconceptions (Chinn & Malhotra, 2002). If children can make discrepant observations, they are often willing and able to change their concepts in response to their observations.

Lastly, a BSA project, started in spring of 2006, called Scientific Inquiry through Plants, provides a forum where students will be able to participate in hands-on inquiry to discover biological core concepts and at the same time have access to the expertise of plant scientists serving as mentors who will be available online (BSA, 2005).

**American Society of Plant Biologists (ASPB) –** The American Society of Plant Biologists promotes the teaching and learning of science using plants. It contributes to the development of plant biology literacy through different programs, educational tools, curricula and fellowship. It provides resources for K-16 teachers, graduate students, and faculty (ASPB, 2005b).

One of the most remarkable contributions of the ASPB in the last years has been the development of the Principles of Plant Biology (See Appendix A; ASPB, 2005a). The list comprises 12 principles stating important science propositions about plants. The objective of the list is to help students understand plants better by establishing connections between our human needs and the many services provided by plants to meet (directly or indirectly) all of those needs. The ASPB standards have been matched to the National Science Education Standards for K-12 education. In addition the Gap Analysis report that followed, integrates the standards with the areas highlighted in Science for All Americans: Project 2061 and with the Science Framework or
Performance Standards for several states, including Texas, Mississippi, Tennessee, and California (Hyps, n.d.).

Several of the ASPB plant biology principles address the issue of plant biodiversity and diversity of life in general. Therefore I have used the list as one of the criteria guiding the selection of activities used in this research.

I have established what science literacy entails and how scientists, educators, and government officials, through multiple means, are working to bring the American students and society in general up to an adequate level of it. In the next section, I address the theoretical framework of science education relevant to this study.

Constructivism and Science Education

Constructivism is a major influence within the education arena. It began as a theory of learning, but expanded to influence theories of teaching, education, origin of ideas, and personal and scientific knowledge. Constructivism offers a “theory of knowledge” (Bettencourt, 1993, p. 39) which can be used to make “sense of all situations where someone is learning” (Dana & Davis, 1993, p. 333). It is considered by some as post-epistemological, in the sense that is not just another way of knowing but rather a referent for teaching, learning, and curriculum (Tobin & Tippins, 1993). Being a controversial topic, there is no clear or singular definition, except that it can be considered “mainstream contemporary science education” (Illman, 1998, para. 3). As an epistemology the premises of constructivism are:

(a) Knowledge is constructed, not transmitted, (b) Prior knowledge impacts the learning process; (c) Initial understanding is local, not global; and (d) Building useful knowledge structures requires effortful and purposeful activity (Physics Education Research Group, n.d., para 3)

Constructivism has been influencing the philosophy of education of teachers for almost two decades now. It has the potential to transform educational theory, and is also considered by some to “speak to the nature of science” (Bentley, 1998, p. 243.; Fleury, 1998).
The birth of constructivism as a philosophy of learning can be traced back to the work of Giambattista Vico in the 18th century. He claimed that humans can only clearly understand what they have themselves constructed (Mintzes & Wandersee, 1998). In his 1744 work *New Science* (*Scienza nuova*), Vico discusses the idea that imagination, memory and reason are linked to the way humans think and act (Institute for Vico Studies, 2005). This view of constructivism also is reflected by Pepin (1998), who argued constructivism gave perspective to the human adventure, has given meaning to humans’ existence and their ability to survive and adapt. Two centuries later, Jean Piaget and John Dewey further developed the idea of human construction of meaning and applied it to childhood development and to classrooms.

John Dewey brought to the development of this idea the social aspect. In his view, learning takes place in a community of learners. It is in this community where students are exposed to unique meaningful experiences and where they actively use materials and construct their knowledge together (Southwest Consortium, 1995).

**Discovery Learning and Constructivism**

Jean Piaget is considered by some to be the “great pioneer” of constructivism and “most eminent developmental psychologist of our age”. He focused on the stages of development of the child’s mind (von Glasersfeld, p. 22, cited in Good, Wandersee, & St. Julien, 1993; Mintzes & Wandersee, 1998, p. 36; Southwest Consortium, 1995). According to Piaget, children will go through assimilation, accommodation, and equilibration (Mintzes & Wandersee, 1998). As the students progressed from one stage to the next, the successes of the previous stage will be brought to the next stage (Shayer & Adey, 1981). Piaget considered it important that teachers understand these stages and help students build up their knowledge step-by-step, discovering ideas and relationships as they are involved in meaningful activities.
In Piaget’s perspective, discovery and active involvement will prepare individuals to be creative, rather than just being capable of repetition. Discovery is the outcome of confronting a pre-existing way of thinking with new ideas (observations) that don’t accommodate to it. This notion, lifting the human mind to the maximum of its intellectual capacity, is very enlightening when we put it in the context of science education. I ask myself: How far has the educational system has deviated from it?, and How many times has it turned off the “curiosity/discovery button”? We see the “stages” and “discovery” applied to the science education setting, when Piaget considers more important the examining of “stages of scientific thought” for developing scientific knowledge (genetic epistemology) (Good et al., 1993, p. 76). In Piaget’s view, psychological study can help explain the growth of scientific knowledge. According to Piaget it “can enlighten us on the true importance and fundamental intuitions…” (Good et al., 1993, p. 76). To understand reality or truth, different branches of science employ different methods.

Therefore, it is important teachers both know their science and at the same time understand the development of the learner’s mind and body. Teachers must play the role of an organizer-mentor who stimulates “initiative and research”, in other words stimulates curiosity and discovery, for learners to gain scientific knowledge (Good et al., 1993, p. 82).

Like Piaget, Bruner also considered discovery to be an essential part of the learning process. In Bruner’s view, students should be problem-solvers, ready to explore difficult problems (Bruner, 1960). He also thought that anything can be explained to some extent to any child at any stage of development (Mintzes & Wandersee, 1998). Looking at the big picture, even though students may not be fully ready for it yet, as they are subsequently exposed to difficult ideas they can better learn about the connections between concepts. He advocates structured knowledge, or what can be explained as conceptual knowledge. Bruner set the basis for discovery learning and conceptual schemes (Mintzes & Wandersee, 1998).
Whether or not students develop better understanding if they are exposed to activities where they decipher concepts by themselves is considered by some an open question (Fay & Mayer, 1994; Mayer, 2004; Whitehurst, 2004). Mayer (2004) disagrees with discovery learning, stating that he opposes the idea that constructivist teaching should be restricted to methods where pure discovery is expected. In an experiment where children were learning programming skills with LOGO (which uses graphical language) it was found that children who had specific programming instructions (guided discovery) learned more than those that used discovery. The group that received more direction was better able to write more elaborate programs (Fay & Mayer 1994; Mayer, 2004).

Ways of Constructivism

In the late 1970’s, constructivism deviated from the Piagetian focus on the mental stages of the learner shifting to focus on “the actual content of student thinking”, a focus on the individual (Cobern, 1993, p. 53). Constructivism is characterized by two basic tenets. First, an individual’s knowledge encompasses a complex set of ideas. Second, students construct their own meaningful knowledge by building upon their own preexisting ideas. The second tenet draws upon Ausubel’s theory of meaningful learning and implies there is a change in ideas (Cobern, 1993). The “building” (hence the metaphor of construction) consists of hierarchically linking by adding, replacing, or modifying new concepts to previously stored concepts in the long-term memory forming propositions (Good et al., 1993, p. 76). In this hierarchy, higher order concepts involving nested patterns form constructs (higher order concepts). Major propositions form principles, which can be organized into theories that help explain the natural world. This pattern of construction results in learning that is to some degree individualized and depends on the particular perceptions of the individuals (Good et al., 1993). Therefore, we can say that as a learning referent the possibilities vary, as does the knowledge constructed by the learner.
It is also considered “an emerging consensus among psychologists, science educators, philosophers of science, and others, that learners (including scientists) must construct and reconstruct their own meaning for ideas about how the world works” (Good et al., 1993, p. 74). Before the apparent “consensus”, science and math education researchers have interpreted constructivism in many different ways as it departed from the Piagetian/Neo-Piagetian avenue. At least fifteen different descriptors of constructivism have been identified by Good et al., (1993). However, these different forms of constructivism, rather than help explain, may in fact obscure critical differences which really matter for the progress and effectiveness of science education research. Three of these attributes are presented below.

**Radical Constructivism** – The *radical* (meaning root in Latin) adjective stresses how constructivism is more than just a method of learning, but instead how knowledge and the process of knowing go together. Developed by Von Glasersfeld, radical constructivism rejects the existence of an external reality. Von Glasersfeld breaks with all traditional conventions, and presents reality as a world dependent on, relative to, and understood by our own (learner) experience (Physics Education Research Group, n.d.; Matthews, 1993; von Glasersfeld, 1993; von Glasersfeld, 1992, cited in Tobin & Tippins, 1993). This reality in a sense is just “not [out] there”, and “no amount of stimuli, experience, or thinking is sufficient to *prove* the existence of an external agent” (Physics Education Research Group, n.d.). According to him, everyone perceives “reality” in a different way than others do.

Von Glasersfeld’s radical constructivism influenced the thinking and practice of some science educators (Mintzes & Wandersee, 1998). However, his view of reality contrasts with the perception of reality in the scientific world. While the meaning of reality for the radical constructivist comes from the interpretation imposed by the individual, we are secluded from the nature of that reality; at best knowledge is just but a mapping of changes allowed by that reality
For scientists presumably there is a reality. Scientists search for, try to understand, and explain that reality. This scientific reality is discovered through the use of the intellect and with the aid of technology (AAAS, 1989, cited in Good et al., 1993). Therefore we can say that the constructed reality can change as new technology becomes available and reveals more information. This is how science progresses in the long-term. However, because the scientific reality is available to “discovery”, then one has to assume this reality indeed already exists. Although these previous ideas may seem contradictory, in essence they are not at the level of epistemology. Scientists acknowledge we can assume reality is there and build a model of it, but we really know about it only through “stimuli and experiences” (Physics Education Research Group, n.d.). Some disagree with the radical constructivist’s dismiss of reality, and argue that there are some instances where consensus on a reality, and acceptance of objectivism, make more sense than an individual interpretation (Merrill, 1992).

In von Glasersfeld’s view of radical constructivism the teaching practice allows opportunities to use ideas in different situations. This is possible by combining the traditional lecture with discussions, images, and time for reflection. As the hands-on experiences, it is important that these have a purpose and that students engage in discussion about them. Therefore three conditions should be met to make the experience meaningful: (a) a question prior to the activity, (b) reflection on the difficulties met, and (c) an accounting of what was met. This approach seems to validate the importance given by other constructivist to process over content during the development of knowledge (Wheatley, 1991, cited in Good et al., 1993).

Good, Wandersee, & St. Julien (1993) warn about dangers of the radical constructivists’ view of the nature of science. As a “postepistemological interpretation”, radical constructivism seems to be limited to “pedagogical and psychological considerations”, and avoids debating the nature of science (p. 72). This is a dangerous position because it can lead to acceptance of
pseudoscientific views. Perhaps, I believe, it could be one of the reasons behind some of the problems both the scientific community and the science educators are facing with the teaching of some concepts today. In a critique to the influence of constructivism in the New Zealand’s curricula and educational system, Matthews (2000) brings up the issue in a similar way, being concerned about the fact that what could make sense is not always the truth,

There is a not-too-subtle difference between the constructivist formulation ‘making sense’ and the realist formulation ‘finding out’…Things can make perfect sense without being true; and making still more sense does not imply any increase in truth content.

It is notorious that people have for centuries thought that the grossest injustices, and the greatest evils, have all made sense (p. 182)

Another problem with the postepistemological interpretation of radical constructivism is the separation of science from science education. The divorce of process and product may hinder the development of the science education field and delay attaining the goal of scientific literacy as exposed by *Science for All Americans* (Good et.al., 1993).

**Social Constructivism** – In social constructivism the social interaction is valued as a “powerful influence” of the knowledge construction process (von Glasersfeld, 1993, p. 24). The social constructivist approach to education had its origins in Vygotsky’s ideas which emphasized the influence of society on the development of the individual. In fact, for this very same reason, learning has a social context that some analysts don’t recognize. Vygotsky was a constructivist (Southwest Consortium, 1995). In the radical constructivist notion, society represents a construct in itself, and as such needs to be analyzed. In contrast, in the social constructivist view, society is assumed to just be there, present. This social context is provided, for example, in the interactions among students and with the teacher. The teacher-student interaction leads to developing a common sense and is a critical component of the learning process (Solomon, 1987, cited in Cobern, 1993). The meaning of reality comes from the individual, but only as one makes sense when different perspectives are brought upon by others through their common interactions.
Therefore, the interaction is not only influenced by the knowledge of the teacher but also by how they interact and understand the way “their students view the world” (Mintzes & Wandersee, 1998, p. 45).

In this line of research, some teaching strategies include group collaboration, class discussion, and teaching in a context that is relevant to the learner (Wood et al., 1995). While collaborating to solve a problem, the learners may arrive at “self-chosen” positions, but also realize they may disagree with others views (Cunningham, 1992, p. 36).

**Personal Constructivism** – Student conceptions are the focus of personal constructivism. In this perspective, learning is achieved as misconceptions are worked out and scientific conceptions which are regarded as true and more plausible replace the original conceptions students had. Novak brought to the discussion Vygotsky’s view of environmental influence on children’s conceptions. According to Vygotsky the way children learn scientific concepts is through creating and resolving conflicts between the prior conceptions and new ideas that are presented to them (Doolittle, 1997). These new ideas, however, need to be presented in a way that they can use. As a network is created between the ideas, they become the student’s own.

In the late 1980’s research in science education began comparing the student’s construct with the actual meaning in science. When poor matches were found, they were addressed as misconceptions or alternative conceptions (Cobern, 1993). Three international conferences organized around the theme of misconceptions drew a significant amount of papers and advanced this line of research (Helm & Novak, 1983; Novak, 1987). Posner contributed a model on conceptual change during the 1980’s which integrated the influence of the environment. It emphasizes mechanism and is considered a feasible and reasonable way of helping students construct knowledge and develop their scientific literacy (Good et al., 1993).
Much research has been done since the 1980’s and the 1990’s where constructivism, in its many forms, constituted the theoretical background. Constructivism has been employed by researchers both as a teaching method and as a referent, with variants within each one of these. In the science education arena, curriculum, methods, and practices have been influenced by both of these views. As a teaching method teachers consider the prior knowledge of the students, and use group work and sensory experiences to foster knowledge creation (Fosnot, 1992). As a referent or set of ideas, constructivism offers a framework to interpret “the learning potential of any situation” or is used as a tool of reflection to help evaluate teacher-student roles, where at times teachers will be playing both, building their knowledge from “experience and social interaction with peers and teacher educators” (Tobin & Tippins, 1993; pp. 8-9). All three angles of education, teaching-learning- reflection, are needed in order to make sense of the educational experiences and help students construct their reality.

Constructivism is controversial in many ways. Both the philosophical – epistemological- and the pedagogical standpoints have been criticized. According to Good, Wandersee, & St. Julien (1993) an important issue that must be considered along with the different interpretations of constructivism is that these represent critical differences among the proponents which are blurred under a “constructivist” umbrella. These different “varieties” of constructivism should be critically considered and debated, since they impact the outcomes of educational practices.

From a philosophical standpoint, the lack of clarity in the way “reality” is defined under the different forms of constructivism is blamed as one communication obstacle between those on the pure science side and those on the education side of the table. This possibly leads to the well-known clashes between these two worlds (Illman, 1998). Some argue that the efficacy of constructivism as pedagogy in teaching science is debatable, and in fact it “gets in the way of good teaching” (Mathews, 1997, p. 13; Mathews, 2000). Some of the examples given to support
this idea include the traditional use of experimental work and the development of class
discussion. They argue experiments most of the time do not work out, and furthermore, some
concepts can not even be explored from an experimental context (i.e., nuclear power) (Hodson,
1991; Illman, 1998). In addition, critics question the role teachers play as moderators of class
discussion, where they remain neutral and do not convey information to the students (Hodson,
1996; Illman, 1998). Although critics don’t call for a complete abolition of practices, they
believe pedagogical practice should be modified to permit knowledge transmission as one of the
approaches to teaching science in the 21st century, including the knowledge necessary for “the
future of life in this planet” (Illman, 1998, line 219).

Human Constructivism

Although this theme was developed earlier as part of the conceptual framework, I include
some aspects here to facilitate a better comparison with the other “modalities” of constructivism
discussed above. I also want to stress what makes human constructivism so unique.

Developed by Joseph Novak in the late 1970’s, Human Constructivism is more than just
another epistemology. Human Constructivism offers a comprehensive theory of education which
offers perspective on how meaning is created through combining a theory of learning, theory of
knowledge, theory of teaching, and theory of management (Mintzes & Wandersee, 1998; Novak,
1998a). In Novak’s words, “Meaningful learning underlies the constructive integration of
thinking, feeling, and acting leading to human empowerment for commitment and responsibility”
(Novak, 1998a, p. 13). Learning – meaning is seen as an emergent property of the interaction of
all the actions that are part of the experience, feelings (manipulations and perceptions), thinking,
and actions. These are human activities, hence the term, human constructivism (Novak, 1998a).

The foundation of human constructivism lies in Ausubel’s cognitive assimilation-
meaningful learning theory. In Ausubel’s view, learning starts with what the learner already
knows. However, his ideas were said by Piagetians to be short on measuring how this learning takes place and what processing skills the learner can use to cope with the new concepts (Shayer & Adey, 1981). Although Piaget had paved the road on this with his mental stages, still more needs to be done to discover the active role of the learner in the process of learning. Learning is a verb. The unique value of human constructivism is in the way it brings together the positive aspects of the radical and social (and personal) constructivist modalities, (i.e., discovery learning, conceptual change); but goes beyond, and finds a way of measuring, thus adding to the teaching practice an *assessment* component, so far absent from other epistemologies.

In addition, it still values all the other four components of every educational situation: learner, teacher, subject matter (knowledge), and social environment (Novak, 1998; Novak, Mintzes, & Wandersee, 2000). These four elements are part of the process of building knowledge. As they integrate, the learner can establish connections between what is already known and the new situations. As connections are established, learning takes place.

Then, how can we know learning occurred or is occurring? The fifth element comes into play: assessment. Assessment is achieved through different tools that can be used in the classroom, (i.e., concept maps, Vee diagrams, etc.) to evaluate whether meaningful learning is taking place as the learners build upon their prior knowledge. These tools are actually capable of exposing the process of knowledge construction. They can be used throughout the learning experience as formative assessment devices or at the end for summative assessment (Novak, et al., 2000).

Human constructivism subscribes to the notion that the “single most important factor influencing learning is what the learner already knows” (Mintzes & Wandersee, 1998, p. 39). To this tenet it adds how knowledge is restructured and concepts are changed, leading eventually to meaningful learning.
Instructional Practice

In this section I present information regarding four areas: curriculum, teaching, learning, and assessment as seen through the lens of constructivism.

Constructivist Curriculum

The constructivist view of learning has been the most obvious influence on science curriculum during the 1980’s (Fensham, 1992). In the constructivist curriculum an understanding of science is gained as a result of the interaction between content and process (Tobin & Tippins, 1993). Knowledge, knower, and culture are one. Teachers are considered mediators, and the focus of the process of teaching is the student not the content. Teachers are expected to interact extensively with the students, and while considering the student’s interests and goals, steer them and provide them with new concepts upon which to build the new knowledge.

Although the constructivist approach has been influential, it still is not the most common practice observed for how the material is presented in the science classroom. Giest and Lompscher (2003) recognize this important problem of the science classroom when they say,

Science education suffers – among other shortcomings- from the dominant orientation toward isolated, nonsituated facts, which are seldom applied to real life situations. This approach leads to difficulties in understanding and a loss of sense and motivation in many students (p. 267)

Furthermore, following this line of thought, Costa and Liebman (1995) advise against the use of the curriculum-discipline recipe a la’ Descartes where content is “organized in discrete compartments” (p. 23). Rather, they suggest an integration of process and content, a way in which content is not devalued but carefully selected and used as “the means” rather than being “the ends”.

They recognize three areas of change for curriculum. First, the traditional disciplines are being replaced by transdisciplinary inquiries which look for patterns and connections. This notion actually originates from the ideas of Vico, who advocated the “interdisciplinary
conception of knowledge” (Institute for Vico Studies, 2005). This proposed change follows also the curricular changes proposed by the NRC for higher education, discussed earlier in this review. Moreover, I believe the notion of integrating different disciplines fits particularly well with what biology education is experiencing in the area of ecology and biodiversity education (discussed later in this chapter), where integration of different disciplines has elevated the study of biodiversity to the more integrated level, namely biocomplexity.

The second area Costa and Liebman (1995) recognize is globalization, which brings together many different voices that enrich curriculum, (i.e., females and indigenous peoples). Thirdly, rather than learners experiencing frustration because they can’t deal with content, Costa and Liebman argue to let them recognize their capacity to learn and to create personal wisdom. As they discover connections, they are able to keep things in perspective and apply this knowledge in everyday situations (Costa & Liebman, 1995). This is in fact the area of change that most closely follows the human constructivist approach to the organization of curriculum.

Human constructivism sees curriculum in a simpler but deeper way, “less is more” (Mintzes & Wandersee, 1998, p. 56). What this means is that even though fewer concepts are presented in the classroom, multiple connections are established between central concepts and objects and events, and between objects and events. These are also stronger, deeper more basic connections, thus elevating knowledge construction to a meaningful level.

In applying this view to the research proposed here, in teaching biodiversity one should consider it to be important how biodiversity develops, what it means, and how it is conserved. For example, it may not be possible for the students to learn about the totality of biodiversity, but rather by focusing on plants they could possibly learn important basic concepts that apply to other kingdoms as well: what it is, the process by which it comes to be, how it is affected, and by corollary how it can be protected, and so on.
Constructivist Teaching

Two former presidents of the National Association for Research in Science Teaching agree that the educational arena during the 1980’s was influenced by a paradigm war between two opposing views, objectivism (positivism) and constructivism. Perhaps it is a war that is still ongoing, in spite of reform movements, and while some argue for a compromise to work together, others believe the issue should be further discussed for the benefit of science education (Crowther, 1997; Illman, 1998). The more recent trend is for research, teacher education and curriculum development to be unified under the constructivist umbrella and there is evidence of general recognition of constructivism (Tobin, 1993; Yeany, 1991).

Stated briefly, positivism strives to understand the world as it is and discover truth. Thus, is the basis of the traditional model of education (Dana & Davis, 1993). This model portrays a passive teaching-learning process which is guided by a set plan. This plan is based on conventional body of knowledge that has been shaped and acknowledged by society. Knowledge is acquired through a routine of lecture-memorization-testing, with knowledge assessed by recalling factual information verbatim.

In contrast, pedagogy takes a new shape under the epistemology of constructivism. The focus is shifted to the learner. The teacher’s role is as a mediator helping students build and interpret concepts, rather than just memorizing them (Tobin & Tippins, 1993). This implies that teachers help students develop learning and reasoning strategies through their interactions (Cobern, 1993; Duschl & Gitomer, 1997). Rather than just covering the material as planned, teachers must critically assess student learning and manage to direct student thinking in the appropriate direction for learning to occur (Bransford, Brown, & Cocking, 1999). Dana and Davis (1993) suggest group learning, problem-centered activities, laboratory activities, and the use of technology as some of the teaching practices that can lead to meaningful learning.
experiences. Meaningful learning involves connecting new concepts in multiple ways to concepts we already know.

**Inquiry** – Teaching by inquiry is the preferred practice in a constructivist classroom. According to DeBoer (1991), inquiry has been the goal of science education since the 1950’s. In fact, inquiry is the main instructional practice advocated by the American Association for the Advancement of Science (1993) and the National Research Council (1996) in the science education reform agenda. As Novak states, inquiry is “the behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious” (Novak 1964, p. 1, cited in Haury, 1993). Inquiry engages students in seeking explanations and solutions for their curiosities.

As inquiry teaching is emphasized, teachers can stimulate curiosity through many different kinds of instructional materials including appropriate textbooks, interactive media, and databases (Haury, 1993). Teachers become guides of the learning process rather than transmitters of science knowledge to passive student receivers. The National Science Education Standards (1996), in fact, supports immersing students in activities that emulate the real world and situations that approximate how scientists work (NRC, 1996). Several benefits of the teaching by inquiry approach have been reported: (a) fostered scientific literacy and improved knowledge of science vocabulary, conceptual understanding, and critical thinking (Haury, 1993).

Inquiry teaching has been shown to positively impact student learning. In research conducted in a non-majors biology course at a community college, students demonstrated a significant improvement in reasoning capabilities and higher achievement when exposed to inquiry rather than expository (facts and concepts) instructional methods (Johnson & Lawson, 1998).
Similar results were found in a study with high school students who were taught biological concepts of genetics, homeostasis, ecosystems, and natural selection (Lavoie, 1999). The instructional method employed in the latter case was the traditional learning cycle emphasizing prediction-discussion, as compared to inquiry (exploration, introduction, application) using hypothetico-predictive reasoning to construct knowledge. Students in that setting had significant gains in process skills, logical thinking skills, and science concepts.

Prior training for science teachers in inquiry teaching is necessary to develop inquiry skills and to help them engage students in inquiry activities. A study with preservice teachers who were biology majors indicated that those teachers were most successful in proposing hypotheses and generating arguments for testing when the causal agent was observable rather than unobservable (Lawson, 2002). Overall they lacked skills associated with the hypothesis-testing process. Lawson (2002) argued this understanding was needed in light of the emphasis being given to teaching science as inquiry. He also asserted there should be consistency in the definitions of hypotheses, predictions, results, and conclusions across the sciences in order to foster progress in students’ understanding of the nature of science, and for science teachers to teach effectively.

A study where pre-service teachers took an environmental inquiry course that included a real field experience showed a positive change in their attitudes towards investigating questions about the environment (Brown, 2000). All the previously cited findings support the idea of using an inquiry approach in teaching biodiversity in the introductory college biology course, since frequently this is one of the science courses that pre-service teachers will experience in fulfilling their science requirements.

**Scaffolding** – Here I wish to expand upon this topic, along with Vygotsky’s zone of proximal development that was mentioned in the introduction. As an instructional strategy,
scaffolding is used by constructivist science teachers to help learners discover and build knowledge. This basic idea is also one of the main ideas in Bruner’s work, known as the spiral organization of curriculum (Bruner, 1960).

According to this notion, each new concept builds upon what was previously learned. In order for this to really happen, then teachers need to interact with the students “to a greater extent than in traditional classrooms” (Bruner, 1960, p. 10). Teachers must plan and implement tasks and guide the students through acceptable scientific pathways of thinking, instead of just transmitting the information to them. Students can be involved in building their knowledge by asking their own questions and answering them. Given that scientific knowledge must be reconstructed by the learner, the culture and experiences of the learner greatly influence what and how things are learned.

The BioKIDS program is an example of an inquiry-focused approach to teaching biodiversity to upper elementary school students. In this program, students use their own data generated from the school yard, plus several technological resources, to gain additional knowledge (Songer & Lee, 2003). When this project was extended to examine the effects of scaffolding, it was observed that the students who experienced scaffolding throughout instruction showed more knowledge gains, in comparison to students exposed to fading scaffolding (Lee & Songer, 2004).

**Classroom Design** – In recent years, there has been a decline of about 16% in the number of students graduating as science majors, compared to an increase in the overall number of bachelor degrees awarded (Harworth, 1993). It has been observed that what steers students away from becoming science majors or from even pursuing more courses in science are the experiences they have in the introductory science courses (Sunal, et al., 2001). These courses are
frequently characterized by a lack of relevance, passive student roles, and emphasis on competition (Tobias, 1990).

Part of the decline problem may be attributed to the challenges experienced by higher education faculty. On one side, they face a wealth of new information produced by scientific research that they are expected to teach, and they sense the pressure to become effective science educators as education research contributes more methods for teaching science to college students (Dana & Davis, 1993; Magner, 1992; Tobin & Tippins, 1993). On the other side faculty, are faced with the dilemma of teaching versus the demands for scientific research and publishing (Sunal, Hodges, Sunal, Whitaker, Freeman, Edwards, et al., 2001).

Addressing both sides of the coin is extremely important. While most science faculty lack familiarity with pedagogy, this must change because “this ignorance will limit the extensive science education reform efforts now under way in the United States” (D’Avanzo, 2003, p. 1127). D’Avanzo encourages college faculty to use a metacognitive teaching approach (for example teaching and encouraging students to ask their own questions and monitor their own understanding), including problem-based learning, using group work, and designing the class to elicit relevant science misconceptions so that these can be addressed in the course.

Teachers who use a constructivist approach for science teaching construct a learner-centered environment. In this environment, the knowledge, skills, attitudes, and beliefs of the learner are valued (Bransford, et al., 1999). Teachers may bring, for example, hands-on experiences to the classroom, primary sources of information (i.e., raw data), and interactive materials. They may also lead students to observations of the natural world. These activities provide the students with unique experiences and a common shared experience upon which the learners can build their new knowledge. Once a problem is identified along with the contextual information, the teacher closely monitors the students and provides them with guidance to direct
their thinking. Throughout classroom discussions, teachers should encourage their students to think independently, to help them achieve their own intellectual identity (Brooks & Brooks, 1993).

In support of teachers who want to design effective constructivist classrooms, the Biological Science Curriculum Study (BSCS) developed the “5-E” instructional model (Bybee, 1966; Miami Museum of Science, 2001). This model provides five stages that are typically applied in the following order to help teachers in their instructional design. These stages of the 5-E model are: (a) Engage – This stage involves using an activity to stimulate interest in the students and help them connect the new concepts to past experiences. The engage level also helps the teacher identify what the students already know and if there are misconceptions; (b) Explore – Instruction in this stage is driven by inquiry. This stage allows student to get actively involved manipulating materials. As they work together, they apply scientific process skills and previous understanding to develop new concepts. The teacher has a dual role of guidance through the inquiry process and facilitator providing the necessary materials; (c) Explain – In this stage the learning transforms the abstract experience into language. Communication is a critical component, where students exchange ideas with peers and with the facilitator providing a supportive network, and opens and avenue for incorporation of new vocabulary (i.e. terms and labels). Students have opportunities for the communicating through writing, videos, drawing, etc. as they construct meaning; (d) Elaborate/Extent- This phase provided challenged for students to go beyond their understanding, gain more information, and develop deeper understanding; (e) Evaluate- This is an on-going process which should be part of each one of the previous stages. As the teacher assesses and evaluates during the instructional process she can determine if students understand the concepts, students inquiry interests (which
can lead to refocusing of the investigation), or if further actions are needed to clear misconceptions or enhance learning.

Although these five steps have been presented in a list, it seems that, when they are applied in the classroom, they will provide a cyclical aspect to the constructivist instruction. Other models of design have been developed that follow a very similar format.

For example The pH Project 7 e’s (Miami Museum of Science, 2001) and the “Constructivist Learning Design” (CLD) lesson (Gagnon & Collay, 2000, 2005) help teachers move away from the “planning for teaching” behavioristic approach toward, instead, planning for learning. The CLD model consists of six elements/steps for the teacher to follow while designing their student-centered constructivist experiences. The first three elements, situations, groupings, and bridge, seem to correspond to the “Engage” step of the BSCS model (Bybee, 1966). These are briefly addressed a continuation: (a) A situation that is given to the students and where the teacher models her expectations from the students; (b) Groupings, which includes two categories: grouping of students (i.e., classroom collaborative groups of 2-6 or more students) and groupings of the materials to be used to graph, model, describe, or write; (c) Bridging, which is like a diagnostic initial activity, is usually performed before students are divided into groups.

This activity can help students link what they knew beforehand with what they might learn. This could take the shape of a class discussion, a problem, a game, or a list.

The next three elements: questions, exhibit, and reflection, are discussed next. These elements seem to correspond to the “evaluate and explain” steps of the BSCS 5-E model: (d) Questions – the idea here is to foster and support individual thinking and promote participation. Questions can arise at any stage of the design. They may include guiding questions to introduce the situation, make the groups, set up the bridge, or encourage reflection.
(e) Exhibit – may take the form of visual representations, acting (or playing a role), a video, or a written description that they use as a record of their thinking that can help the students.

The last step could be considered a combination of the extend and evaluate steps discussed earlier with the BSCS 5-E model: (f) Reflection – stimulates an inner voyage through what the students knew and thought before-during-after the learning experience. It could include what they remember, what they learned, their thinking processes, and what they now carry with them as knowledge, after the experience.

Some science educators argue that the constructivist approach to teaching has a couple of problems: teaching abstract concepts and escaping actual learning of an established body of knowledge (Mathews, 2000; Solomon, 1994). However, it will be interesting to test the effectiveness of constructivist pedagogy in teaching other science concepts, like biodiversity, where the approach is more concrete and can be well-situated in real experience, and where common sense is valuable.

**Constructivist Learning: A Social Process**

Novak and Gowin (1984) see learning and instruction as a two-dimensional continuum. On the Y-axis of the continuum, the way the student learns, can be plotted anywhere between rote learning to meaningful learning. The X-axis represents the type of activities the student experienced during instruction—ranging from reception learning, to guided discovery learning, to autonomous discovery learning. Different interactions and combinations are possible. Under the premises of human constructivism though, those learning experiences which present the learner with situations where meaningful and guided/autonomous learning are possible will be favored.

Constructivist learning is different from other approaches of learning. It involves all domains of learning: mental, manipulative, and attitudinal. Memorization and “regurgitation” of
right answers and isolated facts, won’t work for the constructivist learner. Instead, learners must be actively engaged in making meaning by analyzing and connecting concepts, and the data they encounter is expected to be more memorable (Cobb, 1999; Resnick, 1987). The type of learning experience under constructivism allows the students to experience cooperative thinking, and use tools and artifacts to support the learning process. This makes learning more like their real-life experiences, in context rather than an abstract, general experience (Resnick, 1987).

Learning science has been identified with “constructing personal meaning”. The influence of constructivism is seen through the National Science Education Standards as well as the National Science Teachers Association Standards for Teacher Preparation in their recommendations to the community of educators (Fosnot, 1996; NRC, 1996; Rodriguez, 1998). In their views of how learning is developed, Dewey and Vygotsky emphasized social construction of knowledge. In the introduction I have already explained how Vygotsky’s zone of proximal development (ZPD) sets the ground for social interaction and group learning (Doolittle, 1997). However, it is important mention that social interaction does not necessarily imply a group situation. Social interaction may also imply teacher-student interaction and student-tools interaction.

According to the NRC report *How People Learn*, there are three fundamental conclusions that explain how science learning takes place (Bransford, et al., 1999). First, students have their own ideas, a preconceived understanding of how the world works. These ideas must be accessed in order to change them or build upon them (if correct). Otherwise, students will not keep the new knowledge beyond the test and just revert to the old notions afterwards. Second, factual knowledge, understanding placed in a conceptual framework, and organization that facilitates retrieval and application are needed to develop confidence in the area being investigated. Third, students need to learn how to learn. They can be helped to take control of their learning
(metacognition) by establishing goals and supervising their progress to achieve them. When these ideas are examined, they have a close fit with the human constructivist approach to learning and with inquiry teaching.

The actual mental processes occurring during the active engagement of constructivist instruction is sometimes called generative learning (Wittrock, 1974, cited in Jonassen, Mayes, & McAleese, 1993). Generative learning requires deeper levels of cognitive processing (Craik & Lockhart, 1972, cited in Jonassen, et al., 1993). Information is better remembered when it is generated by the learner instead of just being read (Jonassen, et al., 1993). Depth of processing is measured by the number of categories and number of explanations produced by the learner.

**Group Learning** – Group learning refers to the social interaction that results in building knowledge as peers communicate and exchange information (Linn & Burbules, 1993). For learning to occur, positive interactions between group members are needed. There are different types of group learning: *cooperative* (a task divided into parts and each group member completes one); *collaborative* (two or more work together toward a single solution); and *tutored* (an expert helps a novice gain expertise) (Linn & Burbules, 1993).

According to Linn and Burbules (1993), this type of learning benefits the learner by “fostering cognitive skills, promoting social skills, and imparting work-place skills.” (p. 92). As for the cognitive skills, some proponents argue that collaborative learning increases student interest, promotes critical thinking, help students take responsibility for their own learning, and achieve higher level thinking-- so that they retain information for a longer time (Johnson & Johnson, 1986). Group learning allows students to experience feedback in their work, and learn to value this as part of the learning experience (Bransford, et al., 1999). Mintzes, Wandersee & Novak (2001) suggest group learning, as a way that collaborative work can improve assessment in the biology classroom.
Much of what is known about group learning comes from research conducted in primary and secondary school settings and in the work place. Not much research has been done in higher education (Gokhale, 1995; Linn & Burbules, 1993). A study conducted in an undergraduate industrial technology course at Western Illinois University found group learning is effective in this scenario as well. Students participating in collaborative groups performed significantly better on a critical thinking test, compared to students who were involved in individual tasks (Gokhale, 1995).

However group learning is not the panacea for effective learning. Educators need to evaluate which concepts this type of learning experience is most appropriate for. Teachers play an important role in the organization of cooperative activities. They may establish the group composition, or manage the classroom in such way as to balance attention to content and development of social skills.

In a project called “The Computer as Lab Partner”, students worked in groups to find a solution to a specified problem at hand. Results from the research indicated that responsibility for actions tended to be diluted in the group, and even more, there was a tendency for status and stereotype issues to emerge (Linn & Burbules, 1993). Unfortunately the status issues were not related to science knowledge, but to other characteristics or roles of the group members. Also, it was found that group member status may influence which ideas become part of the discussion and get explored.

**Novice-Expert Learning** – Group learning sets the environment for novice-expert interactions. In a classroom situation, the role of expert (or specialist) may be played by teachers or other peers (Kinchin, 2003; Resnick, 1987). The expertise in any given area comes from previous exposure and learning over time (Bransford, et al., 1999). This allows the learner to be sensitive to the presence of patterns or be able to organize information in ways that complete
novices cannot. It has been suggested that the use of scaffolding as an instructional means may help reduce the differences in content knowledge between the novices and experts (Lee & Songer, 2004). However, Bransford, Brown, & Cocking (1999) are wary about how much a novice can learn from an expert, asserting that what the novice already knows needs to be taken into consideration.

One idea that has emerged from the study of novice-expert interactions is re-organizing the science curriculum. This will lead to focus on main topics or concepts in more depth, rather than teaching a long list of facts. The idea behind this is that it allows learners to develop a more coherent knowledge structure and deeper understanding, rather than memorizing disconnected facts (Bransford, et al., 1999).

**Assessment of Science Learning**

In this section I present information about some techniques which can be used to properly assess constructivist science learning. According to Dana and Davis (1993) proper assessment for learning under the constructivist paradigm is an area that needs much attention. There is a need for techniques where students “can express their personal understandings of concepts in ways that are uniquely theirs.” (Dana & Davis, 1993, p. 332). There is also a need for methods that can assess and reward this understanding (White & Gunstone, 1989).

Constructivism calls for a change in traditional assessment practices. Assessment must move away from evaluating inert knowledge and gets more into evaluating the capability to apply the knowledge. Traditionally, much attention has been given to summative assessment, where the overall student performance, or “result of learning”, is measured at the end of an instructional unit. This type of assessment is characterized by having little impact on the classroom, and by students worrying only about the grade rather than about learning -- perceiving a grade almost as their “pay-day” (Tobin & Tippins, 1993).
Formative assessment, characterized by evaluation being frequent and ongoing, plays an important role in the constructivist classroom. It can trigger shifts in teaching, thereby allowing improvements in science education (Duschl & Gitomer, 1997). This type of feedback gives students in the science classroom an opportunity to revise and improve their work (Bransford et al., 1999). In fact, when assessment is conducted in a longitudinal fashion rather than a one-time window of measurement, it better mirrors the process of knowledge construction (Mintzes, et al., 2001).

Several assessment tools have proven to be exceptionally helpful in trying to assess student understanding of science concepts in the constructivist classroom. Some of these include: concept maps, Vee diagrams, image-based tests, written products (reports, journals, and expository themes), structured clinical interviews, and portfolios (Bischoff & Anderson, 2001; Mintzes, et al., 2001; Mintzes & Wandersee, 1998; Novak & Gowin, 1984; Tsai & Huang, 2002). Following is a discussion of several of these tools as some of these were used in this research.

**Vee Diagrams**

Vee diagrams are a valuable tool that allows researchers to “penetrate the structure and meaning of the knowledge” students and educators seek to understand (Novak & Gowin, 1984, p. 1). They were developed as a tool to help clarify the work in science labs and aid in the construction of new knowledge. They provide a tool to assess critical thinking and knowledge about a scientific process (Mintzes, Wandersee & Novak, 2001). Although Vee diagrams were not used as a data collection method in this study, a Vee diagram was described and used in the introduction as a way of presenting the questions, research plan, and the outcomes of this study. Both Vee diagrams and concept maps are considered metalearning tools, that is, tools that help students learn about learning (Mintzes & Wandersee, 1998).
Concept Mapping

The concept map was born in 1972 as a tool to represent the knowledge shared by students during interviews (Novak 1998; Novak & Cañas, 2006). In a concept map, concepts (patterns of events or objects) are represented by labels which usually consist of just one noun or compound noun inside a box (Novak & Gowin, 1984; Novak & Cañas, 2004). Boxes are connected using linking words or propositions, and they are arranged in a hierarchical fashion. When the boxes and links are read together they form meaningful propositional statements.

Concept maps can be drawn by students to represent concepts and their relationships within a domain, or they can be created by teachers and students based on discussions with a student (Mintzes, Wandersee, & Novak, 2001). One important suggestion is that concept maps should include or “be anchored with” mapper-originated examples (Trowbridge & Wandersee, 1998). As more specific concepts are subsumed hierarchically under more general or comprehensive concepts, they can form part of human’s long-term memory, with knowledge thus learned in a more meaningful fashion (Novak & Gowin, 1984; Trowbridge & Wandersee, 1998).

Since concept maps are based on a theory of learning and knowledge, the maps represent a visual display of the student’s current cognitive structure (Novak & Gowin, 1984; Tsai & Huang, 2002). Concept maps can be scored using a rubric or by comparing them to a criterion map developed by an expert (Novak & Gowin, 1984; Trowbridge & Wandersee, 1998).

There are several approaches to help students in concept map construction. One approach is creating micromaps, which can then be combined into a larger map (Trowbridge & Wandersee, 1998). Micromaps make the technique less frustrating to first time mappers, and give students a sense of accomplishment. Another approach is map coconstruction. In this case a concept map may be created in “real time” as a student’s understanding of a science topic is probed during an interview and validated by the student rather than building the concept map
after an interview process has taken place. This approach adds to the validity of the map
(Trowbridge & Wandersee, 1998). Use of seed concepts (i.e., about five required concepts that
must be included on the map), can also facilitate the construction of micromaps.

Concept maps play a role in “teaching, learning, curriculum, and governance” (Novak &
Gowin, 1984, p. 20). One way in which concept maps aid science learning is making clear to
teachers and students the key ideas to focus upon when learning a task (Novak & Gowin, 1984).
Use of the concept maps can reveal misconceptions, reflect conceptual changes, provide a
platform for reflective thinking, enhance self-esteem, and enhance the learning outcomes of the
students as they engage in metacognitive learning (Novak & Gowin, 1984; Trowbridge &
Wandersee, 1998; Tsai & Huang, 2002).

Concept maps are starting to appear in science textbooks to help students summarize the
information of chapters or units (Novak & Cañas, 2006). Novak and Cañas (2006) anticipate the
use of concept maps as an evaluation tool. They state if this tool were actually included in
national high stakes examinations, it would be a good incentive for teachers to teach students
how to use it. As an assessment tool, maps can help teachers evaluate propositional knowledge
and can be used to document changes in understanding over time (Novak, et al., 2000).

In a 12-year longitudinal study performed within schools in Ithaca, New York, concept
maps proved to be a valuable tool. They showed the progressive change in understanding (or
lack of it) for particular science concepts in school children (Novak, 2004). This study used
audio-tutorial lessons based on Ausubelian principles. Three ideas emerged from the use of
concept maps and support the general understanding of how knowledge is constructed according
to Novak’s human constructivist theory of learning (Novak, 1990), namely: (a) the importance of
the learner’s prior knowledge, (b) meaningful learning is required to create new concepts or
propositions, and (c) knowledge evolves over time.
Another study used concept maps that summarize an expert’s knowledge to help novices to scaffold their learning process (Novak, 2004; Novak & Cañas, 2006). This study built upon Vygotsky’s social construction of knowledge and the zone of proximal development. Interestingly, and very relevant to the research proposed here, Novak considers the use of textbooks as somewhat limiting to the student, because they provide a sequential curriculum. In contrast, the use of concept maps constructed by experts in different areas of knowledge allows the students to have multiple accesses to scientific information and build upon it (Novak, 2004).

Related methods of representation of knowledge have been proposed. These include free word association, controlled word association, tree construction, mind maps, flow maps, and semantic network diagrams (Bischoff & Anderson, 2001; Tsai & Huang, 2002). The problem is that these methods have fewer research studies to establish their effectiveness.

**Interviews**

The objective of an interview is to unveil the student’s cognitive structure, what s/he knows (Novak & Gowin, 1984). The format of interviews can vary from flexible (open) to standardize. Depending on the interaction of clinical interview tasks and the format of the questions, a variety of knowledge claims can be made based upon the interviews. Interviews can take place before instruction, to assess what the students already know, or to help select concepts and examples (Novak & Gowin, 1984). Following instruction, interviews can provide insight to instructors about whether or not they have been successful in “achieving shared meaning with the students (Novak & Gowin, 1984, p. 122).

A strategy suggested by Novak and Gowin (1984) is constructing concept maps starting with a list of given key concepts (seed concepts). Students can add to this list other relevant concepts. This approach reduces the length of interview time, in addition to revealing misconceptions. The maps themselves can serve as a source of questions for the interview
process. Other materials such as textbooks or props can be used as auxiliary materials in the interviews. This is called clinical interviewing. In addition researchers consider the order of the questions important, and they prefer letting the first question to be an open-ended one to avoid students becoming nervous (Novak & Gowin, 1984).

Interviews, along with concept maps, can be used as formative assessments, in harmony with the teacher-student dialogue model (Kinchin, 2003). This teaching model uses concept maps as a tool to open teacher-learner lines of communication in a student-centered constructivist classroom. The concept maps are used to promote reflection and start a dialogue. When different perspectives are generated and the dialogue progresses, it allows teachers to provide formative assessment, individualized feedback, and even reflect upon their own teaching practice (Kinchin, 2003; Tsai & Huang, 2002). However, this model is not accepted by many teachers, as they resist opening lines of teacher-student communication. They frequently do not encourage the use of concept maps, fearing of entering in the “habit of changing habits”, which in the bottom line is a disservice to their students (Kinchin, 2003).

**Portfolios**

Portfolios have become more important as a tool for documenting student learning and for opening new doors in instructional practice. Several benefits are attributed to the use of portfolios. For example, (a) letting students assess their own work and control their own learning, (b) getting the most out of it, (c) perceiving learning as a developmental process, (d) providing an opportunity for on-going assessment, and (e) increasing the use of learning activities that are more consistent with the current ideas of how people learn (Gitomer & Duschl, 1995).

This is important because teachers can become more aware and provide more individual attention on how to help students get the most out of their learning experiences. Tobin and
Tippins (1993) suggest the use of portfolios as viable form of alternative assessment, where student-teacher pairs or peer students have an on-going conversation about the progress of their learning based on the artifacts included in it.

A “portfolio culture” as envisioned by Gitomer and Duschl (1995) would shift the traditional science classroom to one in which major changes take place. Among others, science conceptions and goals, the way instruction takes place, and changing the role and practice of assessment.

An interesting approach to portfolios as on-going assessment is Project SEPIA (Science Education through Portfolio Instruction and Assessment) implemented by Duschl and Gitomer (1997) in upper elementary science classes. In this case, the portfolio stores a student’s ideas and findings. These become a starting point for class discussions. Discussions take place using “assessment conversations” which are basically episodes of student-teacher interaction during the development of a unit. Through these conversations teachers stimulate student understanding, and use student feedback as a basis for achieving conceptual understanding and reasoning. Students keep/record the different activities accomplished throughout the development of the unit in a portfolio.

Tools for Learning Science: Computer Technology in the Classroom

In this section, I present some information on the current use of computers as tools in the science classroom. The information available is extensive, in accordance to the multiple possibilities, including support programs, use of the Internet, and so forth. My focus in the review is on the use of CD-ROM technology and hypermedia.

According to Hawkridge, Jaworske, and McMahon (1990), there are four main reasons for using technology in schools. These are: (a) the need to know how to use it because it’s everywhere, (b) the need to use it in their future careers, (c) students often learn better from
computers than from classes, and (d) computers may facilitate changes in educational practices. Information technology offers multiple possibilities for the science classroom, from the simple use of computers for drill-and-practice activities (computer aided instruction – CAI), and videos, multimedia (interactive videos) to hypermedia (Fraser & Deane, 1999). Furthermore, in many cases the use of technology in the biology classroom allows students to keep up with current scientific information, since the advancements in biology are occurring at a faster pace than textbooks can actually publish them (Simon, 2001).

Some researchers have placed the use of technology within the theoretical framework of constructivism -- a tool the learners can use to build their knowledge through a social process (Bednar, Cunningham, Duffy, & Perry, 1992; Collins, 1991, as cited in Gance, 2002; Jonassen, Peck, & Wilson, 1999; Papert, 1999). A growing interest in the role of constructivism in educational technology reflects how technology has increasingly impacted how we live, work, and learn. According to Papert (1999), the use of digital technology allows children to take greater control of exploring larger worlds. He considers very relevant and important in this new context the ideas advanced by Piaget earlier about the development of the children’s mind—especially, active participation in constructing their own knowledge and the constant creating-testing their own ideas about the world.

Bednar, et al., (1992) argue that in fact constructivism should be considered the “theoretical center” of educational technology. We are living in times where the massive amounts of information are available and keep growing. The quality of such information may also be mixed. Therefore, the goal of technology in the framework of constructivism should be to give the students the ability to look for information and create their own knowledge (Duffy & Jonassen, 1992).
Bednar and associates (1992) give an example of how we teach students about geography. They suggest that rather than teaching facts and principles, the role of the instructional designers should be to teach students to use the domain of geography information as the experts in the field will do. Another example of tools for learning science is the use of mindtools. This type of software technology can support learner engagement and active knowledge construction (Jonassen et al., 1999).

Implementing a constructivist approach for educational technology instruction has multiple risks, such as limiting social (group) interactions and becoming didactic or behaviorist (Fraser & Deane, 1999; Gance, 2002). It also brings challenges such as designing independent learning environments and developing techniques for building knowledge that can be communicated like experts do, running the risk of limiting social (group) interactions (Cobb, 1999). Cobb designed independent learning environments for testing vocabulary acquisition for English as a second language in male and female first year university students at Sultan Qaboos University in Oman. This area of the globe, so far, has been dominated by the traditional transmission of information model. He designed a dictionary toolkit (PET-2000), which allow the students to create their own word stacks. The students could work individually or in groups. These stacks were checked weekly for status of knowledge, use, and definitions; so the students created sort of a personal glossary. Results of the study indicated students developed knowledge of words which was effectively transferred to novel contexts. This suggested that in areas where “experts and learners share an important need” tools and procedures emulating the experts’ skills can benefit the learners (Cobb, 1999).

In contrast, Gance (2002) argues that although computer technology could support constructivism, because of the nature of constructivism itself, the computers alone can not provide a constructivist environment. He states that a constructivist environment requires
engaged learners, real interaction with the materials, a real problem-solving context, and human interaction. Therefore it takes a very creative teacher not to fall in the constraints of technology and still create a constructivist classroom.

In science education in particular, the focus on the use of computer technology converges with the emphasis given to teaching science as inquiry. The use of computer technology may support new forms of inquiry, including giving students the opportunity through NASA- and NSF-funded projects to collect, exchange, and analyze scientific data (Edelson, Gordin, & Pea, 1999). Computers are being used as investigative tools, knowledge resources, and record-keeping tools (Edelson, et al., 1999).

Like PET-2000, several other platforms have been developed in different areas. For example, the ThinkerTools that allow students to learn physics through a constructivist approach which combines computer-based modeling tools and inquiry activities (White, 1995). Learners can benefit from modeling real-world phenomena and processes using STELLA; or they can exchange data and ideas across distances in GLOBE and Kids As Global Scientists (Mandinach & Cline, 1996; Rock, Blackwell, Miller, & Hardison, 1997; Songer, 1996).

Previous research on the effect of computer simulations in biology, chemistry, and physics concluded that they help students make inferences and interpret data. In addition, computer simulations increase student understanding by helping them form better mental images (Good & Berger, 1998). In the cases that were examined, the level addressed was K-12 and the programs consisted of single simulations for very specific topics. Good and Berger (1998) ended their chapter with a word of caution:

The uncommon sense of science requires expert guidance by well-informed teachers to help students construct concepts compatible with scientist’s ideas about our natural world. We need to be very careful that the ‘new clothes’ of technology in education fit the goals of education described in Science for all Americans… (p. 226)
Good and Berger’s ideas and word of caution are supported by empirical research in different areas. One example is the trend to integrate information technology into the clinical laboratory. However, more research is recommended to examine the role of information technology in the classroom for tutoring and enrichment purposes (Handley, 1998).

In another study, a CD-ROM version of the course containing simulations was compared to the traditional laboratory-based course. Findings of this study indicated that although there was a knowledge gain over time, there was no difference in the knowledge gain of the students assigned to the two groups (Kirkwood, Sharp, de Vito, & Nimmo, 2002). The study sought to learn if basic principles of exercise physiology can be taught effectively using a CD-ROM. A case study approach with a formative evaluation and closed- and open-ended questionnaires was used. While the students found the simulations helpful, they preferred doing real experiments, although they recognize there is more control in the computer simulation and it is less expensive. In addition the study indicated that, using the CD-ROM method, students socialized less and did not engage much in as much background reading. Most agreed that computer simulations should be used together with real practical demonstrations as this may facilitate a deeper understanding.

Similar results were obtained by Brickman, Ketter, & Pereira (2005), where students who experienced traditional labs had better grades than the students exposed to CD-ROM delivery of lab materials (this study was described earlier in Introduction chapter).

In another study conducted at a four-year liberal arts college, computer technology was used to replace the traditional textbook (Simon, 2001). In this case the instructor used a website he created for an introductory biology course for non-majors. In fact, a year after creating the website, the contents were made available in a CD-ROM for those students who did not have Internet access. Results of the study indicated that students preferred the web site and CD-ROM over using a textbook. Cost savings, sharing the concise lecture notes of the instructor, reducing
the amount of weight carried, and accessibility from different sites were considered to be the advantages over the textbook.

The con side was the lack of good quality images to complement the material, compared to the image quality in the textbook. In addition, other disadvantages noted were the bother of printing notes, inability to annotate information in the CD-ROM, and the absence of references. Simon (2001) suggests technology is a promising alternative to textbooks in the introductory biology classroom, as it can aid in improving teaching and learning.

However, no clear understanding exists about whether or not and how technology may affect student learning (Cobb, 1999; Ely, 1995; Gance, 2002). The results of computer-aided instruction, where the learners are in control of the educational experience, so far have been mixed, ranging from not being effective to, intermediate, or learners learning more as they have control of the experience.

To the present, learning outcomes are inconclusive when hypermedia has been used in the classroom. Many researchers have come to the conclusion that computers can only enhance student achievement if used properly (NRC, 1999a). However, much still remains to be learned about the potential of technology. Its use does not guarantee learning will improve (NRC, 1999a).

Mintzes, Wandersee, & Novak (1998) also warned educators about educational technology:

When administrators (…) seek to reduce the cost of offering science courses, we anticipate they will challenge…needs for laboratory space, experiments and activities, and the importance of field trips. (p. 346)

So far, most of technology implementation has been dominated by cost and flexibility of access to information. In many ways, we are still subscribing to traditional teaching and learning methods, rather than enhancing the learning experience with the use of technology (Fraser & Deane, 1999). Fraser and Deane argue that implementation of technology should rather consider
potential learning outcomes. Fraser and Deane (1999) suggest care must be given to designing evaluation strategies to determine whether learning gains are due to the use of multimedia or due to the instructional methods being employed. This area was considered in this study.

Furthermore, Olson and Clough (2001) cautioned about the use of technology in the classroom. They argue that although technology is fascinating for the students, still the most important aspect about teaching is the teacher. Teachers should not incorporate technology with the mere goal of attracting students’ attention. Rather, they should consider several factors, including student’s prior knowledge and skills, plus gains and losses among others. From the teacher’s point of view, the likelihood of teachers using technology in the classroom is increased when five different factors are present: (a) technology is easy to implement, (b) there is access to computer technology, (c) there is collaboration, (d) teachers are trained, and (e) teachers have sufficient time (Hope, 1996). Hope also adds that teachers shouldn't be forced to use the technology, but should only be encouraged to use it.

The use of multimedia plays an important role in the learning process of students exposed to scientific explanations. In a study done by Mayer (1997), a significant attribute-by-treatment interaction was obtained indicating that multimedia and contiguity (verbal and visual representations) positively affected the learning of students with high spatial ability who had little prior scientific knowledge. In this research, the scenarios used were a computer program presenting images that explained a specific concept, and a textbook with figures. Therefore students were exposed to text (written or narrated) and a visual aid. Mayer recommended that more research is necessary to investigate how people learn with multimedia. From his point of view, the current interest should not be on the effectiveness of one medium over another, but rather on the effects of multimedia in developing scientific explanations. This means applying the cognitive theory of verbal and visual knowledge construction and its role on the learner's
development of science knowledge. At present, it seems the development of multimedia is happening at a faster rate than the corresponding knowledge of how people actually learn from these sources.

Ecology and Environmental Education: The Framework for Biodiversity

In this section I expose the origins and treatment of ecology and environmental science education in the science classroom. These are the disciplines within which biodiversity is studied. Then, I summarize the limited research that has been done to examine teaching practices, learning experiences, and instructional tools to gain a better understanding of ecology-related concepts and, in particular, biodiversity.

The Emergence of Ecology in the Science Classroom

Ecology is a relatively young science, dating its origin as a formal science to the mid 19th century, when the German biologist Ernst Haeckel, coined the term oekologie. He defined it as “the study of the natural environment and of the relations of the organisms to each other and to their surroundings” (McComas, 2002; Ricklefs, 1990, p. 3).

Ecology and environmental science are intimately related and often the terms are used interchangeably. Environmental science is defined as “systematic, scientific study of our environment as well as our role in it” (Cunningham, Cunningham, & Woodworth, 2003). Some definitions expand it defining that “role” to include the impact of human activities in pollution and degradation of the environment, as well as the impact on biodiversity and sustainability due to local and global development (Wikipedia, 2006). McComas (2003) makes the distinction of ecology being more “concept oriented” while environmental science is more “action oriented”, however he uses the concepts interchangeably in his writing.

Environmental education first entered the science classroom in the late 19th century, along with the “nature study movement” (an approximation of biology instruction), as “conservation
education”. Ecology concepts made it to the classroom around the same time with the 
publication of the book *Nature Study for the Common Schools* by Wilbur Jackman in 1891 
(McComas, 2002). A few years later in 1936 the first edition of Anna Botsford Comstock’s 
*Handbook for Nature Study* came out becoming the first instructional material to support the 
study of nature in the classroom (McComas, 2002).

Environmental Studies in the US started as a discipline in the 1960’s, gaining a distinctive 
place in the public and science curriculum after the celebration of the first Earth Day on April 22, 
1970 (Soule & Press, 1998). In October of the same year, President Nixon signed the 
Environmental Education Act, including environmental literacy as a goal of science education in 
the US (McComas, 2002). In the international arena, the agency UNESCO sponsored two 
conferences which provided the scenarios to identify a position on teaching about ecological 
topics, set criteria, and give recommendations: the Conference on the Environment (1972 in 
Stockholm) and the International Environmental Workshop (1975 in Yugoslavia). In spite of its 
movement into the classroom and the acknowledgement of its importance, ecology and 
environmental education continue to struggle to gain recognition in the science classroom. The 
following paragraphs help render this picture.

Traditionally ecology has been placed at the end of biology textbooks, and consequently 
taught at the end of the semester. When high school biology textbooks have been examined for 
ecology content, results indicated that only about 10% of the textbooks covered topics in ecology 
(Carrick, 1982; McComas, 2003; Wilson, 2000). Furthermore, ecology and environmental 
principles were typically found in the final chapters rather than distributed throughout the book 
(Harper, 1982; Kuechle, 1995). A possible explanation for the habit of leaving ecology for the 
“end” is the fact that ecology appears to be an inclusive, integrative topic. Ecology is a 
multidisciplinary science. It integrates various areas of biology-- as well as other sciences, like
geology, geography, physics, and chemistry. It provides the students with an opportunity to apply and synthesize concepts learned in a “typical year of biology instruction” (McComas, 2002).

One problem to this approach is the high school setting where teachers mostly use textbooks to dictate what will be covered and in what order (Harper, 1982). Many times the last chapters in the textbooks are addressed hastily or not at all due to the increase in size (and content) of textbooks. This is similar to what happens in many introductory biology courses in college (Guzman & Wandersee, 2001b).

One possible alternative to bring ecology “up front” is teaching introductory biology courses using a “top-down” approach. In this way ecology can be taught first and used as a reference point to provide context for explaining important biology concepts throughout the semester. Another possibility recommended by Kuechle (1995) is actually a total change in curriculum. In his view, biology teaching should move away from the phylogenetic approach, eliminate the ecology chapters, and integrate the ecology concepts through the textbook, just as has been proposed for evolution. After all, the depth and comprehensiveness of both these two topics is comparable as they both are informed by and provide a foundation for all of biology (McComas, 2002). This new approach would provide the students with opportunities that promote critical thinking as well. Interestingly, McComas (2003) actually suggests that because of the involvement of ecology-advocacy groups in curriculum development, “one will be well advised to look beyond the traditional textbooks and laboratory manuals for sources of curriculum support.” (p. 174). This study explored one such source of support, in an introductory biology course where the textbook covers biodiversity from the phylogenetic approach, and some biodiversity-related concepts are actually discussed in essays dispersed throughout the book, but mostly not in the biodiversity-related chapters.
Environmental Literacy – The way ecology and environmental science have and are being taught in the science classroom clearly has impacted environmental literacy in the US. The Survey of Environmental Attitudes and Knowledge conducted by the National Environmental Education and Training Foundation in 1997 indicated that two of every three Americans were environmentally illiterate (Robinson & Crowther, 2001). Results of the study also indicated that science literacy is improved with exposure to multiple environmental science classes. According to Robinson and Crowther (2001), these data might “…offer support for making an environmental science class a requirement for all students in high school, as well as part of the university core in higher education.” (p. 13).

As we enter the 21st century, environmental scientists face two important challenges. First, bringing together sound science to explain the complexity of environmental issues, and second, at the same time expressing these complex issues in ways the public can understand, keeping in mind the demographic changes in the US (Hudson, 2001). Perhaps, as the century turns, it may offer the chance to make changes in curriculum and teaching practice to meet these new challenges. Supporting Kuechle’s recommendations stated earlier, Robinson and Crowther (2001) have proposed the alternative of teaching introductory biology from an ecological approach in both high school and college, as this might make more people aware about environmental issues.

A continuation, I describe what has been done in the science education arena to inform the practices of ecology and environmental education. What has been done to help students understand and learn concepts in this area of biology?

Research in Ecology and Environmental Education

D’Avanzo (2003) examined articles which applied cognitive research to college teaching published in the Journal of Research in Science Teaching (1997-2002). She found a minority of
articles addressing the teaching of ecology and geology (n = 9) while most articles addressed physics (n = 33) and chemistry (n = 21), followed by biology (n = 19). Articles in the area of ecology mostly focused on K-12 environmental education. If we assume these limited findings are representative of other journals, then it suggests there may be a need to explore the current state of college ecology education and/or a need for more published research in peer review journals addressing teaching/learning practices in ecology. This kind of research can be helpful in supporting college teaching faculty.

Extrapolating results from research in mathematics, D’Avanzo (2003) suggests one way to improve college ecology education is by applying metacognitive teaching tools. Some of these include teaching students to learn to ask scientific questions, exposing them to group situations where they can discuss and learn from other students, having successful students describe how they study for the class, using problem-based learning, and teaching to the common misconceptions. D’Avanzo (2003) encourages faculty to explore more about these issues and apply them because they help students think “critically and flexibly” (p. 1127). She even goes so far as to suggest the use of two textbooks for teaching ecology, both of which apply metacognition to student learning: Molles, 1999; and Valiella, 1995.

The constructivist approach has been suggested as the best approach to frame research in environmental education. Examining the ways that environmental education has been developing, Ballantyne and Packer (1996) argue that a constructivist approach will help achieve environmental literacy more efficiently. In their view, there are three areas that can be integrated through constructivism: knowledge, attitudes and values, and behavior, thus allowing students to develop meaningful conceptions. They suggest more research is needed in four areas: analyzing and mapping the student’s environmental conceptions; examining in more depth, the relationships between knowledge, attitudes and values, and behavior; evaluating the
effectiveness of constructivism in facilitating the adoption of environmentally sensitive behavior; and last, designing, developing, and testing teaching strategies for environmental conceptions—strategies that address all three levels: cognitive, affective, behavioral (Ballantyne & Packer, 1996).

Most educational research in environmental education emphasizes the development of values (affective domain) rather than examining the development of basic environmental knowledge (cognition) that can support informed behavior (Ballantyne & Packer, 1996). This approach is based on the assumptions that positive environmental attitudes will promote change in environmental behavior, and that it is easier for teachers to teach environmental knowledge this way. In addition, some educators question the teaching of factual information when it is changing so fast, so they prefer teaching the students the process of critical thinking and decision making (Ballantyne & Packer, 1996).

Some studies indeed have used the constructivist approach to investigate how students analyze and develop a better understanding of ecological and environmental concepts. Among the concepts that have been examined are pollution (Brody, 1991; Walls, 1992), marine science (Brody & Koch, 1990), and food webs (Adeyini, 1985; Lisowski & Disinger, 1991). Science education research in ecology has helped to identify misconceptions related to population size and carrying capacity (Brody & Koch, 1989), and about interrelationships of organisms in ecosystems (Griffiths & Grant, 1985).

**Biodiversity Education** – In addressing the need of public understanding of biodiversity, DeBuhr (1995) considers to be critical the integrating of knowledge within the scientific and education communities. The first one provides knowledge of the organisms, the environment, and their interrelationship. The second spreads the knowledge across all age levels through
formal and informal science education. In addition, the science education community contributes the understanding of how people learn.

Two studies directly addressed issues of biodiversity and student learning in elementary education. The first study, BIOKIDS, examined how students can learn about animal diversity by incorporating data from their schools’ backyards and the use of computers (Lee & Songer, 2005; Songer & Lee, 2003). The students were exposed to current technologies such as CD-ROMs, PDAs, and the Internet. By using the Animal Diversity Web, students could learn about local and global animal diversity.

Another study reflected a common theme among biodiversity and environmental education: affective values. That study conducted with Brazilian 6th graders, included students from the urban, suburban, and rural areas. It suggested students in general have low identification with the Cerrado (like savanna) region (Bizerril, 2004). This area in Brazil is currently undergoing a rapid change in the landscape due to population growth pressures. It has been designated as one of the 25 environmental hot spots worldwide because of the environmental threats to the high diversity of species there.

Interestingly, in this study the students preferred learning more about fauna than flora elements, and gave economic reasons for that. Interviews with teachers indicated that, in their lessons, they make reference to the area to a greater degree than it is referred to in textbooks. However, the textbooks’ focus is more on the physical environment and vegetation rather than the biodiversity of the region or associated environmental impacts. In fact, when Bizerril examined the textbooks he found that the theme of biodiversity was discussed for other regions such as the Amazon and Atlantic forests, but discussion of the Cerrado and other regions was limited to mere geographical descriptions. The study revealed a need to increase the identity of
the students with the biodiversity of the local area through environmental education. This could eventually lead to motivate the students to discuss changes that can impact the future of the area.

In trying to find related research on biodiversity, I infer there is a gap in what we know about this topic. Except for the two exploratory studies about plant biodiversity described in the introduction chapter, apparently no one else but me has addressed science education research in this area at the college level (Wandersee & Guzman, 2002).

Having established the framework for biodiversity and the state of what we know so far about the contributions of science education to this field, in the following section I provide some background about the concept of biodiversity itself.

Exploring Biodiversity

What Is Biodiversity?

Biodiversity is a term coined to refer to the diversity of life, in other words, the variation found among organisms of all different kingdoms (Molles, 1999). It is defined as “the totality of the inherited variation of all forms of life across all levels of variation, from ecosystems, to species, to gene” (Wilson, 2001, p. xxv). The term “biological diversity” was first used by Lovejoy in 1980 (Swingland, 2001). The contraction of the term though is more recent, and was used for the first time in 1986 at the first National Forum on Biodiversity in Washington (Raven, 1999a; Wilson, 2001). Originally the term meant numbers of species. The main concern of the scientists back in 1986 was the pace at which species were disappearing globally and the little attention these events were receiving (Raven, 1999a). That simple definition has evolved.

Defining diversity is as complex as the body of knowledge it entails. Proper ways of defining the concept have been debated over 30 years, with different connotations becoming more or less popular according to the particular area of interest or focus (see Table 1; Swingland, 2001). In fact, in an interview for the Biodiversity Leadership Awards, Peter Raven argues that
the concept of biodiversity has changed since its inception in 1986 to include the necessity of building sustainability and managing the diversity of life to preserve it as a resource for future generations (Raven, 1999a).

Biodiversity is considered by some an “ill defined concept” (van Weelie and Wals, 2002, p. 1143), as it can not be understood in a unique manner that fits all contexts. However, this same notion is what makes biodiversity appropriate to provide a perspective of science as an active endeavor and facilitates a connection between society and science. It stretches to include the “ambivalence and uncertainty” related to environmental decision-making, and the need to both respect differences and to learn in context (van Weelie and Wals, 2002, p. 1145).

Table 1

<table>
<thead>
<tr>
<th>Definition</th>
<th>Source</th>
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<tbody>
<tr>
<td>* Number of species, species richness</td>
<td>Swingland, 2001</td>
</tr>
<tr>
<td>* Number and relative abundance of Species</td>
<td>Pielou, 1977</td>
</tr>
<tr>
<td>* Composed of ecological, genetic, and organismal diversity</td>
<td>Gaston &amp; Spicer, 1998</td>
</tr>
<tr>
<td>* Some authors distinguish between biodiversity and the ecological processes that maintain it, and ecosystems (which by definition include abiotic factors)</td>
<td>Reid &amp; Miller, 1989; Agarwal, 1992</td>
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</table>

*Note. All sources cited in Swingland, 2001.*

Levels of Biodiversity

To fully understand biodiversity it is necessary to go beyond mere numbers of species. It is necessary to integrate three different factors or levels: genetics, species, and ecosystems. A brief description of the role of each of these levels follows.
**Genetic diversity** – Refers to the “heritable variation within and between populations” (Swingland, 2001, p. 381). This variation is a result of mutations and recombination through the exchange of genetic material in those organisms that reproduce sexually. Selection, artificial or natural, acts on this variation, and results in differential survival. Over time this results in differences in the frequency of genes and in evolution. Genetic diversity is, in fact, a resource, which is discovered both on a trial-and-error basis and by careful searches (Tilman & Duvick, 1999). Genetic diversity is especially important in the field of agriculture. Conserving the wild relatives of important crop plants (e.g., corn, rice, wheat) might mean conserving differences in resistance to diseases and drought, and higher productivity depending on the soil types (Raven, 1995; Tilman & Duvick, 1999; Wilson & Perlman, 2000). This can be used to develop better varieties of crop plants.

**Species** – Global biodiversity is commonly discussed in terms of species richness or the number of species. Based on this definition, approximately 1.7 million species have been described and 5-100 million are estimated to exist, with a working estimate of about 12.5 million (Wilson & Perlman, 2000). However, species diversity by itself is not considered an appropriate definition of biodiversity because of the inherent problems defining species as a concept (Swingland, 2001).

**Ecosystem** – The definition includes both biotic (living) and abiotic (non-living) components. It is indirectly measured through the diversity of species present, considering both their abundance (i.e., per given area) and types (Swingland, 2001).

**Why Study Biodiversity?**

One could answer this question very simply: to learn more about it so it can be conserved. But why conserve? Because we depend on biodiversity, the different living organisms and their qualities, in order to preserve genetic resources and have a sustainable future (Rossenblatt,
Biodiversity is not only a fundamental question in biology, but may also be considered to be the science of the future of the humankind (Levin, 2001; Molles, 1999).

The study of biodiversity is based on human’s innate curiosity about the living things: How many species are there? What do they look like? How they live? How do they relate to each other and to the environment? (Rutherford & Ahlgren, 1994; Wilson & Perlman, 2000). Learning about biodiversity allows us to gain information about the vigor, health, productivity, and beauty of an ecosystem (Golley, 1998).

Measuring Biodiversity

Measuring biodiversity helps us draw inferences about the processes that influence diversity. From a biological-ecological standpoint, it allows for observing spatio-temporal patterns and examining human impacts. However, from a social perspective, biodiversity can also be attributed a given value, which in a sense is measuring at another level (see discussion that follows). Either way, measuring biodiversity provides important information to support conservation issues and actions (Leitner & Turner, 2001).

From the biology, specifically ecology perspective there are several techniques and indices (i.e., Shannon’s diversity index) that quantify biodiversity. Measuring biodiversity is the foundation of many community ecology studies (Leitner & Turner, 2001; Swingland, 2001). The mathematics and complexity of most models used to estimate species diversity go beyond the level of competency of most introductory biology who are non-majors at the community college where this research will be conducted (many of them usually register in remedial math courses). Therefore, this approach was obviated in the lessons regarding biodiversity.

A much simpler way to look at diversity is considering species richness, which is a measure of the number of species (Whitton & Rajakaruna, 2001). Species richness can be combined with species evenness, which is the relative abundance of various species (how many
per area) as a measure of diversity. In the activities used as part of this research, students were exposed to diversity as numbers of species.

The Value of Biodiversity

From a social perspective view, biodiversity can be shown to have moral, ethical, and economical value (Wilson & Perlman, 2000). Ehrlich and Ehrlich (1992) state there are four fundamental reasons to value diversity: (a) ethical responsibility towards other kinds of life; (b) esthetic beauty of it and indirectly how humans exploit that for education and economic benefit; (c) direct economic value, food, and industrial products; with an enormous potential stored in the genetic variety; and (d) ecosystem services, that help keep alive the human civilization. However, these values are in jeopardy in light of the 6th extinction episode currently underway.

The aforementioned values can be appealing to different sectors of society in light of the importance and need of conserving biodiversity. The moral and ethical values (i.e., preserving the beauty, responsibility for caretaking) are subjective and can be shared with others. These values provide a sense of stewardship and immortality (Rosenblatt, 1999; Wilson & Perlman, 2000).

In some discourses of society it is economics, a monetary value, which seems to drive the message of the importance of biodiversity. This has led scientists to develop the area of environmental accounting (Pimentel & Wilson, 1997). Under the light of environmental accounting, the services provided by biodiversity are measured in dollars. For example, approximately a decade ago, the US alone got a conservative estimate of $319 billion in benefits from biodiversity. Worldwide the amount was $33 trillion (Pimentel & Wilson, 1997). The monetary cost of natural ecosystem services estimated by Pimentel and his students has become the basis for developing a strategy and policies for conservation of biodiversity.
“Hero of the Planet” Dr. Peter Raven considers moral, ethical, or religious points of view important to conserve diversity. He also extends the reasoning to include scientific and practical reasons (Raven, 1999a). In Raven’s view it makes sense to preserve the wild relatives of corn or the redwood trees because of the aesthetic or the genetic value they may have. But, he considers attributing dollar values to be nonsense, because it is basically impossible to measure accurately the infinitesimal value of biodiversity for the survival of the human kind.

Other Relevant Concepts About Species Diversity

In this section I present some concepts related to the numbers and origin of species in an area, which are frequently used to characterize species and the diversity of an area. Students who were part of this study had an opportunity to learn some of these concepts as they worked on the textbook or CD-ROM activities or as they developed their inquiry project about Louisiana native plants.

**Native** – Species that are originally from a particular area, but their distribution is not necessarily limited to that area.

**Endemism** – This concept refers to species that are particular or unique to a place or region (Whitton & Rajakaruna, 2001). Endemics can be extremely localized or rare, and they are not found anywhere else. Both, species richness and endemism are used to describe “hot spots” or threatened geographical areas which have a high concentration of endemic species and a high biodiversity (Whitton & Rajakaruna, 2001).

**Indigenous** – Refers to species that are native, but not unique because they are also native to other locations as well.

**Naturalized** – These are non-native plants which spread and become established in wild areas, but are harmless (see exotic).
**Exotic, Alien, Introduced, Invasive** – These species are native to another place which is not where they are occurring; usually they take advantage of the environment and out-compete the native species (Whitton & Rajakaruna, 2001; Wilson & Perlman, 2000).

**Plant Biodiversity**

Within the area of biodiversity, we shall consider three main reasons why plant biodiversity should receive particular attention. First, plants are essential for our survival, as they are the intermediaries between the living and non-living systems (BSA, 1999). Second, plant biodiversity is considered a unique resource that humans have acquired from nature during our cultural expansion (Tuxill, 1999). In fact, the Botanical Society of America has established in its publication *Botany for the Next Millennium* (1999), that knowledge of plant biodiversity is essential to our understanding of the world. Third, they represent a remarkable proportion of the living organisms, as the number of plant species is estimated to be about 270,000-300,000, with most of them (235,000) being flowering plant species (Wilson & Perlman, 2000). We ought to fully comprehend the role of plants in the biosphere if we are to make life, humans included, sustainable.

Plant biodiversity can be examined from different view points such as evolutionary, ecological, and social. Each of these has implications for education. A brief discussion of some of these follows.

**Evolutionary Perspective**

Diversity within the plant kingdom may be studied from a phylogenetic perspective. In this case, it refers to the different groups into which the kingdom is divided. The appearance over evolutionary time of key characteristics is what sets the groups apart: (a) Bryophytes, non-vascular plants (mosses, liverworts, and hornworts); (b) Pterophytes, seedless vascular plants (ferns, horsetails, club mosses, wisk ferns); (c) Gymnosperms, naked seeds vascular plants
(conifers, cycads, Ginko, gnetophytes); and (d) Angiosperms (flowering plants; the most diverse group). These groups include a total of twelve phyla. The phyla do not share unique common ancestors, but their life histories and ecological characteristics are similar. (Whitton & Rajakaruna, 2001).

It is important to understand the diversity of plants as a result of evolution. Plant scientists have provided information on how the environment and genetic changes are involved in the process of speciation (BSA, 1999). Furthermore, plants can also help us understand about associations with other organisms, which in some cases may result in coevolution (i.e., evolved interdependence of many flowering plants and their pollinators). Therefore, plants are important not only as units of diversity themselves, but also by being an important resource of food and shelter for other organisms, they affect the diversity of other groups of organisms.

One of the multiple examples of coevolution in the most diverse group of the plant kingdom is the case of fig plants and fig wasps (Armstrong, 2006). Different species of figs are indigenous (native) species. In fact, the island of Barro Colorado, located in the Panama Canal Zone and having only six square miles, has 17 native species. Interestingly, almost every fig species has its own coevolved species of wasp pollinator.

Ecosystem Approach

Another perspective from which to study plant biodiversity is the role that plants play in the ecosystems. Being capable of photosynthesis, plants provide a bridge between the biotic and abiotic components of the ecosystem. Plants capture energy as the primary producers of the planet and make it available to other organisms, thus sustaining both terrestrial and aquatic webs of interactions. They also play a critical role in biogeochemical cycles, such as the carbon cycle through carbon fixation (Whitton & Rajakaruna, 2001).
Another important aspect of plants at the ecosystem level is that invasive plants may undergo uncontrolled growth. As a result they threaten the well-functioning of many habitats and survival of native plant species (BSA, 1999). This example is discussed in more detail later.

Social Perspective

From the social perspective we can look at how plant diversity affects human life at different levels, such as in moral and ethical issues, and in other services with direct economic impact. These topics are examined in more detail in the following sections.

Plant Biodiversity’s Impact on Humans

From the practical point of view the plant kingdom has influenced the history of the humankind in many ways including, serving as source of food, fiber, fuel, and medicines (BSA, 1999).

Food – Archaeological evidence indicates that Homo sapiens gathered many plants, plant parts, for their use and consumption, including fruits, nuts, and roots (Garofalo, 2003). By 8000 BCE cereals and legumes were domesticated, and the first evidence of cultivation of these comes from about 6000 BCE (Garofalo, 2003). Checking any graph of human population growth, one can see how the development of agriculture increased the rate of human population growth.

From a historical vista, plants represent a turning point in the history of the world. Columbus sailed from Europe looking for a direct route for spices and ended up bringing along not just allspice and chile peppers, but corn and tomatoes (Hobhouse, 1999). In spite of the spirit of the conquistadores, humans have not exploited the diversity of the plant kingdom as a food source to anywhere near its potential. There are approximately 235,000 species of flowering plants of which humans consume only about 150 species. Furthermore, of these 150 species only six crops, wheat, rice, corn, potatoes, and manioc, provide 80 percent of our calories (Whitton &
Rajakaruna, 2001; Wilson & Perlman, 2000). Other ways in which plants affect our diets is through beverages like coffee and tea, as well as oils (Whitton & Rajakaruna, 2001).

Even with the limited number of species being used as food, the genetic diversity of these species is important in two ways. First, to maintain sources of wild germplasm; and second, to maintain a potential source of new crops. The germplasm is necessary to be able to develop other crops in the future by improving crops through interbreeding or genetic engineering, usually to promote disease resistance (Whitton & Rajakaruna, 2001). An example of such is how scientists have located genetic resistance to potato blight in the gene pools of traditional Andean potato cultivars and their wild relatives (Tuxill, 1999). This new form of potato blight has been threatening the potato farmers in the last decade, and has reduced the world production of potatoes by 15 percent.

**Medicine** – From common to unusual medicines, it is estimated that 80% of the human population derive their medicines from about 35,000 to 70,000 plant species (Whitton & Rajakaruna, 2001; BSA, 1999). According to the FAO approximately 4,000 to 6,000 of these species are traded internationally (Tuxill, 1999). Currently about 120 widely used medical compounds are derived from botanical sources. Some examples are pain relievers like aspirin (*Salyx*); analgesics and cough suppressants like morphine and codeine (*Papaver somniferum*); glycosides for treatment of heart conditions (*Digitalis*); and alkaloids used in cancer treatment (rosy periwinkle and yew). The success in finding medicinal resources in plants suggests that the potential for curing many human diseases lies in the plant kingdom (Whitton & Rajakaruna, 2001).

An unfortunate situation taking place with medicinal plants is that not only are many of these plants endangered due to the loss of habitats, but there is also loss of cultural knowledge. Folk medicine has proven invaluable for the western civilizations. Approximately 89 plant-
derived commercial drugs come from healers’ discoveries (Tuxill, 1999). As civilizations evolve, the younger generations are less interested in learning about traditional healing plants, and perhaps the knowledge will only be rescued by ethnobotanists (Tuxill, 1999).

**Building Material, Fiber, and Other Uses** – Characteristics such as availability, durability, flexibility, and strength have made some plants the perfect source for building material (Whitton & Rajakaruna, 2001). Wood and paper comes from about 200 species of timber trees, like pine, spruce, hemlock, fir, redwoods, birch, beech, oak, mahogany, dipterocarps, bamboo, and rattan (Tuxill, 1999; Whitton & Rajakaruna, 2001).

The list of resources obtained from plants becomes even longer as other areas are explored. Important fibers such as cotton, linen, and jute are derived from plant parts. In addition to being important for their aesthetic value, many industrial products come from plants: latex and resins (66 plant species), essential oils (42 species), perfumes, and dyes (13 species) (Tuxill, 1999; Whitton & Rajakaruna, 2001).

**Loss of Plant Biodiversity: The HIPPO Dilemma**

Many scientists believe that the rate of current extinction of biodiversity in general indicates the planet is going through the 6th event of mass extinction in the history of life (Raven, 1999b; Tuxill, 1999; Whitton & Rajakaruna, 2001). Scientists’ estimates vary between daily losses of 1,000 species to yearly 27,000 species as a consequence of the human pressures on the environment (Tuxill, 1999; Whitton & Rajakaruna, 2001). In the specific case of the plant kingdom, the loss is unprecedented,

According to a 1997 global analysis of more than 240,000 plant species coordinated by the World Conservation Union-IUCN, one out of every eight plants surveyed is potentially at risk of extinction.” …”More than 90 percent of these at-risk species are endemic to a single country… (Tuxill, 1999, para. 7)

Looking at the particular case of plants, about 60,000 of the 170,000 species known from the tropics are expected to go extinct in the next 50 yrs. In the temperate zone, currently there are
about 8,000 endangered species, and 217 plant species have gone extinct in the last 500 years (Whitton & Rajakaruna, 2001). Whether or not we are experiencing a period of mass extinction is a debatable topic among the scientific community. While some scientists argue that we’re in the midst of a mass extinction event, others believe that mass extinction is a misconception, based on the claims that we are underestimating natural resilience, forest recovery, ecosystem management, and positive aspects of some alien species (Public Broadcasting Service [PBS], 2006). However, there is no doubt that we are facing loss of global biodiversity.

What is the cause for losing plant biodiversity? It turns out that it is not just one factor, but rather the combination of several factors reducing the biodiversity of plants, and biodiversity in general. The HIPPO dilemma represents an acronym conservationists use to summarize the main concerns and their interrelatedness (Wilson, 2002). In the following paragraphs I develop the meaning of the acronym, with special attention to how the threats affect plant biodiversity.

**Habitat Destruction** – Many ecosystems worldwide are disappearing with the daunting consequences of decline and/or extinction of many species. In Louisiana we have two examples, the long-leaf pine savannas and wetlands. Long leaf pine savannas are one of the most diverse ecosystems in the US, but only a small percent of them is left in the southeastern US (Thaxton, personal communication, February 2001). For reasons associated both with global changes and local population pressure, wetlands are being destroyed, at a rate of about a football field every 45 minutes (Barataria-Terrebone National Estuary Program, 1999). In the tropical regions, it is also common knowledge that the state of the tropical forests is deteriorating, where forest are been clear-cut for agriculture and pasture (Perlman & Wilson, 2000). As a consequence many unique regions are being affected, like the Cerrado in Brazil and the Hawaiian rainforest, where three-fourths of the land has been clear-cut (Bizerril, 2004; Wilson, 2002).
One of the problems with habitat destruction is that humans are modifying and replacing complex ecosystems with other human-made systems more focused on our needs (Raven, 1995). These natural communities have been in existence for 4.5 billion years, and humans have just started to study them in the last few decades. Raven (1995) considers our greatest challenge is to make the transition towards developing harmony with, and reaching stability in, the natural environment.

One of the dangers of habitat destruction and fragmentation is that it may decrease and even drive to extinction the wild relatives of many of the crops we now depend upon (CAST, 1999). The main impact of and concern regarding agriculture is the loss of genetic variability in the few species that are used as food sources. This reduction results in what the UN Food and Agriculture Organization (FAO) calls an “impressively uniform genetic base” (Tuxill, 1999, para. 23; Whitton & Rajakaruna, 2001). Although some of the loss in genetic variation in crops can be explained through natural causes, like climate change and drought, most is due to anthropogenic causes.

Habitat fragmentation due to human activities like agriculture crops and livestock grazing is considered the most important cause of the current dramatic reductions in plant biodiversity and the loss of wild relatives of crops (Tuxill, 1999; Whitton & Rajakaruna, 2001). In addition, farmers’ preferences for more secure and resistant cultivars, also reduces variation in the gene pool of crops as the wild relatives disappear.

Such reduction in the genetic variability ultimately leads to a high ecological risk. In the US, only a handful of species human consume have been domesticated here, (i.e. pecans, sunflowers, blueberries, cranberries, some squashes). However, most of the food supply in the US comes from plants that have their gene pools somewhere else, (i.e., wheat, potatoes,
soybeans, corn, rice, beans, squashes, and oats). As the wild species go extinct, so goes the potential to improve crops if needed.

**Invasive Species** – These species were accidentally or purposely introduced in new habitats (Perlman & Wilson, 2000; Whitten & Rajakaruna, 2001). There is about 5,000 invasive plant species, most of which were historically introduced for food, fiber, pets, biological control of pests, landscape restoration, or ornamental reasons (Morse, Kartesz, & Kutner, 1995). This is about one-third of the 17,000 native species in the US, and the number is increasing (Morin, 1995). About 42% of the species on the Threatened or Endangered Species lists are at risk primarily because of non-indigenous species (Pimentel, Lach, Zuniga, & Morrison, 1999). Damage due to invading non-indigenous species in the US adds up to more than $138 billion per year.

Non-indigenous weeds are spreading and invading approximately the US wildlife habitat. The lack of control of the invasive species through natural defenses has changed many habitats. One of these pest weeds is the European purple loosestrife (*Lythrum salicaria*), which was introduced in the early 19th century as an ornamental plant (Wilson & Perlman, 2000). Competitive stands of purple loosestrife have greatly reduced the biomass of native plants and endangered wildlife in the US wetlands.

Identification and control of invasive species is one of Raven’s seven-point plan to slow the extinction rates of plants (Raven, 1999, see discussion later).

**Pollution** – Many species are weakened or disappear as a consequence of pollution of both the aquatic and terrestrial habitats. Pollution with the insecticide DDT caused the near extinction of the American Bald Eagle and the Brown Pelican (Audesirk, Audesirk, & Byers, 2002; Perlman & Wilson, 2000).
A study conducted in the grasslands of the UK indicated that pollution with nitrogen accumulates on the floor and alters the species composition of grasslands (Phoenix, Booth, Leake, Grime, Read, & Lee, 2006). They found that herbaceous species decline while sedges and grasses increased.

**Population Growth** – Exponential growth of the human population and our intimate connections with other organisms only aggravates all other threats (Wilson, 2002). Raven (1995) considers human population growth to be the most important challenge because of its links with consumption (discussed later). Some think that human are just going through the same problems that were faced in the past, however in Raven’s view, these problems are at a different and on a larger scale (Raven, 1995; World Book Encyclopedia, 1999). If humans have not been able to deal with problems such as loss of top soil, pollution, and loss of diversity at the current level of population, a growing population will make these problems even worst (Raven, 1995; World Book Encyclopedia, 1999).

An example of human population growth’s effects on plant diversity is how population density explains 35% of the loss in variability in local plants in Britain (Thompson & Jones, 1999). A change in land use for roads, recreation, and urbanization has been accounted to have an even higher negative impact on plant survival than the traditional land use for agriculture.

**Overharvesting** (Overconsumption) – Disappearance of some species is a direct consequence of this threat. For example extinction of many Hawaiian birds came after the occupation of the Polynesians (Wilson, 2002). The strength of these forces proceeds in the same order. Their complex interactions actually are degrading our planet as biodiversity is lost as a direct consequence of these, or because the action of these forces makes some species more vulnerable (Wilson, 2002).
A Plan to Save Plant Diversity

We have exploited the plant kingdom in many ways. Therefore it is imperative that to continue satisfying our needs we understand the diversity of this kingdom, and work to conserve it as the growth in human population increases its demands on it.

Conservation of plant biodiversity is important because of plants’ dominance of the landscape and their unique characteristics,

… consideration of their [plants] biological characteristics, habitat requirements, and conservation status should be an integral component of research, discussion, and policy affecting local, regional, and global biodiversity issues. (Whitton & Rajakaruna, 2001, p. 622).

Education – Botanical knowledge is critical to reducing the worldwide loss of biodiversity (BSA, 1999). In the view of the BSA there are two areas that are pivotal to helping develop the necessary knowledge and understanding. One is exposing students to lessons about plants at the earlier levels of education, and the second, putting higher emphasis on teaching about plants at the college level (BSA, 1999). A high priority established by the BSA for the 21st century is excellence in botany education,

Students need to understand the importance of plants, see how the study of plant ecology relates to their own lives, and understand that ecology can provide the framework for managing environmental problems. (Appendix, BSA Ecological Section, BSA, 1999)

It is difficult to learn about something if the learner can not acknowledge the importance or relevance of what they are learning. Perhaps this has been part of the problem that has led to the critical status of plant biodiversity as exposed earlier. In the next section I discuss briefly a basic step in the process of learning about plant biodiversity.

Preventing Plant Blindness – The concept of plant blindness was introduced in 1998 to the US science education in order to bring to the center stage the role of plants in all aspects of human life. A plant-blind person does not acknowledge the presence of plants in their own environment (Wandersee & Schussler, 2001). As a consequence, the person is unable to: (a)
appreciate the importance of plants in the biosphere and in human affairs, (b) appreciate the visual characteristics of the representatives of the Plant Kingdom, and (c) give plants proper recognition and consideration—avoiding an anthropocentric (or zoocentric) superiority perspective. To prevent this condition, it is necessary to provide learners with meaningful education and experiences that include both scientific and social knowledge.

This study focused in developing activities conducive to prevent some of the symptoms of plant blindness as the students were exposed to the two instructional tools. Throughout the activities in the unit of study, students were able to: (a) pay more attention to the plants that are part of their daily life, (b) recognize importance of plants in the daily affairs, (c) recognize plants in their own geographical region, (d) develop sensibility to the visual qualities of plants and relating these to the adaptations developed, and (e) understand plant reproduction and the implications of this to the diversity of other organisms as well.

This plan is based on the premise that if students can not perceive individual plants, they won’t be able to perceive the diversity of the kingdom. If so, they would not be able to develop an understanding of the importance of conserving the diversity of plants, both at the local and global scales.

**Role of Botanical Gardens** – Throughout the world there are 1,600 botanical gardens which, together with nurseries and seed banks, maintain and tend about 25 percent of the flowering species and ferns (Tuxill, 1999). Many of these gardens play an active role in preserving plant species, for example through the propagation of rare plants for possible reintroduction in nature. Seed banks preserve stocks of seeds for breeding material. They gained importance in the early 1970’s when there were large looses in corn (US) and winter wheat (SU) due to uniformity in the gene pool (Tuxill, 1999). The Millennium Seed Bank of the Royal Botanic Garden at Kew presently has almost the entire UK flora and plans to have 24,000
species of the world’s flora (Royal Botanic Gardens at Kew (RBGK), 2006). Both seed banks and botanical gardens are depositories of many species that are already gone in their natural environments. The RBGK is sponsoring a ten year (2000-2010) global initiative. This project has two main goals: (a) to conserve 10% (about 24,000) of earth’s seed plants by 2010, (b) to develop research to support and promote efforts to conserve seeds (Smith, 2006). They want to preserve 45%-70% of the world plant biodiversity.

However, in spite of all of these possibilities, the foregoing alternatives only represent a fraction of what a real ecosystem is. Nothing is better than keeping the habitats where originally plants evolved.

**Comprehensive Plan to Save Plant Biodiversity** – As president of the International Botanical Congress, Peter Raven presented a paper at the *Millennium Symposium*. This paper included a comprehensive plan aimed to save plant biodiversity (Raven, 1999b). Such plan called for the need to (a) find out which plants are most endangered and conserve them through an organization related to the UN; (b) allocate more funding to support plant research. This should include strengthening museums and institutions that help preserve plants and literature about plants, as well as training local scientists in developing nations so they can help protect their countries’ biodiversity; (c) improve the accessibility of information about plants through the Internet to everyone; (d) focus on minimizing the effects of invasive species on plant diversity; (e) encourage every country to keep a national record of its common, rare, and endangered plants; (f) focus on conserving medicinal plants, which are important to the subsistence of human population; and (g) fund international research in plant population and reproductive biology so that the understanding of these areas can help in preservation.
Bringing to the classroom the opportunity for students to gain local- and global- scale knowledge about plant diversity is a necessary step that fits into this plan. The study proposed here will hopefully shed some light about what may be the best educational practice to help community college students achieve an understanding of plant biodiversity.

**Biocomplexity**

Earlier in the discussion it was established that ecology is a field of biology that is fed by many different science fields. In addition, the HIPPO dilemma also makes us aware of a range of forces acting against biodiversity. So, how can all of this information be integrated? It was not until recently that scientists have envisioned an approach to try for integrating this knowledge in order to explain the processes of life, the status of biodiversity, and the consequences to the future of life. To bring the level of understanding of biodiversity to the highest level, one must first become aware of biocomplexity.

The concept of biocomplexity was introduced by the National Science Foundation in 2001, and was identified then as a priority area for research and education (Colwell, 2001). It refers to phenomena that result from interactions within and between organisms and the physical environment. This construct encompasses different scales and disciplines, including the integration of biological and environmental aspects as well as socio-economic and cultural factors (Colwell, 2001; Greenler & Greenler, 2002a). This concept must be studied “as a whole as well as piece by piece”. As a developing field it is necessary to start integrating it into the undergraduate biology classroom and curriculum if we are to develop citizens who can understand it and scientists who can contribute to this new field (Greenler & Greenler, 2002b).

The concept of biocomplexity may lie beyond reasonable learning expectations for an introductory biology course. However, the ideas of “seeing the whole” may help in creating the
notion of interdependence and the need for biodiversity. In addition, the pedagogical approach used to teach about biodiversity using the CEB CD-ROM is a tool that can help students begin to grasp the idea of biocomplexity.

Summary

In conclusion, the literature review presented here demonstrates the current status of science education at all levels. It also presents some efforts from government and academia—both in science and science education fields—trying to improve collegiate science education. The human constructivist theory of learning provides not only a theoretical framework, but also research-tested tools that can be used to organize and present the learning experiences for this study. This is also the only theoretical framework that provides tools for assessment of learning via constructivist practices and inform whether learning is actually taking place.

The development of computer technology and learning tools, and its growing accessibility to the community college classroom potentially provides a vehicle for improving learning in the science classroom. Sound educational research is needed to test and either support or reject the long-held assumption that computers improve learning.

Various sources have been used in the endeavor of exploring the biodiversity concept, including textbooks, books, encyclopedia, CD-ROM, and the Internet. In general, education in ecology and related areas like conservation biology and the environmental sciences seems has been neglected for years. Therefore, the general lack of scientific literacy in this area and the associated negative consequences for life in our planet are not surprising.

In particular, existing research indicates there is a need to educate the public about the importance of plants. Many professional institutions and organizations, like the ESA, BSA, and ASPB, are taking a standing on this issue. A common theme echoing throughout them was the
imperative need to educate and increase public awareness of the urgency of conserving species biodiversity, and in particular plant biodiversity. There is clearly a need then to search for and test approaches that might yield the best practices and tools that we need to teach effectively about plant biodiversity. This research adds more light regarding this issue in science education. In the US, more than 50% of all college students take their introductory college biology course at public community colleges. Therefore, this was the setting were this study was conducted.
CHAPTER 3

METHODS

“If facts are seeds that later produce knowledge, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow.”

Rachel Carson (1965)

The main goal of this exploratory study was to look at the learning gains associated with incremental, supplementary use of interactive CD-ROM technology in a non-majors introductory biology course. The research was driven by the theory of human constructivism and used a mixed-methods, quasi-experimental research approach (Tashakkori & Teddlie, 1998), using case studies and both qualitative and quantitative data collection and analysis. The data collected helped identify students’ learning gains about plant diversity after using two different instructional tools.

This study leads to a better understanding of how community college students learn about biodiversity. It may result in instructional improvements that can be applied to the community college biology classroom, provided school contexts are similar to the one where this study was conducted. A brief overview of the goals and methods I employed to achieve each aspect of the study follows.

Goals

First, determine the value added to an introductory biology course by the sequential use of a supplementary, interactive CD-ROM that meets standards of excellence and addresses biodiversity.

I used a mixed methods approach to study the effects of the treatment after students participated in textbook-based illustrated lectures followed by a series of activities from the CEB CD-ROM. The data collection activities included case studies, pre- and post-survey, concept
maps, and periodic quizzes to gauge student progress and the value added incrementally by the series of treatment activities.

Second, determine if the use of the CEB CD-ROM enhances the students’ ability to develop and pursue selected guided-inquiry questions (of the type endorsed by the National Research Council) about local plant biodiversity with respect to threats to biodiversity.

Students worked in collaborative groups to gather salient information about local plants. This allowed them learn about plant life history concepts and threats. Students prepared a presentation to share the information with the class. Students created a Louisiana Plant Biodiversity table based on the class presentations.

Third, develop a new rubric to determine a student’s level of understanding of plant diversity throughout the study, based upon the history of the biodiversity concept.

I examined the historical development of the concept of biodiversity within the framework of the history of ecology from the origins to the current development of this major ecological concept. I aligned the levels of the rubric with the Life Sciences Standards developed by the NRC (1996) and other standards. The rubric was validated by a panel of experts. This rubric allowed me to categorize each student’s level of understanding of plant diversity and detect changes (level-of-understanding shifts) that were likely to have been initiated by particular stages of the treatment or to detect stasis.

Design

Rationale for a Mixed Methods Design

Traditionally there has been an emphasis in using quantitative research in studies within the field of science education. In the social and behavioral sciences however, there has been an ongoing debate for many years about the use and value of qualitative versus quantitative data
(Guba & Lincoln, 1994; Tashakkori & Teddlie, 1998). As new questions arise in science education, they call for more qualitative data to inform the process of education and explain the reasons that lie behind the numerical outcomes.

How can we know the underlying reasons why a student chose the wrong answer on a test? Qualitative research provides the foundation for understanding how students learn by using exploratory, explanatory, and descriptive techniques. It derives from the constructivist paradigm, while the quantitative research derives from the positivist approach (Patton 1990). Qualitative research takes place in the natural world and the process of data collection uses methods that are interactive, full of descriptions, and humanistic (Marshall & Rossman, 1999). Sampling is purposive (not random), and observation and interpretation are essential (Gilchrist & Engel, 1995).

Qualitative research allows researchers to explore the learning experience as a student’s personal experience, leading to interpretation (Marshall & Rossman, 1999). The researcher often becomes a data-collection instrument for the process being examined and the participants are part of the research site. Self-report data from students is analyzed as well.

In contrast, quantitative research seeks objectivity through randomization, controls, large samples, standardization, and replicable measurement. Its purpose is to make widely applicable generalizations and look for cause-effect explanations.

Methodological Approach

The focus of the study was be exploratory. It assessed and identified learning gains of the participants to detect the value added by successive stages of the treatment as well as overall progress toward understanding plant diversity. These gains were explored across three different levels of community college biology students (high, medium, low performers) and two groups
(textbook only-based instruction vs. textbook + CD-ROM based instruction). Therefore, it was a comparative mixed method, multiple-case, and quasi-experimental design (Tashakkori & Teddlie, 1998; Yin 2003). According to Yin (2003) multiple case designs produce evidence that is more compelling and robust than individual case studies. It is considered quasi-experimental because subjects were not randomly assigned to the treatments, but rather they were pre-assigned as they were already members of a particular section (Gribbons and Herman, 1997). The cases were limited in number, purposely selected, and stratified according to achievement levels (by low-medium-high GPA).

I used a parallel/simultaneous design with multiple applications within each stage of study. The data collection and analysis were both qualitative and quantitative during each stage of the treatment (Tashakkori & Teddlie, 1998). Use of mixed-methods, combining qualitative and quantitative approaches during different phases of the proposed study, helped in achieving well-rounded data collection, ready for triangulation and analysis (Tashakkori & Teddlie, 1998). The information obtained was used to answer the stated questions of interest in the best possible way.

The primary units of analysis were the six participant students (case studies) and the entire class enrolled in a public community college biology course in the Deep South. The type of instruction and documents collected from the students constituted subordinate/embedded units of analysis (Tashakkori & Teddlie, 1998; Yin, 2003, p. 40).

Two course sections were used. One was the treatment group and students were exposed to textbook and CD-ROM-based instruction. The other course section was used as a comparison group, and those students only experienced textbook-based instruction. Both course sections were taught by the same instructor; addressed the same topics, on the same days of the week, and for the same extent of time.
Research Site

This study was conducted at a public rural community college in the Deep South. The institution opened in 1999, and is fully accredited by the Southern Association of Colleges and Schools. It has an open-door admission policy. The student population at this college was at the time of the study approximately 1,000 students, presenting a mixture of traditional and non-traditional students. The latter are defined as students who are not recent high-school graduates, or who are returning to college after several years out. Many students attending this institution are first-generation college students. The majority of the students are from the rural area (80%) where the college is located. The student ethnicity at the time of the study was distributed as 75% white and 25% African-American. Many students usually attend this college in a part-time basis.

Instructional Tools

Textbook

The textbook used in the course was the widely used *Biology: Life on Earth* 6th edition (Audesirk, Audesirk, & Byers, 2002). The authors of this textbook consulted, during the book’s writing process, with biology educators representing different areas of expertise, as well as excellent teaching skills. The book is intended to engage non-major students, those who most likely are experiencing their last exposure to formal biology education in their lives.

The book comes with a student CD-ROM which provides interactive exercises and quizzes based on textbook material. The book focuses on concepts, communicates the scientific processes, and emphasizes evolution as unifying theme. It includes brief case studies and essays on various topics throughout the book.

The textbook teaches the diversity of life in five chapters and uses an evolutionary biology approach. The following themes are addressed: systematics, bacteria, protists, fungi, plants, and
animals. Before the unit on diversity, the book includes a unit on evolution (four chapters). The unit following the diversity chapters focuses on the study of plants, and that material is taught in three chapters. Throughout the textbook, the students can find “Earth Watch” essays which present different themes related to plant biodiversity (among other themes). Essays addressing plant biodiversity-related issues will be incorporated with the chapters as part of this investigation’s unit of study.

Software

The software that was used in this study was *Conserving Earth’s Biodiversity* (Wilson & Perlman 2000, version 2002). A search in Google (key words: biodiversity-education-software) and a search among several biology education materials publishers lend to several examples of software addressing biodiversity available in the market. These were found to serve a variety of purposes from education in the classroom (addressing elementary to middle school level) to organization of data bases for institution-based biology research. Those intended for K-16 education were limited in focus, such as *Cal Alive!*, which addresses middle school education on biodiversity in the state of California (California Institute of Biodiversity, 2006). Other examples found include several scientific and education software designed by a non-governmental organization working with UNESCO. These (a) addressed a single taxon, *Birds of Europe*; (b) addressed to taxonomic research conducted by professors, such as *Linnaeus II 2.6*; or (c) focus on taxa descriptions, such as *World Biodiversity Database* (ETI Bioinformatics, 2006).

*Conserving Earth’s Biodiversity* was unique in that it met several criteria: (a) One of the two authors is the leading figure in ecology and conservation biology, E.O. Wilson of Harvard University. He was raised along the Gulf Coast, and is an award-winning biologist and author; (b) It is intended for high school AP students and college students; (c) It provides a global view
of biodiversity at the same time that as it focuses on a tropical and a temperate region study cases; (d) It offers the instructor the flexibility to adapt lessons to the local perspective of the students, which is an important aspect of meaningful learning.

In addition, CEB is an interactive, multimedia learning tool designed to support teaching about conservation biology and environmental science. The program covers five major topics: (a) Distribution of life on Earth, (b) History and diversity of life, (c) Threats to biodiversity, (d) The practice of conservation biology, and (e) Social aspects of conservation. Topics are organized hierarchically, and there are cross links among topics and subtopics.

The CD-ROM has five exemplary lessons that can be used by teachers. These are organized as learning themes that can be accessed from the table of contents: (a) Introduction to Biodiversity, (b) Human impact on the land, (c) Human population growth and resource use, (d) Biodiversity under threat, and (e) Small populations at risk. These examples include a suggested sequence for the topics to be studied. Learning theme # 1 could have been used for this study. However, I used an independent lesson exclusively for this research, whereby the CD-ROM activities were additional or enhanced the material to which the students were already exposed in the textbook. In this way I was able to answer the research questions I have posed more distinctly. The study lesson included sections from the different CEB topics and was focused on plant biodiversity. Some sections of the program have an “Explorations” component, which includes interactive models or maps. Some sections also have a “Further thought” component, which are questions to consider issues discussed at a personal or local scale. As the lessons permitted, I used some of the explorations and further thought questions, and adapted these for students in both groups. Whenever possible, I used a global and local-regional (Southern) perspective of the issues at hand.
The *Conserving Earth’s Biodiversity* CD-ROM is considered to be an example of “hypermedia”. Students are offered 21 videos, 10,000 color photos, 80 essays, 100 taxa overviews, maps, and case-study of Costa Rica and the Hyannis Coastal Ponds. The program allows students to explore different topics according to their degree of intellectual development (i.e., introductory versus advanced students) and allows further exploration by connecting the constantly updated program’s web site, in addition to external web links. All sections start with an introduction, wherein E.O. Wilson himself presents an overview of the topic and raises questions.

This study was independent of any publishing-company bias for two reasons. First, using the instructor-designed lesson (as described above); and second, the *Conserving Earth’s Biodiversity* CD-ROM license was purchased by the college at full price in the fall of 2005, via a successfully funded grant proposal which I wrote – not donated by the publisher.

The program is installed in 23 computers in the computer laboratory, including an instructor’s computer with multimedia projector and speakers. Therefore, the class met in the computer laboratory, located near the regular classroom, during class period to use the program whenever necessary.

**Course and Instructor Selection**

**Course**

The General Biology II course, Biol 1020, is not taught sequentially to General Biology I therefore, background biology knowledge may vary somewhat among the students. General Biology II can be used to meet the science credits requirements for the General Education program. As such, it is part of the Science Articulation Matrix established by the State Board of Regents. Therefore it is transferable to other higher education institutions in the state. This
course covers the concepts of biological diversity, physiology, and behavior of living organisms while providing an overview of the evolution of life on Earth.

Instructor and Researcher Role

As the researcher of this study, I played the dual role of college biology instructor and researcher. As an instructor I have taught this course for eleven semesters. I strive to establish an atmosphere of respect, assurance, and support, creating an environment conducive to learning. I encourage students to ask questions when they don’t understand. The course has always included activities that provide students with experiences beyond the textbook information, (i.e., Internet work, group projects, field trips, videos, etc.). Being a small-class setting, I know all students by their first name. Under a strict ethical relationship, in many cases students trust me with personal information, (i.e., health conditions, work experience, academic/personal goals, etc.).

In addition, I have some experience with students outside of the college classroom in a professional and strictly confidential one-to-one mentoring interaction. During four semesters I was an official student mentor. As such, I interviewed students and monitored their progress in achieving self-set academic goals during the semester.

As a researcher in science education, I have limited experience performing qualitative research. Some of it includes using the CEB CD-ROM that was used in this study (Guzman 2000; Guzman & Wandersee, 2001a; Wandersee & Guzman, 2002).

Sampling

The sample for this study was one of convenience (Tashakkori & Teddlie, 1998). Potential participants are from the sections of the Biol 1020 course taught by the researcher.

According to Yin (2003) in a multiple case study, cases must be carefully selected. These must function as literal replicates, predicting similar results, or as theoretical replicates,
predicting contrasting results for predictable reasons. I carefully selected my study’s participants using stratified, purposive sampling for the six multiple cases (Tashakkori & Teddlie, 1998). The sample was stratified using the following as selection criterion: student ability level as indicated by their latest GPA. After the records of the students enrolled in both sections of the course were obtained, the students were grouped into three categories: high (>3.0), medium (2.0-3), and low-performing (<2.0). Students were informed about this research and were invited to participate. Three case study students from each course section were selected (n = 6). To the maximum extent possible, participants were chosen to represent the female: male ratio and ethnicities composing the entire classroom. The selected students were invited to participate in interviews and concept map co-construction out of class time. Students completed class-wide activities as part of the requirements for the course. Information about academic achievement of other students in the class will also be available to the instructor.

A preliminary code based on gender, section, age, and last two digits of their social security number was used to identify participants while the research was ongoing. This code was modified to names in order to simplify recognition of the participant’s treatment and level by the reader. For all participants, the first letter of the name indicates the group they represented: Tanya, Thiab, and Trevic represented the textbook only intervention; Carla, Caleb, and Cyrenec represented participants in the textbook + CD-ROM intervention. The last letter of the names indicate the performance level according to the current GPA of the student: “a” for high performers, “b” for medium performers, and “c” for low performers. A thick description of each case study participant was created, while guarding their privacy and confidentiality.

Participants’ Description

**Tanya:** Tanya is a Caucasian female student who attends college part-time and works a 10 hr. part-time job. She has no other activities that take up a significant part of her time. She is
single. Tanya graduated high school and started college the semester after. She started at another institution and transfer to the one she currently attends. At the time of the study she was her fourth semester. She plans to attend dental school to become a dental hygienist, and was visiting schools in her free time to get more information about requisites. Her grade point average was 3.16. She has had science courses before in elementary and middle school. In high school she had courses in the area of physical science, chemistry, and physics. She had the first introductory biology course the semester before the study. Her most memorable science-related experience was from middle school, when the science club invited elementary students and did many different experiments. She can be described as a very responsible student. She never missed class and was always ready. She has a very calm personality and is quiet in the classroom. She tends to listen more than do the talking. She tends to not answer even though she might know the correct answer, but is afraid of it being incorrect. These characteristics were also evident during the interviews when her behavior was mostly shy, and she tended to speak in a low tone voice. For the first interview she was quite nervous. As time progressed she became more confident during the interviews. Base in her performance in class she is a hardworking student that does well with rote learning.

Thiab: Thiab is a Caucasian female student who attends college part-time and works a 20-hr. part-time job. She has no other activities that take up a significant part of her time. She is single. Thiab graduated from high school and had a gap of one year before starting college. At the time of the study she was in her second semester at the institution and was cross enrolled at another institution. She is a first generation student and only child. Thiab wants to become a sonographer. She did not recall having science courses in elementary or middle school. She had biology, chemistry, physical science, and environmental science in high school. She was taking her first college science at the time of the study.
Her grade point average was 2.17. Her most memorable science-related experience was from her environmental science teacher, it was a fun class. She was in class 98% of the time. She missed for being sick. She is a very responsible student with all her class work completed on time. Thiab has a very outgoing personality. She likes participating in class asking questions and answering, even if she is guessing the answer. She likes learning big words and using them. She tends to self-doubt. She always volunteered to read aloud in class. She tends to summarize some of the information in her own words, and may not be necessarily correct. She talked clearly in the interviews and sometimes tended to go on the sideline when discussing some themes.

**Trevic:** Trevic is a Caucasian male student who attends college full time. He is single and planning to marry his girlfriend in the next year. He dedicates 10 hours a week to music. Trevic graduated high school and immediately attended college. At the time of the study he was in his fourth semester at the institution and was planning to transfer to another institution. He is a first generation student. He wants to become an accountant. He had science classes in elementary and middle school. He had biology, general science, and chemistry, in high school. The biology course at the time of the study was his second science course in college, and the first one had in fact been his most memorable science experience. His grade point average was 1.86. He did not recall any most memorable science-related experience. Trevic was in class most of the time. He had three sick-related absences. He was a pretty good, responsible student. He participated in class and asks questions. He is very concerned about keeping himself healthy and eating and exercising appropriately. He seems to be more of a visual learner, and is very brief in his responses, oral and written. He was very nervous in the first interview. In following interviews he did better. Sometimes he seemed to have limited or stereotyped views.

**Carla:** Carla is a Caucasian female student who attends college full time and works a 30 hrs part-time job. She is involved a youth leader in church. She is single. She graduated from
high school and attended Bible College for a year. At the time of the study she was in her third semester at the institution. Carla wants to become an emergency room–trauma doctor. She wants to transfer to a major university that has a medical school. She had all science courses in elementary, middle school, and high school. At the time of the study she was enrolled in her second college-level course, and taking two others. Her grade point average was 3.17. Her most memorable science-related experience was from a high school teacher who was her first good science teacher and made her want to learn more about science. She was in class 99% of the time. She missed twice for being sick. She is a very responsible student with all her class work completed on time. Carla had an outgoing and friendly personality. She is quite in class, and seldom would ask questions. Sometimes she is apprehensive of not giving the right answer. She memorizes information very well. She is more of a visual learner and likes using mnemonics too. She talked clearly during the interviews and in contrast was very outgoing, more herself.

**Caleb:** Caleb is a Caucasian male student who attends college full time. He is single. He works part-time 40 hrs. a week. He graduated high school and immediately attended college. He transferred from another institution and hopes to transfer back after completing some credits at the current one. At the time of the study he was in his second semester at the current institution. He wants to pursue major in art, with the goal of designing cars. He had science classes in elementary and middle school. He had general biology in high school. The biology course at the time of the study was his first science course in college. His grade point average was 2.38. Caleb was in class 95% of the time. He was a pretty good, responsible student. He tended to be quiet or shy in class, but more talkative in person. He seems to be a very calm, methodical, focused person. He does what needs to get done to fairly complete any task. He completes most school work at school due to his demanding part-time job.
Cyrene: Cyrene is a Caucasian female student who attends college full time and works a 25 hrs. part-time job. She is married and is a mother. She graduated from high school started college and then stopped for two years. At the time of the study she was in her second semester at the institution. She is interested in biology and wants to pursue an ultrasound or radiology career and work in a hospital. Cyrene had science courses in elementary and middle school. In high school she had biology, physical science, physics, and chemistry. The biology course at the time of the study was her first science course in college. Her grade point average was 1.51. Her most memorable science-related experience was from her high school chemistry teacher who had her doing experiments with magnesium and also do group work. Her most-memorable non-school science-related experience was volunteering at the coroner’s office after taking a forensic anthropology course. That allowed her to experience if she could cope with different kinds of deaths. She attended class 99% of the time. She is a very responsible student with all her class work completed on time, going above and beyond, typing any homework that needed to be turned in. Cyrene was mostly quiet in class. She would seldom participate. Outside the class she is a very outgoing person. She started the first interview a little nervous, but moments after was already very talkative. Her hand and face expressions were complementary of her speech. She is a good problem solver and likes applying information.

Variables

Although identification of variables is irrelevant for qualitative research, I identified them here because I used a mixed-methods approach and collected some quantitative data. There were three independent variables for this research: (a) the instructional tools – the CEB CD-ROM and the textbook, Biology: Life on Earth (Audesirk, Audesirk, & Byers, 2002); (b) instructor-designed activities, some of them based on activities in the CD-ROM; (c) the level of performance of the student (academic achievement).
The dependent variable for this research was the learning gains of the students. This was determined quantitatively by class-wide pre-and post-surveys, and formative assessment throughout the plant biodiversity unit by periodic quizzes, pre- and post-concept map construction. In addition, at the participants’ level the learning gains were determined by two other concept maps, interviews, and the quality of their development of inquiry skills as demonstrated in the final group presentation and evaluated according to the biodiversity rubric. Three independent evaluators were used to establish the reliability and validity of the rubric.

The qualitative equivalent to dependent variables was the patterns and themes that emerge from the inquiries and propositions exposed by the participants. These patterns and themes appeared in the documents that were collected as participants completed the CEB CD-ROM activities and textbook related activities, including the concept maps, and open-ended interviews. The quality of the concept maps, open-ended interviews, and field observations was the qualitative equivalent to “dependent variables”.

Research Phases and Activities

In this section I describe the three phases of this research which correspond to the questions of interest. With each question I describe the activities that were used for data collection. A flow chart was designed to summarize the sequence of lessons and activities that were used to investigate questions one and two of this research (Figure 2). Further discussion of the lessons follows in the section Plant Biodiversity Unit of Study later in this chapter.

First Question

What, if any, is the “value added” incrementally to a non-majors introductory biology college students’ baseline understanding of biodiversity by supplementary, sequenced use of the exemplary interactive CD-ROM on Biodiversity, Conserving Earth's Biodiversity?
Figure 2. Flow chart of research phases, activities, and data collection for questions one and two.
Activities – All students were taught the plant biodiversity unit of study (discussed in the next section). The activities of the study unit were intended to provide information to help achieve the first and second goals of the study. Both qualitative and quantitative data were collected for this part of the study. Quantitative data was collected as a pre-and post-survey and as periodic quizzes that were given after each chapter and associated lessons (Chapters 18 and 21). In addition, a post-quiz was given at the end of the study unit. Periodic quizzes and assignments are important for the group using the textbook + CD-ROM instruction. Savenye (1992) argues that formative evaluation of instruction is critical for instruction delivered using interactive technologies, as well as the use of both qualitative and quantitative methods.

Qualitative data was collected in the form of concept map construction, interviews, instructor observations, and documents from students’ activities. The documents included activities (worksheets), essay, and list of species.

Second Question

Does the use of the CEB CD-ROM enhance these students’ ability to develop and pursue selected guided-inquiry questions about local plant biodiversity with respect to threats to biodiversity?

Activities – After students were exposed to the plant biodiversity unit of study, they engaged in a two-fold collaborative effort, as small groups and as a class, and explored the plant diversity of Louisiana. Students gathered information about their chosen plant. They used the plant to apply the concepts learned during the study lesson, such as plant identification, world distribution, plant structure and reproduction. They also applied other biodiversity concepts such as value and services, threats, and genetic variation, as pertinent to their case. The latter concepts were to be used as criteria to distinguish a unique role of their plant in Louisiana’s plant diversity, making it a good model plant.
Students paired to explore the Louisiana plant of their choice. When larger groups of three students were formed, students were asked to look up for information for one additional plant. The number of plants was limited for two reasons. First, it was expected that having one plant as their focus will make students interact more as a group, exchange ideas, and reach consensus through their discussions. When group presentations were part of my pilot study and pairs of students worked on two plants, they worked independently and not as a group. Second, presentations from the pilot study tended to take longer due to the questions asked by the class; therefore, having a smaller number of plants this time allowed for the completion of the class presentations in a reasonable amount of time. Throughout the presentations, the students completed the table entitled “Louisiana Plant Biodiversity”. This table kept them engaged during the presentations and gave them an opportunity to evaluate the information received and to decide what made the plants presented interesting to them, while at the same time allowed them to sample the plant diversity.

The students submitted a portfolio including a copy of their Microsoft Power Point® presentation, an individual conclusion, and a copy of their completed table of Louisiana Plant Biodiversity. These final documents were collected for qualitative and quantitative analysis.

**Third Question**

Can a rubric be developed and validated, based on the history of the biodiversity concept, which differentiates college students’ progress and levels of understanding of biodiversity?

**Activities** – I developed the Plant Biodiversity Literacy Rubric (PBLR) based on the history of the concept of biodiversity. I developed a time line to serve as a summary of the historical development of the concept of biodiversity focused on plant biodiversity, which constitutes the main background of the rubric. I used multiple sources of information (American
Museum of Natural History, [AMNH], 2003; Gaston & Spicer, 2004; Levin 2001; Ricklefs & Schluter, 1993; USGS 2004; Wilson 2002). These resources were selected after an extensive literature review. The following sources were used to define the qualities of each level and the history of the development of the concept of biodiversity: the National Research Council Life Sciences Standards (1996) as integrated with the ASPB’s twelve principles of plant biology (ASPB, 2005a), the definition of biodiversity as exposed by the AMNH (2003), and the forces that according to conservation biologists join to “weaken and extinguish biological diversity” summarized as the HIPPO dilemma (E.O. Wilson, 2002, p. 51).

In addition, I included three elements modified from the Florida Writes rubric as part of each level: focus, organization, and support (Florida Writes, n.d.). Focus refers to the accuracy with which the study subjects integrate ideas under the major unifying theme of biodiversity. Organization refers to the ability to articulate ideas using logical connections between concepts. Support refers to the ability to use definitions and examples.

The PBLR rubric helped set the standards that can be used to evaluate the progress and levels of achievement as students’ progress in their understanding of the concept of biodiversity. The rubric could likely be used to evaluate any document produced by students after been taught a biodiversity study lesson. I used it to evaluate the subjects’ concept maps, the revisited essays, and the final group presentations. This gave me the opportunity to judge the progress and overall performance of the students as they are exposed to different learning activities (interventions).

**Validation** – A committee of three experts validated the rubric and verified its reliability. These experts included an ecologist with a focus on research on plant diversity, a wild-life biologist, and a science educator with experience in plant biology education. To validate the rubric each expert rated 4 concept maps for each participant and the Louisiana Native Plant presentations using the PBLR.
Plant Biodiversity Unit of Study

The plant biodiversity unit of study exposed students from two course sections to different instructional approaches in a series of lessons. Students in both sections participated in textbook-based lectures. These lectures included the traditional material delivered in class by the instructor on the aforementioned chapters (following the course outline), and six selected Earth Watch essays. These essays included themes such as reasons for preserving diversity, the role of genetic diversity, endangered species, and exotic invaders. Essays were selected based on two criteria: (a) discussed at least one plant diversity-related concept, and (b) included the same or very similar information as the activities selected from the CEB CD-ROM.

In addition, students in the comparison section were exposed to six CEB CD-ROM activities used as supplementary information. I created a CEB CD-ROM Content Guide, which allowed me to carefully examine and analyze the contents of the program. This provided a strong basis for the selection of activities that were conducive to the understanding of plant biodiversity. The activities selected from the CEB CD-ROM covered the themes presented in lecture, presenting the same basic information or very similar. However, depth, examples, and figures varied. Whenever possible the activities in the guide were matched to the Principles of Plant Biology (ASPB, 2005a; for a list of principles see Appendix A), the Life Sciences and Science in Personal and Social Perspective standards (NRC, 1996), and also reference to science literacy via Project 2061 (Rutherford & Ahlgren, 1990). Selected sections of the guide are included in Appendix B.

Lessons

This research started following the introductory chapters on evolution. Therefore, the students entered the new study unit with a basic background on the mechanisms that are involved
in the process of speciation and the importance of genetic variation for this to happen. The following is a discussion of the lessons to which the students were exposed.

**Lesson One, Numbers of Species** – Students were exposed to the lecture on Chapter 18, “Seeking order amidst diversity.” This chapter covered basic information on biodiversity, including taxonomy and classification of living organisms, the domains and kingdoms of life, the species concept, and formally introduces the concept of biodiversity to the students. The concept of numbers of species related to species diversity is briefly addressed in Chapter 18 of the textbook. Following lecture, all students completed two activities. The students in the textbook-only group used the Chapters 18 through 22 from the textbook for completing both Activity #1 and #2.

Students in the CD-ROM+ textbook group were exposed in addition to the CEB. Activity #1 of the CD-ROM consisted of the section “Diversity of Life”, where students listened to the introduction and completed the activity “Numbers of Species: Described Species” (Appendix B). The section on “Diversity of Life” answers questions on how many species exist and which groups are most or least diverse. In this interactive activity students explored the number of species contributed by four groups of organisms of their choice. The worksheet for the activity asked in addition to look for the numbers of species in the “flowering plants” and “other plants”, if these were not previously selected as one of the four original groups. For Activity # 2, the students completed the section “Tree of Life”, listened to the introduction and explored the subsections “Kingdoms Archaebacteria and Eubacteria”, “Kingdom Protista”, “Kingdom Fungi”, “Kingdom Plantae”, and “Kingdom Animalia”. The section “Tree of Life” provided a description of the major groups of organisms and how are they related, thus exposing the students to the broad diversity of life.
Lesson Two, Levels of Biodiversity – All students read the essay “Why preserve biodiversity?” by E.O. Wilson. The essay describes the concept of biodiversity and its three levels by providing examples of each level (i.e., levels were not identified as species, genetics, ecosystem). The essay discussed the possible consequences if the species network is disrupted, and gave examples of some of the threats to biodiversity. Following, students in the textbook-only group completed an activity based on the textbook. The students in the textbook + CD-ROM group explored the sections “Introduction” and “Reasons for Conservation” and the subsections “What is biodiversity?”, “Ecosystems”, “Species”, and “Genes”.

The selected sections for this activity exposed students to a concrete definition of biodiversity. It focused on the questions “What is biodiversity?” and “Why is conservation important?” For each section in this activity the students covered pre-selected readings that focused on plant diversity at the three levels of biodiversity: (a) Ecosystem: forest services, pollination and pest control, wetlands and freshwater ecosystems; (b) Species as resources: natural fibers, natural chemicals, medicinal plants, crop species; and (c) Genes as resources: variation in wild species, disease resistance in crops, chemical variation in medicinal plants, food varieties.

At the beginning of this activity all students also received the long-term activity sheet, “Golden List of Plant Species”. They were encouraged to list there any plants that they encounter in the textbook, CD-ROM, or outdoors and which they found interesting for any reason. They recorded the plant name (common), place where they encounter it, and what grabbed their attention. This list was collected at the end of the study unit.

At the end of this lesson students wrote an essay, which the revisited at the end of the study unit noting changes, if any, in their views.
Lesson Three, the Plant Kingdom – All students were exposed to the lecture on Chapter 21, “The plant kingdom” and the short essay “Plants help regulate the distribution of water”. The chapter provided the students with a broad perspective of the plant diversity from an evolutionary standpoint, addressing the evolution and adaptations of plants different groups (phyla) of plants and their main characteristics. The essay helped establish the importance of plants as part of the ecosystem. Following, students in the textbook-only group completed an activity based on the textbook. The students in the textbook + CD-ROM group re-visited the section “Diversity of Life, Tree of Life: Kingdom Plantae”, and worked on other screens not assigned before, to answer specific questions based on the different plant groups. Students were instructed to partner and discuss findings with another student.

Lesson Four, a Unique Plant – All students were exposed to a special lecture based on selected concepts from Chapters 23, “Plant form and function” and Chapter 24, “Plant reproduction and Development”, focused on a single plant. These chapters gave students background information on basic plant-related concepts, while exposing them to some of the diversity of structures, functions, and plant-organisms interactions. I considered this knowledge helpful in establishing and evaluating the importance of plants and their role in the ecosystem/biosphere, and therefore the importance of plant diversity.

This lecture also served as a model for their final project. Students received guidelines for their project on a Unique Louisiana Plant, and were instructed to start working on their projects, so they could have reasonable time to finish it.

Lesson Five, Global Patterns – This lesson was based on selected sections from Chapter 41, “Earth’s diverse ecosystems” and the essay “Crops, livestock, and wild genes”. The information from the chapter exposed students to the patterns of distribution and diversity of terrestrial ecosystems (biomes). The information on the essay helped the students establish the
importance of preserving species in the wild. After the lesson, students in the textbook group completed a textbook-based activity; while students in the textbook + CD-ROM group completed an activity based on the CEB section “Global Biodiversity”. These students visited the subsections “Introduction” and the “Global Patterns”. In the latter they explored the “Introduction”, “Biomes”, “Centers of food Plant Diversity”, “Conservation Hot spots”, and “World deforestation” subsections.

In the CEB activity the students allowed students to explore the global distribution of biodiversity, the geographical location of the areas with higher plant species concentration, and where food plant species come from. They also assessed the patterns in world deforestation. The students were able to compare how one aspect of biodiversity may affect others, and how everything is connected, investigating some areas that are crucial to conservation of plant diversity.

Lesson Six, Threats to Biodiversity – This lesson was based on three essays: “On dodos, bats, and disrupted ecosystems”; “Exotic invaders”, and “Do recombinants hold environmental promise or peril?” Afterwards, students in the textbook group completed a textbook-based activity. The students in the textbook + CD-ROM group visited the section “Threats to Biodiversity”, the subsection “Habitat Loss” where they visited the subsections “Forest Loss in the U.S.” and “Wetland Destruction”. In the subsection Exotic Species”, they visited the subsections “Introduction”, “Purple loosestrife”, “Fire ants”, and “Gypsy moth.”

In the essays and chapters in the textbook, the concept of deforestation was brought up several times. The activity on Forest Loss in the U.S. complemented the textbook by providing a visual activity, animation of forest loss. Limited information (one paragraph) was provided about the wetland ecosystem in the textbook. However, I considered this information to be an important component of the plant biodiversity picture for students in the Deep South who should
be knowledgeable of one of the most common ecosystems where they live. Furthermore, this activity served as background information for the exotic species activity. The exotic species activity provided information on how the invaders threaten local species and ecosystems.

Data Collection

Qualitative Data Collection

One of the principles for case study data collection is using multiple sources of evidence that meet at the same set of facts or findings (Yin, 2003). Different sources of evidence could be used, including analysis of documents and artifacts, archival records, interviews, direct observations, participant-observations (Patton, 1990; Yin, 2003). What follows is a description of the sources of qualitative data that I used for this study: interviews, documents, concept maps, and observations.

Interviews – Interviews are one of the most important sources of data. Clinical interviews originated in the Piagetian tradition. However, they have been modified by Novak and Gowin (1984) becoming a human constructivist research approach used to explore the learner’s cognitive background and probe to understand their process of learning.

Oral data collected from the interview process can be examined and used to form explanations and an understanding of the cognition process. Interviews can vary from flexible interviews to more standardized interviews. General recommendations for interviews include the use of props, and a progression in the depth of the questions from more to less familiar. The questionnaire should start with open-ended factual questions (Novak & Gowin, 1984).

Some guidelines for the interview questionnaire following Novak & Gowin (1984) are: demonstrating patience and good listening skills, avoiding irrelevant discussions, rephrasing interviewee’s questions using their own words, and avoiding teaching the interviewee. In
addition, interviewers must remain neutral during the interview process, and not providing feedback to the interviewee.

Interviews were used as part of the data collection to help determine the learner’s conceptual development (Novak & Gowin, 1984). A total of thirty interviews, five interviews times six participants were conducted for this research. The first of these interviews preceded the CEB CD-ROM activities. The second through fourth interviews followed the CEB CD-ROM activities #2 through #4. The fifth interview was conducted at the end of the study unit. Three of the interviews, second, fourth, and fifth included concept map co-construction (discussed later in this chapter). Having the sequenced interviews provided me with information on what the subjects already knew about the upcoming lessons and allowed for sequential comparison between the two groups. In this way I was able to detect if there were any learning gains as a result of the instructional interventions.

For the interviews I used standardized, open-ended interviews (Yin, 2003). All six participants were asked the same type of questions with respect to textbook and/or CD-ROM content according to the intervention they were exposed. Some individual interviews had additional questions that deviated from the interview protocol, as the researcher wanted to know more about a particular answer given by a participant. During the interviews of the participants that were exposed to textbook + CD-ROM I asked questions aiming to reveal their learning experience with the additional instructional tool and how they compare the CD-ROM experience to the textbook experience.

At the end of the last interview, I gave an overview of the CD-ROM activities to the “textbook only” participants showing them the additional material that was presented to the textbook + CD-ROM group and asked for their comments. The interviews allowed the researcher
to compare the participant’s understanding, but at the same time provided some flexibility and opportunity for the participants to elaborate on their explanations (Yin, 2003).

During the interview process I used ecology-related and plant diversity-related props (i.e., pictures, diagrams, maps, etc.). Protocols for interview sessions one through five are in Appendix D. All interviews were recorded in digital video, therefore creating a source of data that provided visual information in addition to the oral information. This approach was suggested by a participant during the pilot study conducted in the spring 2004. It facilitated the collection of observations of the participants during the interview process without distracting the researcher from the interview itself. The oral part of the videos was transcribed and saved as Word documents. These documents were coded to identify learning gains and examples provided by the participants.

**Documents** – One way of supplementing participant observations and interviews is by gathering and analyzing documents which have been produced during the research (Marshall & Rossman 1999). Two strengths of this method are being “unobtrusive” and “rich in portraying the values and beliefs of participants in the setting” (Marshall & Rossman, 1999, p. 116). In addition, documents can be reviewed repeatedly (Yin, 2003). Several types of documents were collected from this research and analyzed, including activities (worksheets), essays, list of species, and portfolio with presentation and plant table.

The activities were completed by the students after the lectures or discussions of essays. The students in the textbook group had textbook-based activities, while students in the textbook + CD-ROM group had CEB-CD-ROM based activities. These activities were designed to match content as closely as possible.

All students wrote an essay entitled “My Reasons for Conserving Biodiversity” after the third activity. At the end of the study unit, students were given an opportunity to revise this essay.
and change, if they wanted, their original ideas by writing a short essay. On the same day, students received a “long-term” activity, the Golden List of Species, which is a plant list created by each student as they were exposed to the unit of study. The last document collected were the portfolios with the presentations and a Louisiana Plant Biodiversity table (completed as part of the presentation sessions).

**Concept Maps** – Concept maps allowed me to record and trace how the cognitive structures of the learners changed throughout the study, including identifying student’s biodiversity/ecological misconceptions. From the learner viewpoint, this tool should facilitate easier learning and recall of the subject matter. From the assessment point of view, concept maps can help in evaluating, planning, and organizing instructional material.

Dr. Knight Roddy (personal communication, February, 2005) warned me about the use of concept maps when students have not been previously exposed to this experience. To avoid potential problems, I incorporated the use of concept maps in other course topics covered before the Plant Biodiversity Study Unit. Therefore participants had some previous experience in concept map construction. The students were given instructions to construct concept maps based on the guidelines established by Novak and Gowin (1984).

Although there are several approaches to construct concept maps, the one I selected for this study provided a list of seed concepts to the participants. I reminded the students they could use other concepts which they may recall, and add any definitions and examples they considered important (Griffard, 1999; Roddy, 2003; Trowbridge, 1995). These seed concepts represented the information the participants were exposed through their textbook and the CEB CD-ROM. All students participated in concept map construction at the beginning and end of the Plant Biodiversity Unit. The first class-wide concept map created by the students was considered a diagnostic, while the second class-wide concept map created after completing the unit of study
helped identify if there were any learning gains or misconceptions present as compared to the first concept map. Class-wide concept maps were completed during class time for two reasons: (a) students could be instructed they could not use any external sources of information, and (b) to encourage students to only use the concepts they felt confident of and to make sure they included labeled links (propositions) between the concepts that appear on their maps.

In addition, participants co-constructed two other concept maps during interviews four and five. Therefore, a total of four concept maps were collected per interviewee (including the class-wide pre- and post concept maps). The post concept map was discussed with the participants during the last interview, and they were given the opportunity to revise it.

**Instructional Tools as Artifacts** – The various instructional tools used in the plant biodiversity study unit were evaluated by the panel of experts as part of assessing the face validity of the assessment instruments. These include: textbook chapters and essays, instructor (researcher) lecture notes (Microsoft Power Point® format), and the CEB CD-ROM activities.

**Field Notes** – I collected direct observations from the course sections and individual participants as the unit of study progressed (Yin, 2003). Observations can be use to help discover interactions in the natural setting (Marshall & Rossman, 1999). They also recommend observations to be systematic, recording detailed events in a non-judgmental, and concrete as possible way. I created an observation checklist to collect class-wide general observations as the students were exposed to lecture and individually working on their worksheets or activities in the computer laboratory. This facilitated the process and standardized the criteria (Appendix E). For two lectures, classroom observations were corroborated by an independent observer.

Field notes serve the purpose of preserving the details of an event (Patton, 1990). Since the participant interviews were videotaped, this allowed obtaining detail observations that enhanced the information gathered from the transcription of the verbal data obtained through interviews.
These observations were transcribed. An independent observer reviewed the interview tapes to help corroborate and validate the researcher’s notes from the observations recorded from the interviews. This allowed creating an interview context rich in details and context.

**Quantitative Data Collection**

All phases of this study included collection of quantitative data, given that this research had a mixed-method design approach. This included closed questions with assigned numerical values that were followed by quantitative analysis (Tashakkori & Teddlie, 1998, p. 19). I used a pre-post-survey, quizzes, and the Unique Louisiana Plant group presentation data.

**Survey** – Surveys are used to describe attitudes, beliefs, and behaviors. Administering surveys has advantages and disadvantages. Among the advantages are the “accuracy, generalizability, and convenience” (Marshall & Rossman, 1999, p. 130). However, they are not appropriate for complex patterns of interactions. They can be administered to a sample of the population and then can make inferences to the population—but not in this study, because of its limitations. The survey used in this research provided information about learning progress for specified concepts, but also for selected science skills and attitudes toward science of the participants.

The instrument I used as a pre-post survey was the Student Assessment of Learning Gains (SALG). This instrument was developed by Elaine Seymour (1997). Since its development, the instrument has been used by faculty to learn how different elements of their courses affect student learning, and how much students had gained from different aspects of the courses. The instrument is available for modification by its users,

The structure of the instrument is such that the content of the questions can be changed by users with different learning objectives (whether in chemistry or any other discipline) while preserving the format that is exclusively designed to obtain students’ assessments of their learning gains. (Seymour, 1997, para. 3 in section Development of an Exclusively “Gains-Related” Instrument).
At the moment, the website has various instruments available for different disciplines. I chose to modify the only one available that was developed for a biology course. I modified the concepts section to include concepts related to the topic of plant biodiversity. To do this, I first selected questions from the instructor’s tests bank (ancillary materials from Audersirk et al., 2002) for the chapters of the textbook that were part of the study unit of plant biodiversity. Second, I selected some statements considered to be part of general biodiversity knowledge which appeared on the “Biodiversity in the Next Millennium” poll commissioned by the American Museum of Natural History (AMNH, n.d.).

One section of the survey only appears on the post survey and was intended to assess course-wide learning gains. Validity and reliability of this instrument has been already established. However, because of the modifications that I have made, the instrument was validated a panel of experts. The survey was used as a data collection instrument, which was given at the start and end of the study unit (see Appendix F).

**Quizzes** – Two short quizzes (formative assessments) following lessons one and three were given based on material that was covered both by the text book and CD-ROM activities. Questions for these quizzes came primarily from the test bank prepared as supplementary material for instructors teaching this course, and made available through the publishing company.

A third quiz (post-test) was given at the end of the Plant Biodiversity unit of study. It included some of the questions used in the two earlier quizzes and questions based on the latter phase of the study. Some of the questions were modified from the “Plants in Peril” quiz from the Center for Plant Conservation (O’Reiley-Lill, 1996), as these questions were related to the material presented in class. The face validity of the three quizzes were validated by a panel of experts.
Louisiana Unique Plant Model Presentations – Students prepared group presentations following guidelines provided by the researcher. Student’s work on this set of data started with lesson number four of the study unit. The presentations were delivered at the end of the study unit during the last class meeting before the post unit activities (i.e., concept map, quiz, post-survey). The group presentations were evaluated using the Plant Biodiversity Literacy Rubric (PBLR) developed in the third phase of this study.

Marshall and Rossman (1999) identified several strengths and weaknesses for the methods of data collection that I used (Appendix G). Whenever possible I tried to minimize the weaknesses of the methods, by being systematic and also by sharing my views with experts and considering their perspectives when interpreting data. As a final note in the process of data collection, Marshall and Rossman (1999) also recommend the use of color-coding to keep track of events, dates, and so forth, as this strategy facilitates piecing together the information later. I used this approach in the study to differentiate among the different activity packets given to the students. Color-coding helped in keeping the data organized and easy to track.

Data Analysis

Qualitative Analysis

I used qualitative data analysis for the interview transcripts, concept maps, activities (including the golden list of species), and the essays. With this analysis I expected to capture any learning gains over time of the students that who are exposed to the CD-ROM instructional intervention, as compared to the ones who did not experienced it. In addition, the analysis of the activities and essays revealed the pattern of themes experienced by the participants in each group. Tashakkori and Teddlie (1998) state,

The essence of qualitative analysis of any type is the development of a typology of categories or themes that summarize a mass of narrative data (p. 119)
The information collected helped in finding the themes that reflected student knowledge gains and helped build a typology of plant biodiversity literacy.

**Interviews, Activities, and Essays** – First, interviews were transcribed from the digital video data and a Microsoft Word® document was created for each interviewee. Interviews took place before and after the different lessons. The participants’ responses to the interview questions were used for a concept propositional analysis (CPA) (Novak & Gowin, 1984). In this technique the transcripts of interviews are edited to extract propositions revealed by the learners. I created a table for each participant wherein I summarized their propositions at each interview (following the unit lessons to which they were exposed). This phase of the data analysis required multiple readings and looking at the data from different perspectives (Marshall & Rossman, 1999). The activities, essay, and golden list of species were analyzed using a simple valence analysis to obtain patterns in the data by using categories set *a priori* (Tashakkori & Teddlie, 1998).

**Concept Map Analysis** – Maps were analyzed both qualitatively and quantitatively by using a series of preset criteria. These criteria included presence of the most important concepts, acceptable labeled links, map reflectance of misconceptions, and complexity (hierarchical levels and cross links) changes over time. In addition, the PBLR was used to determine the level of literacy of the participants in regards to plant biodiversity. Several techniques are available for evaluating concept maps (Novak & Gowin, 1984; Wandersee, 1990). I scored the concept maps according to the concept map checklist (Wandersee, 1990).

**Quantitative Data Analysis**

Class-wide, the students in the textbook only group and in the textbook + CD-ROM group were assessed empirically at the start and end of the study (CM1 vs. CM4 and pre-survey vs. post-survey) and throughout the study unit (three quizzes). The selected participants were
assessed before, during, and after lessons of the study unit through activities, concept maps, interviews, and pre- and post-survey.

The PBLR was used to assess the student’s understanding of plant biodiversity considering the concept maps and the final group presentations. Causal-comparative methods were used for analyzing the pre-post survey data, pre-post group concept maps, and the performance in the quizzes and the post test.

Descriptive statistics were computed for each group (textbook only and textbook + CD-ROM). Given the quasi-experimental design of the study, basic inferential statistical analyses were used to get an idea of the trends of the data, but were interpreted with caution. In addition, the total class size and the number of participants were small, thus power was limited by the sample size. Gribbons & Herman (1997) and Gall, Borg, and Gall (1996) coincide in warning about the use of statistical significance testing under the circumstances like the ones stated above, “nonrandom sampling, nonrandom assignment, or low statistical power” (p. 186, Gall, Borg, & Gall 1996). The parametric paired samples $t$-tests were applied to concept maps, quizzes, and survey data to test for the significance of the difference between the textbook group and the textbook + CD-ROM group. If the data had a non-normal distribution, the Mann-Whitney U test was used instead. Further description of tests used is in the overview of statistical analyses in the next Findings and Discussion chapter.

The $t$-test is recommended for small sample size assuming that the distribution of scores is normal (Gall, Borg, & Gall, 1996). It is acknowledge that a Type I error is possible when multiple $t$-tests are done between two groups. However, the content of quizzes for chapter 18 and 21 are considered, in a sense, independent because they are assessing different material, the posttest, though, will include some general questions in addition to specific questions based upon
the latter part of the unit of study. In addition, I am interested in looking at the incremental change in the student’s understanding as the unit unfolds.

Trustworthiness/Verification

Trustworthiness of the study was established first, by controlling the information delivered to the students. A single instructor taught both course sections, assuring all students were exposed to the same quantity and quality of material and instruction. An additional control in this regard is that students’ learning was assessed with the same quizzes, which were part of their course grade. The only difference between the groups was the format and sources for the additional activities following lecture. The lectures were taught in the same building, on the same days of the week, but different classrooms. The researcher also used triangulation of data sources, which is a major strength of case studies (Yin 2003). Trustworthiness was enhanced by methodological triangulation, analyzing data with a combination of quantitative and qualitative approaches, and analyzing from different view points (theory triangulation) (Yin 2003).

Even though the sampling is purposeful, internal validity was achieved by maximizing the difference between the groups, maximizing possible heterogeneity, and having representatives of all achievement groups (high-medium-low achievers). To the extent possible, both genders were represented in the same proportion in both participants’ groups. However, it was not possible to match gender and achievement level.

For the pre- and post-survey, activities, and quizzes, I minimized error by including the maximum possible number of students enrolled in the course, as long as they consented to be part of the research. Approximately 50% of the student population at this rural community college attends full-time, and about 80% hold at least one part time job and/or have family responsibilities. The data collected from this study has limited direct transferability only to other rural community colleges serving a similar student population. The data collected could provide
valuable information for biology teachers designing courses in other community colleges in the parish, state, and region.

**Ethical and Political Considerations**

The administration of the community college were the study was conducted granted full permission to conduct this study. Administration staff provided support in the early stages of the research by providing information about the academic records of the participants under strict confidentiality.

An application for exemption for Institutional Review Board (IRB) oversight was submitted and approved (Appendix H). All students were informed on the first day of classes that an educational research study would be conducted during at some point of the course and some of the activities planned for the assessment of the course were also part of the study.

At the start of the study unit, students were reminded again about the research, and the researcher asked for anyone interested in volunteering to meet with her later. All students were informed about the nature of the research and their voluntary and anonymous status if they choose to participate. At the time of the first survey, all students were asked to sign if they consented being part of the research. In addition, the participants filled out a biographical information sheet and signed out the consent forms (Appendix I). I made it clear to all the students that their participation in the research is voluntary, and they could opt that their activities and other information provided to not be used for the study. To do so they would write “NO” on the activity sheets, surveys, or quizzes provided in class.

**Preliminary Study**

I conducted a pilot study during the spring of 2005 and fall 2005. The pilot study is considered an important part of research because it can provide information about the logistics of the inquiry (Yin 2003). The objectives of the first part of the pilot study were to use some of the
data collection techniques and estimate the time it will take the students to complete the different activities in the CD-ROM. The techniques explored were concept map co-construction and interviews. In addition I was able to determine the feasibility of conducting the research at the institution selected. This first pilot was limited by the availability of the CEB CD-ROM (only two copies running on two computers). This only permitted me to have students complete the activities at their own pace on their own time.

The second part of the pilot study permitted testing of some class-wide activities, as program license had been acquired by the institution, and the program was installed on 16 computers. Once the CD-ROM was available in the computer laboratory, I was able to try out the sequence of some activities, and monitor timing within the lecture at the class level. In addition, students had the opportunity to work on the guided inquiry phase.

A description of methods employed is included in Appendix J. The data collected from the pilot study were not analyzed. However, reflections based on students comments and my field notes were used to improve the study being proposed here.

The following are some of these reflections: (a) Make program available in the computer laboratory, in order to incorporate its use as class-wide activities. This will provide more sources of data, keep the time lapse between activities the same for everyone, and make it easier for those students selected as participants since they will not have to complete activities in their own time; (b) One main issue that needs to be controlled for the actual research is the time frame of the activities. Given the activities were not incorporated during class time and study subjects needed to find convenient times to participate, not all study subjects completed the activities at the same time. In addition there are differences in the time period study subjects took to complete the activities and in the time lag in between activities; (c) Have a comparison section, since it will be more difficult to have some students in the same section and not others using the
CD-ROM.; (d) Provide more detail with the activities, which sections need to be completed and what activities. A worksheet may help keep track, and may also help those that work more slowly to know what they need to complete. When student were provided only an answer sheet, without more specific instructions not all of them completed activities as expected; (e) Revise list of concepts for concepts maps and consider providing a list of possible links. Students had severe lack of vocabulary. This problem was not addressed in the study, as counting links is one way of measuring student understanding of concepts; however, it surfaced again, and the researcher believes should be addressed in the future; and (f) Have all students create a concept map before and after the lecture material has been covered. It can serve the function of an open-ended pre-post-test. These reflections were taken into account in the design and plan of this study.
CHAPTER 4

RESEARCH FINDINGS AND DISCUSSION FOR QUESTION ONE:
INCREMENTAL EFFECTS OF SUPPLEMENTAL, SEQUENCED USE OF
EXEMPLARY INTERACTIVE CD-ROM, CONSERVING EARTH’S BIODIVERSITY
ON STUDENTS’ UNDERSTANDING OF PLANT BIODIVERSITY

“We will conserve only what we love. We will love only what we understand.
We will understand only what we are taught.”
Baba Dioum, African environmentalist (1968)

Overview of Statistical Procedures

As an exploratory study, themes were compiled and compared across treatments
to create a typology of plant biodiversity that reflects students’ incremental learning gains. A
variety of resources was used to collect both qualitative and quantitative data. Qualitative data
collected included interviews, essay, and activities. Quantitative data collected included quizzes
and pre- and postsurvey. Some data were considered both qualitative and quantitative, including
the golden list of species and concept maps. Multiple sources of information allowed for
triangulation of the data.

Concept Maps

Concept maps are a useful tool to assess the students’ progressive understanding of the
concepts by helping document the changes in knowledge over time (Trowbridge & Wandersee,
1998). In this study, students were required to create concept maps four times. All students had
previous experience with a fill-in concept map and a collaborative concept map, as these were
required activities for earlier lessons not related to this research. For this research, all students
created concept maps before the study unit started and at the end of the study unit. In addition,
participants created concept maps following lesson one (during the second interview) and
following lesson three (during the fourth interview). A list of seed concepts was provided to all
students. The number of concepts varied from 23 seed concepts for the first and second concept
maps, to 26 seed concepts for the third concept map, and finally to 21 seed concepts for the last concept map. Some concepts were added, removed, or changed according to the lessons the students had experienced. The students were encouraged to use only those concepts they felt comfortable with and to add any additional concepts they considered appropriate and that were part of their understanding.

Concept maps were scored using a checklist (see Table 2). The criteria in the checklist were based on Wandersee’s Standard Concept Map Checklist and the scoring rubric (Trowbridge & Wandersee, 1998). The original checklist was modified to accommodate for the needs of the current research. All concept maps were rated three times to assure consistency in the use of criteria selected.

Table 2.
Concept Map Checklist (Adapted from Trowbridge & Wandersee, 1998).

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Yes</th>
<th>Frequency</th>
<th>Value Points</th>
<th>Points Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of correctly used seed concepts</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mapper-added correctly used new concepts</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Links between concepts are valid and precisely labeled</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cross-links are valid and precisely labeled</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Map contains examples that are from seed concepts</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Map contains examples that are original (or from other</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>sources such as, book, CD-ROM, and/or lecture)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The map is tree-like and contains __hierarchical levels</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Misconceptions (incorrectly linked concepts or invalid links)</td>
<td></td>
<td></td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td></td>
<td></td>
<td></td>
<td>156</td>
</tr>
</tbody>
</table>
In addition, concept maps were evaluated and rated using the PBLR (see Appendix K). These findings are presented and discussed along with main research question three in Chapter 6.

**Clinical Interviews**

Clinical interviews were analyzed using concept proposition analysis to identify the presence of misconceptions and how either correct or misconceptions changed over time. The original transcripts of the interviews were used to extract the propositions exposed by the participants. Following Novak and Gowin (1984), the propositions extracted included key words that represented knowledge of the concept. Depending on the original interview questions, these varied in grain size from words or short phrases, to a few lines that expressed an idea. The interview questions followed the lesson’s objectives. Therefore, statements in the instruction section of the analysis consisted of the concepts expected to satisfy the objectives.

For the purpose of this study, learning gains were defined as the acquisition of knowledge that was previously absent or the change of a misconception to a correct proposition. Participants’ propositions were examined and compared to the instruction statements. The researcher determined whether the proposition represented actual knowledge or an alternative conception (labeled as misconception). Then, pre- and postintervention propositions were compared, and the change in propositions, if any, was recorded (see Appendix L). A coding system was created to identify correct propositions and those that were misconceptions as well as to identify the origin of the examples contributed by the participants (see Table 3). Example codes were only used if the origin of the example could be traced. When used, the same instruction was evaluated in the same way for all participants. To verify propositions were coded appropriately, the coding procedure was repeated three times.
Table 3
Codes for Propositions and Examples Used in the Concept Propositional Analysis

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning – proposition changed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning Gains</strong></td>
<td>From (preinstruction)</td>
</tr>
<tr>
<td>mc+</td>
<td>incorrect</td>
</tr>
<tr>
<td>+</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Vague</td>
</tr>
<tr>
<td></td>
<td>No examples</td>
</tr>
<tr>
<td><strong>Learning Loss</strong></td>
<td></td>
</tr>
<tr>
<td>mc -</td>
<td>Correct</td>
</tr>
<tr>
<td>mc</td>
<td>None or vague</td>
</tr>
<tr>
<td>-</td>
<td>Correct or vague</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td><strong>No change</strong></td>
<td></td>
</tr>
<tr>
<td>mc0</td>
<td>Incorrect</td>
</tr>
<tr>
<td>0</td>
<td>Correct</td>
</tr>
<tr>
<td></td>
<td>Incorrect</td>
</tr>
<tr>
<td></td>
<td>Vague</td>
</tr>
<tr>
<td><strong>EXAMPLES</strong></td>
<td>From</td>
</tr>
<tr>
<td>T</td>
<td>Textbook</td>
</tr>
<tr>
<td>CD</td>
<td>CD-ROM</td>
</tr>
<tr>
<td>B</td>
<td>Both: CD-ROM and text</td>
</tr>
<tr>
<td>L</td>
<td>Lecture/Local – example was not in textbook or CD, but considered important information for the understanding of local plant diversity</td>
</tr>
<tr>
<td>A</td>
<td>All possible, CD, T, and L</td>
</tr>
<tr>
<td>G</td>
<td>General knowledge- applied from daily life or from other lectures/courses</td>
</tr>
</tbody>
</table>

(Table continued)
Next, the number of propositions per category and examples were tallied. A summary of these per participant and instructional group - textbook and textbook + CD-ROM - was provided after each lesson (see Tables 10, 13, 16, and 33).

Activities

Students in the textbook group completed textbook-based worksheets. Students in the CD-ROM group completed CD-ROM-based worksheets that may include some activities from the CD-ROM. All worksheets are referred to as “activities” from now on. These activities completed throughout the study unit were analyzed using a simple valence analysis as described by Tashakkori and Teddlie (1998). A set of *a priori* codes was selected to categorize all questions that were answered correctly. These codes reflected major criteria according to the information presented in the textbook chapters and the CD-ROM along with the focus of the questions in the activity. Therefore, new categories were added as needed for each lesson/activity. Other experts in the area reviewed the codes. The activities were coded three times to corroborate that answers were properly coded.

Quizzes

All students were assessed with three multiple-choice quizzes that took place following lessons one and three and at the end of the study unit (after the group presentations but before the postsurvey). A panel of three experts determined the face validity of the quizzes by revising the content of the lecture, the textbook chapters, and the activities from which the quiz content was
derived. The grade students achieved on each of these quizzes was part of their course grade. Therefore, information from the CEB CD-ROM was included on the test only if it were covered in the textbook as well. It was expected that as some information was reinforced, students in the CD-ROM + textbook group may perform better in the quizzes as compared to the students who experienced the textbook-only intervention.

Quizzes were analyzed quantitatively using descriptive statistics. Group means were compared using an independent sample t-test (MS Excel®, 2003). Results are discussed with the two lessons (one and three) that they were a part of and at the end with the post-unit findings.

Survey

The survey instrument used for this research was the Student Assessment of Learning Gains (SALG). Pre- and postsurvey instruments are included in Appendix F. This is a free, online survey instrument developed by Seymour and available through the Wisconsin Center for Educational Research (Seymour, 1997). The site provides a template and a variety of examples for different disciplines. For this research, a biology example was modified to create two versions. Students completed the first version, pre-SALG, at the beginning of the study unit, after working on concept map #1 and before the start of the lessons of the study unit. The pre-SALG consisted of five main questions, which assessed general science understanding and attitudes toward the theme of plant biodiversity. The survey also assessed the influence of research-related activities and resources as well as other research-related skills that is, preparing a presentation. Students completed the second version, post-SALG, at the end of the study unit, once lessons, concept maps, quizzes, and group presentations were finished. The post-SALG had three additional questions assessing the effectiveness of the tools used and the perspectives the students will carry into their future.
Items on the survey were organized into clusters that included related information to facilitate the analysis (Gall, Borg, & Gall, 1996). Section V of the survey included some of the main ideas students were exposed to through the study unit. Items in this section were first coded using the same *a priori* codes used for the simple valence analysis. Then, coded items were organized into sub-clusters that matched the levels of the PBLR. Clusters and survey items included in each cluster are listed in Table 4. Then, the frequency of responses for each question and for clusters was calculated. Results for the pre-SALG and post-SALG for each group are presented at the end of the post study unit (see second to last section of question one in this chapter).

**Results and Discussion**

This section summarizes the information gathered to answer the first question explored in this research. The focus of this question was finding out whether students who were exposed to the CD-ROM in addition to the textbook reflected any value added to their learning when compared to students who were exposed only to the textbook.

Data were analyzed and presented to the reader in units corresponding to lessons. This approach allowed to account for any incremental effect of the intervention on the learning of the participants. Findings for lessons one through three, and lessons five, six, and post unit are presented and discussed in this chapter. The data collected from lesson four was used to answer the second question of this research (see Chapter 5). Survey data were analyzed as a two-point over time information, pre-post and were also compared across treatments. A summary and discussion were provided following the analysis to show the effects of the unit of study experience on the participants’ learning and to determine if those exposed to the CD-ROM experienced any gains. As the data were gathered, the researcher extracted ideas from the data and explored for presence of any patterns within each group.
Table 4.
Clusters Used for Analysis of the Student Assessment of Learning Gains Pre- and Postsurvey.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cluster description</th>
<th>Survey items included</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Science understanding</td>
<td>1-6</td>
</tr>
<tr>
<td>2</td>
<td>Interest in science</td>
<td>7-9</td>
</tr>
<tr>
<td>3</td>
<td>Personal connection to biodiversity</td>
<td>10-11</td>
</tr>
<tr>
<td>4</td>
<td>Activities that facilitate learning</td>
<td>12-19</td>
</tr>
<tr>
<td>5</td>
<td>Resources that facilitate learning</td>
<td>20-25</td>
</tr>
<tr>
<td>6- L1</td>
<td>Biodiversity-Evolution</td>
<td>26-28, 31, 35</td>
</tr>
<tr>
<td>6- L2</td>
<td>Genetic-ecosystem-species diversity</td>
<td>29, 30, 32, 34, 43,</td>
</tr>
<tr>
<td>6- L3</td>
<td>Plant structure-reproduction-growth</td>
<td>36-38, 41, 44, 49-51</td>
</tr>
<tr>
<td>6- L4</td>
<td>Goods and services from plants</td>
<td>39-40, 42, 48, 52</td>
</tr>
<tr>
<td>6- L5</td>
<td>Threats to plant biodiversity</td>
<td>33, 45, 53, 54</td>
</tr>
<tr>
<td>6- L6</td>
<td>Conservation issues</td>
<td>46, 47</td>
</tr>
<tr>
<td>7</td>
<td>CD-ROM as learning tool</td>
<td>55-61</td>
</tr>
<tr>
<td>8</td>
<td>Textbook as learning tool</td>
<td>62-68</td>
</tr>
<tr>
<td>9</td>
<td>Scientific aspects, skills and attitude to carry on</td>
<td>69-76</td>
</tr>
</tbody>
</table>

*Note. Clusters 7, 8, and 9 apply only to the postsurvey.*

Lesson One

This lesson consisted of a lecture on Chapter 18, *Seeking order amidst diversity*, (Audesirk, Audesirk & Byers, 2002). After discussion of the lecture notes, students in the textbook-only group ("textbook group" from hereon) completed two activities based on the textbook. These were designed to match the content of the CEB activities as closely as possible. Therefore, this activity was based on the information in Chapter 18, but it also required the students to browse
information about the number of species from other chapters in the textbook. Students in the textbook + CD-ROM group (“CD-ROM group” from hereon) completed two activities from the CEB CD-ROM. Lesson plan and objectives are in Appendix M. Examples of completed activities are included in Appendix N.

Other assessments for this lesson included the quiz and participants’ interviews with concept map co-construction. Students had a quiz on Chapter 18 in the class period after all lesson activities were completed. After the quiz and before the next lesson started, participants were interviewed and participated in concept map co-construction. Three evaluators corroborated the face validity of the quiz. In addition, one of these evaluators corroborated that the lecture and quiz reflected the objectives of the lesson. One of the evaluators found four of the questions in the quiz to be somewhat more difficult because they required interpretation. Participants were interviewed before and after the activities. Interview analysis is at the end of this section. Results and discussion of the activities follow. It was expected that lesson one as well as the corresponding activities would bring students to the first level of the PBLR, Darwin (see development of research question three in Chapter 6).

**Activity One** – In this activity, students explored the diversity of life in terms of the number of species. The activity considered two perspectives, the total number of known species and the individual contribution to diversity by the Domains Bacteria and Archaea, and the different kingdoms in domain Eukarya.

Questions two and four in this activity were analyzed for correctness and patterns observed. This analysis could provide a better insight into the students’ understanding about the concepts explored by these questions. Question two inquired about the total number of known species. In the textbook group, 99% of the participants answered correctly, stating 1.4 mi, the number provided in the textbook. Tanya was apparently confused with the number of species discovered
each year, 7-10 thousand, and wrongly stated the answer as 7-10 mi. In the CD-ROM group, 100% of the participants answered 1.6 mi, the number provided in the CD. Interestingly, at the time of the interview, 100% of the participants in the textbook group kept the 1.4 mi figure, although Tanya added a qualitative comment, “it is ___, I think.” In the CD-ROM group, 100% of the participants switch to the number given in lecture as part of the range discussed in lecture, 1.4 to 1.6 million species. Participants in both groups answered correctly, and there were no differences in their learning of the concept assessed in question two.

Question four assessed student understanding of the idea of how the total diversity of life is distributed among living organisms. It focused on how the number of plant species compared in relation to the number of species of other groups of organisms. Students were expected to make predictions based on their general knowledge and information obtained from the lecture. They would later corroborate their expectations by looking for the actual information in the textbook or by completing the “Described species” activity in the CEB (Activity 1, see Appendix N). Students were not expected to remember actual numbers but rather to remember the trend of which groups were more or less diverse. Table 5 provides a summary of the trends observed among student responses.

According to the information in the textbook (Chapter 18), “Of all the species that have been identified thus far, about 5% are prokaryotes and protists. An additional 22% are plants and fungi, and the rest are animals” (p. 358-359, Audersirk, Audersirk, & Byers, 2002). From this information and the pie chart presented in lecture, it was expected that students could deduct the following trend: A>> Pl and F>>> P and AB. In the textbook, it is also stated that the diversity of prokaryotes is largely understudied, and there could be many more. This might had led to confusion in the students.
Table 5
Patterns of Responses on the Trend of the Numbers of Species Contributed by Each Kingdom.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Prediction</th>
<th>After activity</th>
<th>Interview #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanya</td>
<td>P&gt;F&gt;Pl&gt;A</td>
<td>Pl&gt;F&gt;P = A</td>
<td>A&gt;Pl&gt;BA&gt;F = P</td>
</tr>
<tr>
<td>Thiab</td>
<td>P&gt;F&gt;Pl&gt;A</td>
<td>Pl&gt;A = Pr = F</td>
<td>BA&gt;A = Pl&gt;P&gt;F</td>
</tr>
<tr>
<td>Trevic</td>
<td>BA&gt;P&gt;Pl&gt;A</td>
<td>Pl&gt;BA&gt;P</td>
<td>BA&gt;Pl = A&gt;P&gt;F</td>
</tr>
<tr>
<td>Carla</td>
<td>A:birds&gt;insects&gt;roundworms&gt;fish</td>
<td>A:insects&gt;fish&gt;roundworms&gt;birds&gt;Pl</td>
<td>A:insects&gt;Pl&gt;BA&gt;P&gt;F</td>
</tr>
<tr>
<td>Caleb</td>
<td>A:(insects)&gt;BA&gt;P&gt;invertebrates</td>
<td>A:(insects)&gt;Pl&gt;P&gt;A(invertebrates)&gt;BA</td>
<td>A&gt;Pl&gt;P&gt;F&gt;BA</td>
</tr>
<tr>
<td>Cyrenec</td>
<td>A:(insects)&gt;BA&gt;Pl&gt;F</td>
<td>A:(insects)&gt;Pl&gt;flowering=others&gt;A:(fish&gt;birds)</td>
<td>A:insects&gt;Pl&gt;P&gt;BA&gt;F</td>
</tr>
</tbody>
</table>

Note. The responses include a prediction, the pattern obtained from the textbook or CEB CD-ROM, and what the participants stated at the time of the interview.

Note. BA indicates Archaea and Bacteria domains; P indicates kingdom Protista, F indicates kingdom Fungi, Pl indicates kingdom Plantae, A indicates kingdom Animalia, and Invert indicates invertebrates.

Both groups differed in their predictions about numbers of species following the lecture. Observing what the participants in the textbook group predicted, it seems that the pattern that Tanya and Thiab described followed the information gathered from the textbook’s chapters that discuss each group of organisms. In contrast, participants in the CD-ROM group seem to follow a mixture of the information presented in the textbook and the CEB CD-ROM. Carla only considered kinds of animals. Caleb and Cyrenec placed in first position animals, insect group, followed by Bacteria and Archaea as the second group with the most organisms.

After students had predicted which kingdoms were more or less diverse, students in the textbook group had to find out the number of species in the different groups using Chapters 19 through 22. Tanya wrote there were 50,000 species of animals, which only reflects the number of species of mollusks; however, she did not specify if it was her intention to include only this...
group. Thiab assigned a 40% to plants and then 20% each to Protistas, Fungi, and Animalia. Trevic did not find the number of animal species. By the second interview (post lesson and post quiz), 100% of the participants in the textbook group remained with their misconceptions about the number of species contributed by different groups of organisms. Tanya was the only participant able to place species of plants in the right trend compared to animals and the other groups. It is apparent the idea of the possibility of having more bacteria to identify still influenced her notion of the currently known species; other than that, her answer would have been correct. Although Thiab and Trevic placed plants correctly in a second position, for both of them there was an equal contribution of plant and animal species to the diversity of life. Thiab also seemed to be confusing the notions of “discovered” species vs. “to be discovered,” but she also recognized that the diversity of insects plays a major role in the diversity of the animal kingdom:

Thiab Bacteria and Archaea maybe make like half of all species, then animals because there are a lot of insects and more are added; there is also a lot plants.

The predictions of the participants in the CD-ROM group probably were influenced by the fact that the table in their worksheet was split, with a two-row table dedicated to plants only. Cyrenec was the only participant who included plants in the original prediction (see Table 5). All participants predicted animals to be the most diverse group. This could be explained both by remembering the fact from the textbook and the lecture, or by being influenced after listening to the introduction by E.O. Wilson and by seeing the long list of animals presented as part of the design of this activity in the CD-ROM. Appendix O shows CEB’s Described Species activity. All participants in the CD-ROM group revised their predictions correctly according to the information provided in the activity. By the second interview, all three participants in the CD-ROM group correctly placed plants as the second-most diverse group after animals, and two, Carla and Cyrenec, indicated insects represented a significant amount in the animal kingdom:
Carla There are a lot of animals, most insects, I thought there were more birds than there are, and insects totally freak me out, it’s gross there are so many!

Caleb kept in mind the numbers could change if more bacteria were discovered:

Caleb Animals have the most now, but bacteria may have the most if they are discovered - Plants, protists, and fungi come next, and few bacteria.

Overall, these findings suggest that participants in the CD-ROM group were able to gain a better understanding of the contributions of different groups of organisms to the diversity of life as compared to the textbook group. In particular, they shared knowledge of the contribution of the plant kingdom in relation to other groups of organisms, and some clearly recognized how the numbers could change (Caleb). Participants in the textbook group seemed to keep some of their misconceptions (see Appendix L, Tables L1-L6).

The open-ended questions for this activity were based on the “Further Thought” section of the CEB’s “Described Species” activity. In the program, E. O. Wilson asks the questions orally. These questions had the purpose of helping students establish a connection between the numbers of species they have observed and why they may be important in terms of their role. A simple valence analysis was applied by selecting a priori codes as described by Tashakkori and Teddlie (1998). The codes (themes) were based on seven major criteria according to the information presented in the chapters and CD-ROM, as well as the focus of the questions. They were used to categorize the responses as follows: NSPP, for number of species; EVOL, for evolution (adaptations, dominance, ancestors); ORGN, for examples of organisms in the category; ECOENE, for energy flow or mode of acquiring this (producers, food chain); ECOSERV, for shelter or part of a biogeochemical cycle; HARM, for whether it negatively impacts other organisms through disease or other interaction; and BENE, for human-oriented benefit obtained from the organism. Once all responses were coded, themes were tallied for all participants in
each group. The percent of responses in each category for each question was calculated using the responses in each category and the total number of responses for that question (see Table 6).

Table 6  
Importance of Different Organisms in the Ecosystem.

<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (n = 4)</th>
<th>CD-ROM (n = 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebrates</td>
<td>(10)</td>
<td>(5)</td>
</tr>
<tr>
<td>EVOL</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>ECOENE</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Flowering Plants</td>
<td>(n = 6)</td>
<td>(n = 3)</td>
</tr>
<tr>
<td>NSPP</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>EVOL</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>ECOENE</td>
<td>17% 33%</td>
<td></td>
</tr>
<tr>
<td>ECOSERV</td>
<td>17% 67%</td>
<td></td>
</tr>
<tr>
<td>Other groups (choice)</td>
<td>(n = 0)</td>
<td>(n = 2)</td>
</tr>
<tr>
<td>NSPP</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>ORGN</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>

Note. Percents represent times each theme was present in the participants’ responses. N = total number of responses per group; n = total number of responses per question (color-coded sections).

Note. NSPP - number of species; EVOL - evolution (adaptations, dominance, ancestors); ORGN – examples of organisms; ECOENE - energy flow or mode of acquiring this (producers, food chain); ECOSERV - shelter or part of a biogeochemical cycle.

The participants in the textbook group contributed 67% of all responses, which included seven different themes describing the importance of both vertebrates and flowering plants in the ecosystems. Their responses for the “Other groups” category were vague (Thiab and Trevic) or represented a misconception (Tanya):
Thiab    All of the groups of organisms are important to everyone; it is called biodiversity.
Tanya    They are all important. Remember our body is composed of bacteria. Our bodies are specialized to fight viruses.

In contrast, two of the CD-ROM participants’ responses to describe flowering plants and “other organisms” included only four themes. Responses for the role of the vertebrate group were either not provided (Carla) or too vague (Caleb and Cyrenec):

    Caleb   Mammals are far less important than I had anticipated.
    Cyrenec They stabilize ecosystems. Every species plays a role in the ecosystems.”

Several possibilities may explain the fewer responses in the CD-ROM group. For example, the participants may have been “looking” for a specific entry that indicated the role rather than inferring an answer from the information read for several organisms. Another reason could be the lack of specificity of the question. It seems Caleb interpreted the question in terms of the numbers of species rather than the role, and likewise, in his contribution stated above, the responses provided for flowering plants and other organisms were “not as important” and “very important.” It is important to note that although the CD-ROM group presented fewer themes in their responses, there were no misconceptions in these.

Both the textbook and CD-ROM groups had no answers at all for one of the groups of organisms (questions), although these were not the same. In the case of the textbook group, looking for information to answer the question about “other organisms” required browsing two different chapters in addition to the two they had already browsed. When the researcher inquired about this “no answer,” Trevic commented, “Ma’am, I looked over [it] but couldn’t find the answer for that one,” while Thiab said, “I remember it was a lot of work! I did not have time to go over everything.” The CD-ROM group had no answers for the “Vertebrates” question. To answer the question, they could have checked out five pages (“clicks” or computer screens) which covered the information on different groups of vertebrates. Similar to the textbook group
participants, when Carla and Cyrenec were asked during the interviews why they did not complete these questions, they said they couldn’t find the answer:

Carla I checked some groups, but it really didn’t say why [they are important]…. No, it was not in the information, in the section.

No further inquiry was done to find out why they could not infer the correct response; maybe it was due to lack of background. The researcher recognizes this issue could have been followed-up more during the interview, but she did not since the focus of the research was plant diversity and interview time was limited. However, the researcher suspects the lack of answer to these questions is due to the students’ expecting to read something that told them a direct statement “The importance of --- in the environment is ---.” These questions attempted to assess implicit rather than explicit or factual knowledge.

Both groups did describe flowering plants, the textbook group resulting in a higher number of themes than the CD-ROM group. This could be attributed to the amount of material to which students were exposed. Students in the CD-ROM group opened to a screen describing plants in general. They had the opportunity expand in their search of information by clicking on highlighted key words. However, no students were observed in the classroom doing so. In contrast, the textbook students had a 16-page chapter in which to look for information.

Figure 3 provides a summary of all themes over all questions for each group. The CD-ROM group had half the number of themes as compared to the textbook group, with two themes overlapping. This finding suggests that based on how students answered the questions referring to the importance of organisms in the ecosystems, those students in the textbook group performed better than students in the CD-ROM group did. Perhaps the interaction with other students in the class enhanced their responses, while the students in the CD-ROM group tended to work by themselves all the time.
Activity Two – The purpose of this activity was to have the students explore the characteristics of the organisms in the diversity of life. The activity consisted of both close-ended and open-ended questions. A simple valence analysis was used to look at the pattern of responses generated by participants in both groups considering all questions. In addition to those used for activity one, new codes were added to reflect basic themes of distinguishing characteristics of the organisms: CELL, for type of cell prokaryotic or eukaryotic; REPR, for type of reproduction; STRCT, for structure; and HAB, for habitat. Like with activity one, incorrect or vague propositions were not coded; only correct propositions were coded.

The participants in the CD-ROM group contributed a slight majority of total responses (56%). The main difference with the textbook group was in the themes describing Bacteria and Archaea, whereas the CD-ROM room had five more themes than the textbook group (see Table
For other categories of organisms (i.e., protists, fungi, plants, animals) some themes varied, but both groups tended to have the same number of themes.

<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (38)</th>
<th>CD-ROM (49)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria/Archaea</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL</td>
<td>40%</td>
<td>7%</td>
</tr>
<tr>
<td>HAB</td>
<td>40%</td>
<td>14%</td>
</tr>
<tr>
<td>STRCT</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>NSPP</td>
<td></td>
<td>14%</td>
</tr>
<tr>
<td>EVOL</td>
<td></td>
<td>7%</td>
</tr>
<tr>
<td>ECOENE</td>
<td></td>
<td>7%</td>
</tr>
<tr>
<td>HARM</td>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>BENE</td>
<td></td>
<td>7%</td>
</tr>
<tr>
<td><strong>Protista</strong> (n = 7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL</td>
<td>14%</td>
<td>38%</td>
</tr>
<tr>
<td>ORGN</td>
<td>43%</td>
<td>38%</td>
</tr>
<tr>
<td>ECOENE</td>
<td>43%</td>
<td>25%</td>
</tr>
<tr>
<td><strong>Fungi</strong> (n = 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CELL</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>REPROD</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>NSPP</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>ORGN</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>ECOENE</td>
<td></td>
<td>20%</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th></th>
<th>Plants</th>
<th></th>
<th>Animals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 7)</td>
<td>(n = 8)</td>
<td>(n = 9)</td>
<td>(n = 9)</td>
</tr>
<tr>
<td><strong>CELL</strong></td>
<td>29%</td>
<td>38%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td><strong>REPROD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NSPP</strong></td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EVOl</strong></td>
<td>29%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ORGN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ECOSERV</strong></td>
<td>13%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HARM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BENE</strong></td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** N = total number of responses per group; n = total number of responses per question (color-coded sections).

**Note.** Code meanings are NSPP - number of species; EVOL - evolution (adaptations, dominance, ancestors); ORGN – examples of organisms; ECOENE - energy flow or mode of acquiring this (producers, food chain); ECOSERV - shelter or part of a biogeochemical cycle;

(Note cont.)
HARM - impact on other organisms through disease or other interaction; BENE - human-oriented benefit obtained from the organism; CELL - type of cell prokaryotic or eukaryotic; REPR - type of reproduction STRCT - structure; HAB - habitat

Figure 4 provides the overall typology of themes from this activity. Notice the same number and kinds of themes are present. The two groups only vary in the proportion of responses that were coded in each category.

Figure 4. Typology of the Characteristics of Organisms in Different Kingdoms Based on All Responses for Lesson One, Activity Two. Note. See text for codes descriptions

When coding students responses, eight misconceptions were identified in how participants in the textbook group describe organisms. Tanya seems to confuse the concept of kind of cells with the concept number of cells. Both Tanya and Thiab did not have clear the kinds of cells that different organisms have:

Tanya Archaebacteria have prokaryotic cells and Eukaryotic cells.
Thiab  Protists have both eukaryotic and prokaryotic cells. 
[kind of cells] Plants have diploid cells.

Trevic’s activity revealed multiple misconceptions. He was confused about the organisms that belong to some of the domains, and apparently was confused with the concepts “prokaryote” and “protista”, and with the kinds of cells:

Trevic  Kingdom protista includes Bacteria and Archaea.
Eubacteria have full range of organelles and resemble the cells of multicellular organisms.
Eubacteria die easier than Archaebacteria.
Kingdom protista has fungi, plantae, and animalia cells.

The activity also revealed five misconceptions among the participants in the CD-ROM group. Like in the textbook group, some participants were confused with the kinds of cells that the different organisms have and the organisms included in different groups:

Carla  [Bacteria and Archaea] Have both prokaryotic and eukaryotic cells. 
Archaea can tell or show the effects of extreme environments we can’t get used to.
[Fungi] Did not know algae was classified as fungi. I thought it was grass-like.

Cyrenec  [Bacteria and Archaea type of cells] are Eukaryotes.

The researcher was able to verify with Carla that her second statement represented a confusion she had related to the information about lichens. These were discussed in the fungi section of the CEB CD-ROM. Another of Carla’s misconceptions caught the attention of the researcher while she walked around the classroom to monitor students’ progress in the activity, “Thought trees produced oxygen…not plants.” This misconception was addressed when she turned in the activity. The researcher asked the participant which organisms photosynthesize, to what she responded “Plants”. When asked if trees were plants, she assented. Then, Carla realized she meant protists.

When asked to reflect on the experience of these activities, all participants expressed they were benefited in some way. Interdependence of species was a predominant theme for both
groups. When plants were considered as a theme, it was present in the responses for two of the participants in the textbook group but for only one participant in the CD-ROM group. Responses in the textbook group varied from very specific to very broad:

Tanya    This [activity] help[ed] me know that there are different organisms - plants, animals, and fungi, that live in my surrounding. Many different species contribute to the life I live. As humans we would not survive without plants. [italics added]

Thiab    Brain power of mammals and development of the nervous system. There are different groups of plants. Plants reproduce in different ways. [italics added]

Trevic    All species require each other to survive.

Some of the responses from participants in the CD-ROM group included:

Carla    Gives insight into kingdoms. Leaning how fungi produces penicillin- antibiotic looking at pictures of so many different organisms- helps appreciate it more.

Caleb    Learned about plant reproduction and the different structures. Interesting looking at so many different kinds of organisms; there is so much more to know out there!

Cyrenec  Learning about bacteria that thrives in very extreme environments. Different species have different functions and all are important. There are so many different organisms- looking at the pictures.

When considering exploring the characteristics of the different organisms that make up the diversity of life, there were no substantial differences in what the students in the textbook and the students in the CD-ROM groups achieved in terms of understanding. Seems an advantage of having the CD-ROM in addition to the textbook in this case would be the easy access to the information.

**Classroom Observations** – The behavior of some students in the textbook group suggests they had anxiety or were somewhat upset. This could be possibly due to the need to find some of the information by browsing five chapters of their textbook. In fact, two male students (in a class of 11, with six females and 5 males) asked, “Where am I supposed to look for the answer?” One of the female students commented, “I thought we were in Chapter 18.” These comments in
class may be complaints about having to look for information in other chapters. It was also observed that Trevic looked for the information at a fast pace, whereas Tanya and particularly Thiab stayed longer in completing one question. Tanya remained very quiet and completed all the work by herself. There were four student-student interactions, where they shared where to look for the information or expressed confusion with what they needed to do. When this happened, the instructor intervened to repeat instructions or offer individual support.

Students in the group exposed to the CEB CD-ROM worked in the computer laboratory. This group worked in an activity that included a visual aid that consisted of an empty area in the screen representing the totality of known species and a list of groups of organisms. Students selected organisms by clicking on the list, and as a result, a colored rectangle with an area proportional to the number of species of that organism will appear on the screen. Students could then click on the colored area to gain additional information about that particular group of organisms. Students in the CD-ROM group worked mostly in isolation, and there were no student-student interactions. A possible explanation is the set-up of the laboratory where computers are housed in separate cubicles. Students were given directions on how to access the program’s section of interest. One male student (in a class of 6 males and 9 females) asked whether they had to do all groups of organisms or just what fit on the table in the worksheet. In addition, a female student inquired whether they had to read the information for all groups of organisms. It was also observed that Cyrenec attempted an additional activity where the number of known and expected species was compared for each group. Caleb completed the whole area, indicating he visited or tried all types of organisms found in the list.

Quiz #1, Chapter 18 – This quiz included factual questions and some application questions (see Appendix P). Three evaluators established face validity. All questions came from the material discussed in the textbook and lecture, and 12 of the 25 quiz questions were
reinforced through the material covered in the activities. Therefore, students in either class had the potential of performing at the same level. It was expected that any differences in student performance in this quiz could be attributed to the tool that was used for concept reinforcement, textbook and CD-ROM.

As indicated by the mean percent scores, class-wide and at the participant level, students in the CD-ROM group tended to perform better on the quiz than students in the textbook group (see Table 8). Although inferential statistics are to be used and interpreted with caution, due to the experimental design of this research, an independent samples $t$-test was performed (MS Excel®, 2003). Class-wide results suggest there is a statistically significant difference between the mean percent scores for the textbook group (58.0) and for the CD-ROM group (66.9) ($t = -2.684$, $p = 0.006$). The trend remains the same when considering the subset of participants. There is a statistically significant difference between the mean percent scores for the textbook group’s participants (57.0) and for the CD-ROM group’s participants (76.0) ($t = -4.427$, $p = 0.005$). This suggests it is likely to find higher quiz values for the participants in the CD-ROM group than in the textbook group.

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Results for Quiz #1 – Chapter 18.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class-wide</td>
</tr>
<tr>
<td></td>
<td>Textbook</td>
</tr>
<tr>
<td></td>
<td>58.0 ± 5.1</td>
</tr>
<tr>
<td></td>
<td>(10)</td>
</tr>
<tr>
<td>Participants</td>
<td>57.3 ± 2.3</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
</tr>
</tbody>
</table>

*Note.* Scores are expressed as the average of percent scores considering class as study unit and participants. Number of quizzes considered is given in parentheses.

**Concept Maps** – All students created a concept map at the start of the study unit. This map (CM1) reflected their understanding and familiarity with concepts before exposure to the study unit. Class-wide comparisons were done at the end of the study unit and are discussed later.
in this chapter. Following lesson one, the participants created a second concept map (CM2). Result for participants’ CM1 and CM2, as well as the learning gains are in Table 9; examples of concept maps are in Appendix Q. The total number of concepts used for map construction was the same for both concept maps. Because of the nature of the lessons, some concepts may vary. Therefore, the percent of old (previous map) and new (present lesson) concepts is provided.

### Table 9

<table>
<thead>
<tr>
<th>Group</th>
<th>Average Scores (mean ± SD)</th>
<th>Score Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CM1</td>
<td>CM2</td>
</tr>
<tr>
<td>Textbook (3)</td>
<td>39.1 ± 6.6</td>
<td>44.3 ± 12.9</td>
</tr>
<tr>
<td>CD-ROM (3)</td>
<td>50.3 ± 9.3</td>
<td>66.3 ± 6.4</td>
</tr>
<tr>
<td>TI # concepts</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>% old/% new</td>
<td>0/100</td>
<td>61/39</td>
</tr>
</tbody>
</table>

**Note.** Number of participants for each group is given in parentheses.

The average CM scores for the CD-ROM group tended to be higher than for the textbook group for both CM1 and CM2. A look at the spread of the values suggests that at the start of the study unit, the students in both groups were scoring in a similar range. There were no initial strong differences between the CD-ROM and textbook groups for the scores of CM1. After the first lesson, a look at the scores for CM2 suggests that the CD-ROM group’s average scores were, in fact, higher than the average scores for the textbook group. In addition, when the scores are compared over time within each group, both groups reflect a score gain from CM1 as compared to CM2. This suggests there was a learning gain after the students were exposed to the lesson, and this learning gain tended to be higher for the CD-ROM group as compared to the textbook group.
A check of the data reveals that for CM2, the factors that contributed most to the higher score of the CD-ROM group were the number of links, the hierarchical levels, and the cross-links (see Appendix Q). These are important components of concept maps, as they reflect the ability to integrate information and connect knowledge; therefore, the more of these, the higher the level of cognition. In contrast, both groups had a similar number of misconceptions. Concept maps represent the current cognitive structure of the student (Novak & Gowin, 1984). Therefore, it can be assumed that by the end of lesson one, the participants in the CD-ROM group were reflecting a higher level of cognition regarding basic concepts of biodiversity as compared to the participants in the textbook group. Since they all started at a similar level (i.e., similar concept map scores), it may be inferred that the CD-ROM as an instructional tool influenced their general understanding of biodiversity possibly resulting in learning gains.

Clinical Interviews – Each participant was interviewed before (preinstruction, interview #1) and after (postinstruction, interview #2) the first two activities. Protocols for each interview are in Appendix D. The purpose of the preinstruction interview (#1) was to establish the base level of knowledge the students had at the start of the study before they were exposed to the activities. Students were given the opportunity to look over the concept map constructed in class. The postinstruction interview (#2) was intended to reveal any learning gains as a result of the textbook-based and CEB-based activities to which they were exposed. A concept map co-construction session followed this interview. Appendix L, Tables L1-L6 show the concept propositional analysis results for the participants exposed to each intervention. The results for all participants across treatments are summarized in Table 10.

The total number of learning gains, examples, and learning losses was approximately the same for both the textbook and the CD-ROM groups. Learning gains are the result of two factors: incorrect propositions that were changed to correct ones (mc+) and new concepts that
Table 10
Results of Concept Propositional Analysis for Interviews #1 and #2.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Learning Gains</th>
<th>Examples</th>
<th>Learning Losses</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanya</td>
<td>mc+ + tl</td>
<td>T CD B L A G Other</td>
<td>tl mc- mc - tl mc0 0 tl</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 17 20 14</td>
<td>14 1 1 1 5 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiab</td>
<td>3 19 22 15 1</td>
<td>16 2 2 4 4 7 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trevic</td>
<td>3 18 21 14 2</td>
<td>16 1 1 1 3 3 4 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9 54 63 43 1 2 46 1 3 4 8 8 16 24</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Carla       | 5 15 20 1 7 6 | 14 3 3 3 3 6 |
| Caleb       | 7 18 25 1 14 5 | 20 4 4 4 1 2 |
| Cyrenec     | 5 18 23 1 11 4 1 | 17 |
| Total       | 17 51 68 3 32 15 0 0 1 0 51 0 0 7 7 7 4 8 |

Note. Values represent participants’ learning gains, examples contributed, and learning losses for pre- and postinstruction for lesson one.

Note. Codes are: mc+, incorrect proposition changed correctly; “+”, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- an correct proposition changed to incorrect; mc, changed from none or vague to incorrect; “-”, a correct proposition changed to none, vague, or correct proposition but not adequate to the instruction; tl, total. Examples: T, textbook; CD, CD-ROM; B, both CD and T; L, lecture; A, all, T+CD+L; G, general knowledge. Examples: T, textbook; CD, CD-ROM; B, both CD and T; L, lecture; A, all, T+CD+L; G, general knowledge; other: M*, use of a metaphor.
were acquired. Twenty-five percent of the learning gains for participants in the CD-ROM group were the result of restructuring their knowledge related to biodiversity, while participants in the textbook group had 14% of knowledge restructuring. The participants in the textbook group reflected a higher number of conceptions that did not change. Also, participants in the CD-ROM and textbook groups provided a similar number of examples. However, participants in the CD-ROM group drew the majority of these examples from the CEB CD-ROM.

Summary of Lesson One

Lesson one exposed students to basic biodiversity concepts, including the tree of life, hierarchy of classification, number of species, distribution of diversity among all living organisms, and basic characteristics of organisms. The performance of students in the activities regarding their learning about total number of species was similar for both groups. Differences were observed in how students were able to identify patterns in the contribution of different kingdoms to the diversity of life. Participants in the CD-ROM group were able to determine an accurate pattern while participants in the textbook group still had trouble doing so by the end of the lesson. Open ended questions in the activities revealed students in the textbook group used more themes, twice the number in some instances, in their description of species as compared to students in the CD-ROM group. Also, in the CD-ROM group, time was stated as a factor for some students not completing all the questions. However, this was not corroborated by the observations, as no students indicated this problem during the time they were working. For students working in the CD-ROM group, the researcher believes there was poor inferential reasoning, as the information was available even though the students stated it was not. The question were students were asked to describe how important a certain kind of organism was in the functioning of the ecosystem was not factual, but rather students needed to open several screens, read, and infer the answer. It seems students were not at that high a level of thinking at
that time. While students in the CD-ROM group had fewer themes, they also had fewer misconceptions. Though it is not clear whether they were able to clarify their meanings while the worked on the activities or if this correlated to the lower number of responses. Results from other activities supported the former premise.

The quizzes reflect that student in the CD-ROM group tended to perform at a higher level than students in the textbook group. This suggests the CD-ROM had a positive impact on the learning of students in the CD-ROM group. This was corroborated by how well the students did on the concept maps and later in the interviews. Both sources of data pointed to the CD-ROM group students being positively affected by the study unit. This suggests an effect of the instructional tool, the CEB CD-ROM, used to enhance their learning experience. Students in the CD-ROM group had higher knowledge structure and were able to negotiate their misconceptions, resulting in higher scores and higher learning gains as compared to the students in the textbook group.

An inspection of each participant’s propositions during the post-unit interview (Interview #2) and the second concept map, suggests both textbook participants and CD-ROM participants are in level one of the PBLR.

Lesson Two

This lesson consisted of the discussion of the essay “Why Preserve Biodiversity?” (Audersirk, Audersirk, & Byers, 2002). The essay presented a view of the different levels of biodiversity. Afterwards, both groups worked on activity three, which included questions and an essay. During this lesson, students also received a yellow sheet entitled “Golden list of species”, where they kept track of the plant species they encountered that captured their attention. The list was completed throughout the remainder of the study unit; therefore, discussion is reserved for end of this chapter. Participants were interviewed before (Interview #2) and after (Interview #3)
the activity. The lesson plan and objectives are in Appendix R. Experiencing lesson two and the activities designed to go along with it should allow students to reach the second level of the PBLR, Lovejoy (see development of research question three in Chapter 6).

**Activity Three and Essay** – The purpose of this activity was to expose students to a working definition of biodiversity that included all levels of diversity, species, ecosystems, and genetics, from a broad view. This allowed for students to recognize the need to conserve biodiversity. Students in the textbook group answered questions based on the essay. Students in the CD-ROM group explored the different topics in the CEB CD-ROM and answered questions. The questions in the activity for the textbook group were designed to match the topics covered by the questions in the CD-ROM. However, the information offered in the textbook was more concise than the information offered in the CD-ROM. After questions were completed, students in both groups wrote an essay about their reasons to conserve biodiversity. This essay was revisited at the end of the study unit. Examples of activity three and essay are in Appendix S.

A simple valence analysis was used to look at the pattern of themes in the responses generated by participants in both groups considering all questions. Some codes used for previous activities were not used here because they were not appropriate for the information presented in this lesson. In addition to the ones kept from lesson one, new codes were added to reflect the themes of lesson two: GENDIV, genetic diversity of organisms; GENMAN, reference to genetic manipulation; ECOINT, positive species interactions; ECODIV, ecosystem diversity; BENEMED, medicines or drugs; BENEMAT, raw materials; BENEFood, species as source of food for human consumption; BENECON, other economical benefits excluding those already coded for, and BENEChEM, species as source of other chemicals for human use. Of particular interest for this study is how students learned about plant biodiversity; therefore, PLANT was also used as a theme for this activity in order to account for any diversity-related responses that
were based on plants. As with previous activities, only correct propositions were coded; incorrect or vague propositions were not coded (see Table 11).

The total number of responses offered by participants in the CD-ROM group was higher than the total number offered by participants in the textbook group. When the different categories were considered (i.e., definition of biodiversity and the three levels of biodiversity) the percentage of themes in all categories was higher, 70%, as compared to the textbook group. This result was not unexpected. The quality of the material to which students were exposed was assumed to be the same, since it was from the same author (E.O. Wilson). However, the quantity of the material was different. Students in the textbook group read and discussed a one-page long essay. Students in the CD-ROM group had, in addition, the sections “What is Biodiversity?” and “Reasons for conservation,” where there were three specific sections discussing each level of biodiversity, each with three to four additional subsections for the students to read. During the interviews, the CD-ROM participants commented about this section:

Carla  I liked the picture of the hanging bridge when he [E.O. Wilson] was young…doing research, that was neat! And the videos.
Caleb  All the pictures…[it] is you know, kind of [like] you are there.
Cyrenec  Very well organized, lots of interesting information. Definitely a lot more than the book, that’s for sure! I wanted to keep reading. It made you think of things you never imagined.

The responses offered by participants varied in the number of plant examples included. The responses in the textbook group included 10 plant examples, while the CD-ROM group included four times that with a total of 43 plant examples. Some of the responses were:

Tanya  Crops may be benefited from the genes found in their wild relatives, scientists can get genes from a disease resistant wild corn in Mexico and use it to enhance the disease-resistance of corn or make it perennial. [Genetic level; coded as GENDIV, genetic diversity of organisms.]
Thiab  Plants support the diversity of the ecosystem because they are food to others. [Ecosystem level; coded as ECOSERV, Ecosystem service.]
Trevic  We get oxygen and medicines for cancer. [Species level; coded as BENEMED, benefits, medicines. Notice plant theme is implied and no specific reference was made to the plant name, even though it was in the text.]
Table 11
Reasons for Conserving Biodiversity, Considering Ecosystem, Species, and Genetics Levels.

<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (22)</th>
<th>Plants</th>
<th>CD-ROM (54)</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity</td>
<td>N = 3</td>
<td>n = 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSPP</td>
<td>33%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVOL</td>
<td></td>
<td></td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>ORGN</td>
<td>67%</td>
<td></td>
<td>40%</td>
<td>1</td>
</tr>
<tr>
<td>ECOINT</td>
<td></td>
<td></td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>GENDIV</td>
<td></td>
<td></td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Ecosystems</td>
<td>N = 6</td>
<td>n = 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAB</td>
<td></td>
<td></td>
<td>18%</td>
<td>3</td>
</tr>
<tr>
<td>ORGN</td>
<td>17%</td>
<td>1</td>
<td>18%</td>
<td>1</td>
</tr>
<tr>
<td>ECOSERV</td>
<td>33%</td>
<td>1</td>
<td>18%</td>
<td>2</td>
</tr>
<tr>
<td>ECOINT</td>
<td></td>
<td></td>
<td>18%</td>
<td>2</td>
</tr>
<tr>
<td>BENEFOD</td>
<td>50%</td>
<td>2</td>
<td>12%</td>
<td>1</td>
</tr>
<tr>
<td>BENEECON</td>
<td></td>
<td></td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>HARM</td>
<td></td>
<td></td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>N = 7</td>
<td>n = 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAB</td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORGN</td>
<td>29%</td>
<td>2</td>
<td>21%</td>
<td>3</td>
</tr>
<tr>
<td>ECOSERV</td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BENEFOD</td>
<td>21%</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>BENEMED</td>
<td>43%</td>
<td>2</td>
<td>21%</td>
<td>3</td>
</tr>
<tr>
<td>BENEMAT</td>
<td>14%</td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>N</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>BENECHEM</td>
<td>21%</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Genes</td>
<td>N = 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAB</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORGN</td>
<td>50%</td>
<td>2</td>
<td>17%</td>
</tr>
<tr>
<td>BENEFOD</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BENEMED</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HARM</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENDIV</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENMAN</td>
<td>33%</td>
<td></td>
<td>17%</td>
</tr>
</tbody>
</table>

Note. Percentages reflect time the category appeared in the participants’ responses for each definition/level.

Note. The number of responses including a plant example is under “Plants.”

Note. N = total number of responses per group; n = total number of responses per question (color-coded sections).

Note. Code meanings are NSPP - number of species; EVOL – evolution (adaptations, dominance, ancestors); ORGN – examples of organisms; ECOSERV - shelter or part of a biogeochemical cycle; HARM - impact on other organisms through disease or other interaction; HAB - habitat; GENDIV - genetic diversity organisms; GENMAN - reference to genetic manipulation; ECOINT - positive species interactions; BENEMED - medicines or drugs; BENEMAT - raw materials; BENEFOD - species as source of food for human consumption; BENECHEM - species as source of other chemicals for human use; PLANT - any diversity-related responses based on plants. BENECON - other economical benefits

Carla       Did not know the forest absorbed carbon dioxide… and forest trees help guard the forest floor from heavy rainfall. [Ecosystem level; coded as ECOSERV, Ecosystem service.]

Caleb       Rosy periwinkle gives us two anti-cancer drugs. [Species level; coded as BENEMED, benefits, medicines. This is an example that was also present in the textbook essay.]

Cyrenecc    After testing 6,273 varieties of rice for resistance to the grassy-stunt virus, only one species of rice can fight it off. Rice is one of the most important crops today in many nations. [Genetic level; coded as GENDIV, genetic diversity of organisms.]
There were three categories that included six responses from the participants in the CD-ROM group. These responses were examples present in both the essay from the textbook and the CEB CD-ROM. This finding suggests the participants did not lose from the information earned in the classroom from the textbook but actually added tremendously to it.

The overall typology of themes from this activity for both groups shows that participants in the CD-ROM group used approximately twice the number of themes in the responses (13) as compared to the textbook group (7) (see Figure 5). These results suggest the CD-ROM contributes a higher wealth of more varied information along the different levels of biodiversity for those students exposed to this instructional practice and teaching tool.

Figure 5. Typology of the Levels of Biodiversity Based on Responses for Lesson Two, Activity Three.

Note. See text for code descriptions
Considering the essay question was based on their personal reasons for conservation, it was treated separately and attitudinal categories were used to code the statements. Ten additional theme categories were used for the essay question. Seven of these were selected from Kellert’s attitudinal typologies, which originally applied to learning about animals, and the researcher adapted them to learning about biodiversity (Thompson & Mintzes, 2002). A brief description of these seven typology categories follows: NATURE, interest in experience with diversity and nature; ECOL, concern for the environment as a system, for interrelationships between wildlife species and natural habitats; HUMAN, interest in and affection towards biodiversity; MORAL, concern for the right treatment of biodiversity, with strong opposition to exploitation; SCIENT, interest in the physical attributes and biological characteristics of organisms, plants in particular; AESTHE, interest in artistic and symbolic characteristics of organisms, plants sin particular; and UTILIT, concern for the practical and material value of organisms, plants in particular, their parts and/or habitat. Kellert’s original DOMINIO category was adapted to RECRE, interest in biodiversity for recreational purposes; and original NEGATIVE was adapted to THREAT, including any reasons contrary to conservation, indifference or dangers to biodiversity. The tenth category added was PLANT to indicate any reference to plants in general present in the essay. Findings are summarized in Table 12.

The themes of ecology, moral, utilitarian, threats, and plant were present in the essays of both the textbook and the CD-ROM groups. The moral theme, exposing a concern for the right treatment of biodiversity, was only present in one essay in each the textbook group and the CD-ROM group:

Tanya We alter nature greatly by cutting down trees, building up farmlands, pollution and economical developments...[species] will continue to disappear if we keep contributing to hurting our ecosystem.
Cyrenec  Just because man thinks he has rights over everything in the world, doesn’t make it right or true. We should learn to conserve all life and resources on Earth. It is necessary for us (humans) to survive as well.

The nature theme was only present in the CD-ROM group:

Caleb  […] my love for the outdoors…when I go out to hunt or fish …I expect to see everything thriving.

Table 12. Personal Reasons for Conserving Biodiversity.

<table>
<thead>
<tr>
<th>Personal (essay)</th>
<th>Textbook (12)</th>
<th>CD-ROM (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATURE</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>ECOL</td>
<td>25%</td>
<td>23%</td>
</tr>
<tr>
<td>MORAL</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>SCIENT</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>AESTHE</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>UTILIT</td>
<td>25%</td>
<td>23%</td>
</tr>
<tr>
<td>THREAT</td>
<td>25%</td>
<td>8%</td>
</tr>
<tr>
<td>PLANT</td>
<td>17%</td>
<td>15%</td>
</tr>
</tbody>
</table>

*Note.* Percentages reflect time the theme appeared in the participants’ essays.  
*Note.* N = total number of responses per group.  
*Note.* NATURE - interest in experience with diversity and nature; ECOL - concern for the environment as a system and for interrelationships between wildlife species and natural habitats; MORAL - concern for the right treatment of biodiversity, with strong opposition to exploitation; AESTHE - interest in artistic and symbolic characteristics of organisms, plants in particular; UTILIT - concern for the practical and material value of organisms, plants in particular, their parts and/or habitat. THREAT - any reasons contrary to conservation, indifference or dangers to biodiversity; PLANT –indicates reference to plants.
It can be argued that this last response depends on the personal experience of the student, so those who are not outdoor persons would not write about this theme. However, the trigger or motivation for the student to write about it could come from experiencing the personal reasons given by E.O. Wilson in the CEB CD-ROM, which were accompanied by visuals showing him experiencing nature. Visual cues are an important component of learning and eliciting memories (Driscoll, 1994).

Clinical Interviews – During the second interview, participants were exposed to questions regarding the levels of biodiversity and these were re-visited at the beginning of interview three (see Appendix D). The objective of interview three was to reveal if there had been any learning gains associated with lesson two or if participants are building an understanding based upon previous concepts. Appendix L, Tables L7-L12, shows the results for the concept propositional analysis. A summary of learning gains, losses, and examples across all participants is provided in Table 13.

Participants in the CD-ROM group had about twice the total number of learning gains as compared to participants in the textbook group (see Table 13). These learning gains represented propositions which included examples that were exclusively from the textbook or from CD-ROM, or examples that were present in both textbook and CD-ROM. Compared to participants in the textbook group, the participants in the CD-ROM group used less textbook examples. This suggests the information in the CD-ROM is not substituting that of the textbook but rather is providing perhaps a broader pool of information from where concepts can be accessed.

Some of the learning gains experienced by participants from both groups were incorrect propositions that were corrected. There was almost no difference in the number of misconceptions between participants in the textbook and CD-ROM groups. Some participants in
Table 13.
Results of Concept Propositional Analysis for Interviews #2 and #3.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Learning Gains</th>
<th>Examples</th>
<th>Learning Losses</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mc+</td>
<td>Tl</td>
<td>T</td>
<td>CD</td>
</tr>
<tr>
<td>Tanya</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Thiab</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Trevic</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>13</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Carla</td>
<td>1</td>
<td>12</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Caleb</td>
<td>14</td>
<td>14</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Cyrenec</td>
<td>1</td>
<td>15</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>41</td>
<td>43</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Values represent participants’ learning gains, examples contributed, and learning losses for pre- and postinstruction for lesson two.

Note: Codes are: **mc+**, incorrect proposition changed correctly; “+”, from none, vague, or no examples to correct and/or more specific; **mc0**, an incorrect proposition that remained incorrect; **0**, proposition remained correct, or an incorrect was lost; **mc-** an correct proposition changed to incorrect; **mc**, changed from none or vague to incorrect; “-”, a correct proposition changed to none, vague, or correct proposition but not adequate to the instruction; **Tl**, total. Examples: **T**, textbook; **CD**, CD-ROM; **B**, both CD and T; **L**, lecture; **A**, all, T+CD+L; **G**, general knowledge. Examples: **T**, textbook; **CD**, CD-ROM; **B**, both CD and T; **L**, lecture; **A**, all, T+CD+L; **G**, general knowledge; **other**: **M***, use of a metaphor.
each group were able to negotiate their understanding of levels of biodiversity, as seen in the following examples, where the participants develop an understanding of the ecosystem level of biodiversity:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Levels of biodiversity: ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiab:</td>
<td></td>
</tr>
<tr>
<td>Preinstruction</td>
<td>Evolution, reproduction, and extinction …or, should that be the domains and kingdoms, and family, species?</td>
</tr>
<tr>
<td>Postinstruction</td>
<td>Different plants make the ecosystem and provide food for the animals. [ecosystem function]</td>
</tr>
<tr>
<td>Cyrenec:</td>
<td></td>
</tr>
<tr>
<td>Preinstruction</td>
<td>The different groups of organization, domains, kingdoms, phylum, class, order, family, genus, species.</td>
</tr>
<tr>
<td>Postinstruction</td>
<td>Ecosystems – wetlands and rain forest, and cultivated lands. [Diversity of ecosystems]</td>
</tr>
</tbody>
</table>

It was noticed that during the interviews, sometimes participants from both groups were not consistent in their reasons about conservation or what they considered causes and consequences for the conservation concept. Additionally, some participants made more propositions before than after the lesson activities. Even when correct preinstruction propositions were stated, they were not revisited or mentioned again in the post interview at all; these are identified as “learning losses.” The participants in the CD-ROM group had slightly more of these losses (8) as compared to the participants in the textbook group (6). These losses were an unexpected outcome. The failure to determine the cause for these losses is a weakness during the interview process of the research, which was caused by the researcher not having at hand a transcript of the previous interview. Several reasons could be possible for these losses. It could be information committed to short-term memory; therefore the participants forgot the original statements, or these could have been just casual comments that did not come from deep thought. Another possibility is that once the participants were exposed to the study unit, the instruction organized their way of thinking, and since they were trying to remember and go by what was covered in
that specific lesson, they therefore imposed “self-limits” to what they could answer. Their answers also might be dependant upon schemata formed as they are exposed to the information in the class activity, and afterwards they wanted their responses fit to that schema (Driscoll, 1994). When it did not fit, they discarded it.

Summary of Lesson Two

The findings for lesson two suggest that student learning of biodiversity and the concepts associated with ecosystems, species, and genetics levels is enhanced by the use of the CEB CD-ROM. The number of plant-related responses in the CD-ROM group was four times that of the textbook group, suggesting the use of CEB CD-ROM and textbook likely enhances learning of plant-biodiversity as compared to the use of the textbook only. As indicated earlier, the larger quantity of material to which participants in the CD-ROM group were exposed is likely a factor in the difference observed in the higher number of responses and the wider variety of themes as compared to the textbook group. The CD-ROM allowed the students to be exposed to multiple examples both in more in-depth and detailed material. The information was well organized in sections and included images and videos.

The participants’ essays revolved around the same themes. This suggests that both instructional tools had a similar effect in what appeals to the personal level to the student. In only a couple of instances, they were different.

After examining each participant’s propositions during the post-unit interview (Interview #3), the researcher determined that by the end of lesson two, Tanya and Thiab were at level 2 while Trevic remained at level 1. All participants in the CD-ROM group were at PBLR level 2.

Lesson Three

This lesson consisted of lecture on Chapter 21, *The Plant Kingdom* and the essay “Plants Help Regulate the Distribution of Water” (Audesirk, Audesirk, & Byers, 2002). After the lecture,
both groups worked on activity number four. The learning of the plant kingdom was assessed class-wide with quiz #2 in the class period after the activities were completed.

Participants were interviewed before (Interview #3) and after (Interview #4) the lesson. Participants worked on concept map #3 during the postlesson interview. Experiencing lesson three and the activity was expected to help students reach level three of the PBLR. The lesson plan and objectives are in Appendix T.

**Activity Four** – The purpose of this activity was to help students explore the diversity of the plant kingdom from an evolutionary perspective. Students were exposed to basic characteristics, functions, and the life cycle of plants in each phylum. During the lecture, students had a hands-on experience where they were exposed to live or preserved samples of all phyla.

The questions in the activity for the textbook group were designed to match those in the activity from the CEB CD-ROM in terms of topics or concepts addressed (see examples in Appendix U). In contrast to the material in lesson two, the amount information offered in the textbook regarding basic characteristics and the life cycle for plant phyla was more detailed than the information offered in the CD-ROM. However, for vascular plants, the information in the CD-ROM was more extensive as it included descriptions of families and specific examples. Appendix V shows an example screen from CEB’s Plant Kingdom’s families. To balance this difference, students in the textbook group were offered alternative book-based plant references in the classroom (Balick & Cox, 1996; Musgrave, Gardner, & Musgrave, 1999; Vaughan & Geissler, 1999).

A simple valence analysis was done, as described earlier, using the same *a priori* codes used for previous activities. New codes were added based on the themes presented in the textbook for Chapter 21 and the information provided in the CEB CD-ROM: GROW, for mode of growth (herb, tree, shrub, vine), including evergreen vs. deciduous and TAX, for any group-
related theme (i.e., flowering plants). All codes were considered as the activity was analyzed, and once analysis was done, codes that were not used were eliminated from the results table (see Table 14). As with previous activities, only correct responses were coded.

Participants in both groups contributed approximately the same number of responses over all groups of questions (see Table 14). The higher number of responses in the textbook group for the characteristics of the plant kingdom and vascular plants was expected due to the larger amount of material in the textbook as compared to the CD-ROM. The ECOENE theme appeared in most of the responses for unique characteristics of the plant kingdom for both groups. This suggests the notion of the role of plants in energy flow or mode of acquiring energy was not only present in both instructional tools (textbook and CEB CD-ROM) but was also considered important by participants in both groups. Some example statements exposed how the participants responded to the question, “List some of the unique characteristics of the plant kingdom”:

- Tanya  Plants photosynthesize.
- Thiab  Plants get carbon dioxide and sun to photosynthesize.
- Trevic  They do photosynthesis, get energy from sun.
- Caleb  Plants are responsible for most of the transfer of sun’s light energy into energy we can use.
- Cyrenec  Turn the sun’s energy to food and fuel and produces oxygen.

Photosynthesis as an energy process was not a concept covered in this course, but these responses reflect different levels of processing. While the responses coming from the participants in the textbook group seem to be more limited to mentioning the process and what is needed for it, the responses of the participants CD-ROM group avoid the concept word but explain what the outcome is, or maybe the ecological or functional purpose, of that process. This suggests there are differences in the source of information. Information about a concept may be present, but how it is presented to the students may make a difference in their understanding. Avoiding the
Table 14
Characteristics of the Plant kingdom and Major Phyla.

<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (53)</th>
<th>CD-ROM (55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique characteristics of Plant Kingdom</td>
<td>n = 9</td>
<td>n = 7</td>
</tr>
<tr>
<td>EVOL</td>
<td></td>
<td>14%</td>
</tr>
<tr>
<td>ECOENE</td>
<td>33%</td>
<td>29%</td>
</tr>
<tr>
<td>CELL</td>
<td>22%</td>
<td>14%</td>
</tr>
<tr>
<td>REPR</td>
<td>22%</td>
<td>14%</td>
</tr>
<tr>
<td>HAB</td>
<td>22%</td>
<td>14%</td>
</tr>
<tr>
<td>GROW</td>
<td></td>
<td>14%</td>
</tr>
<tr>
<td>Practical connection</td>
<td>n = 9</td>
<td>n = 4</td>
</tr>
<tr>
<td>ORGN</td>
<td>44%</td>
<td>25%</td>
</tr>
<tr>
<td>ECOENE</td>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>HAB</td>
<td>22%</td>
<td>50%</td>
</tr>
<tr>
<td>TAX</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Vascular plants</td>
<td>n = 14</td>
<td>n = 7</td>
</tr>
<tr>
<td>EVOL</td>
<td>7%</td>
<td>14%</td>
</tr>
<tr>
<td>ORGN</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>REPR</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>STRCT</td>
<td>43%</td>
<td>43%</td>
</tr>
<tr>
<td>GROW</td>
<td>7%</td>
<td>14%</td>
</tr>
<tr>
<td>TAX</td>
<td>7%</td>
<td>29%</td>
</tr>
<tr>
<td>Category</td>
<td>Gymnosperms n = 13</td>
<td>Gymnosperms n = 14</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>NSPP</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>EVOL</td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td>REPR</td>
<td>85%</td>
<td>38%</td>
</tr>
<tr>
<td>STRCT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAB</td>
<td></td>
<td>23%</td>
</tr>
<tr>
<td>GROW</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>TAX</td>
<td></td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Angiosperms n = 25</th>
<th>Angiosperms n = 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSPP</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>ORGN</td>
<td>20%</td>
<td>18%</td>
</tr>
<tr>
<td>ECOENE</td>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>HARM</td>
<td></td>
<td>4%</td>
</tr>
<tr>
<td>REPR</td>
<td>24%</td>
<td>6%</td>
</tr>
<tr>
<td>STRCT</td>
<td>12%</td>
<td>8%</td>
</tr>
<tr>
<td>HAB</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>ECOINT</td>
<td>16%</td>
<td>6%</td>
</tr>
<tr>
<td>BENEMED</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>BENEMAT</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>BENEFood</td>
<td>4%</td>
<td>14%</td>
</tr>
<tr>
<td>BENEChem</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>GROW</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>TAX</td>
<td>4%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Note. Percentages reflect time the category appeared in the participants’ responses for each (Note continued)
group of questions (indicated by color shaded area). N = total number of responses per group; n = total number of responses per question (color-coded sections).

Note. Code meanings are NSPP - number of species; EVOL - evolution (adaptations, dominance, ancestors); ORGN – examples of organisms; ECOENE - energy flow or mode of acquiring this (producers, food chain); HARM - impact on other organisms through disease or other interaction; CELL - type of cell prokaryotic or eukaryotic; REPR - type of reproduction; STRCT - structure; HAB – habitat; ECOINT - positive species interactions; BENEMED - medicines or drugs; BENEMAT - raw materials; BENEFOD - species as source of food for human consumption; BENECHEM – species as source of other chemicals for human use; GROW - mode of growth (herb, tree, shrub, vine), evergreen vs. deciduous; TAX, for group-related reference (i.e., flowering plants)

jargon may make the concept clearer to students who are at early stages. While “photosynthesis” may be a “black box” to some students - i.e., the student may or may not know what that involves- “turning the sun’s energy to food” can possibly tell that student more. If this is true, then it would be interesting to pursue research into whether the CD-ROM as a learning tool might facilitate the understanding of selected difficult concepts. It would be interesting to follow what the student actually understands by photosynthesis through more in-depth questioning or perhaps a think aloud protocol. The researcher considers it may be of interest following up with a content analysis of the plant-related concepts and comparing how these are addressed in the CD-ROM versus textbook, something that was outside of the scope of this research.

The practical connection section reflects the textbook group had about twice the number of responses as compared to the CD-ROM group. This question was a practical application of the concept of epiphytic plants discussed in the lecture and the misconceptions we can get from the
common names of plants. As mosses were discussed in lecture, students were informed about the
difference between mosses and the Louisiana plant, *Thilandsia spp.*, called Spanish moss. They
also were exposed to live material of both. In addition, the epiphytic growth habit was discussed
and differentiated from a parasitic plant. The activities for the textbook and CD-ROM group
included a question asking: 1) What kind of plant was in the picture [The researcher explained in
class that “kind” refer to which group or phyla that plant belongs.]; 2) Is the plant a parasite?;
and 3) To which Louisiana plant may it be similar? The textbook participants looked at an orchid
figure in the book. All other plants in other figures were flowering plants with some adaptations.
The CD-ROM group looked at a bromeliad in the first screen of the plant section. In the textbook
group, all students recognized the orchid as a flowering plant similar to Spanish moss. However,
regarding the growth habit (HAB), this set of questions revealed a misconception about growth
habits. Students still associated growing on a tree and being a parasite:

- **Tanya**  Maybe?
- **Thiab**  Is a parasite because is living on a tree. [then she revised her own answer]
  But…if it is like the Spanish moss, then it is not.
- **Trevic**  Yes, it’s growing on the tree.

The participants in the CD-ROM group showed different misconceptions. They recognized it is
not a parasite and is similar to Spanish moss. However, they attributed other incorrect
characteristics to it:

- **Carla**  Non-vascular. Similar to ferns.
- **Caleb**  Bryophyte, non-vascular plant.
- **Cyrenec**  Non-vascular, lives from the tree, similar to ferns.

It is possible students were confused because in the place on the CD-ROM where the bromeliad
figure was, the screen had information about bryophytes. Thus, maybe students were guided (or
mis-guided) by the text rather than by applying (transferring) the concept they were exposed to
in class. It is important, though, to make note that this set of “application questions” was
researcher-created and not part of the CD-ROM or textbook; students used either one just as visual support for the questions.

Regarding vascular plants, the textbook group had twice the number of responses as compared to the CD-ROM group. Both groups treated the STRCT theme, referring to structural characteristics excluding reproductive, equally. The themes REPR and ORGN were not present in the responses by the CD-ROM group’s participants, perhaps because the reproduction information was limited or not available in the CD-ROM. However, Chapter 21 in the textbook described the reproductive cycle of one sample organism for each phyla.

The trends observed for the gymnosperms and angiosperms were different from the patterns observed so far. Although both groups had similar number of responses for gymnosperms, the responses from the CD-ROM group had a broader variety of themes than the responses from the textbook group. An influence of the visual information vs. textual information is seen here. Although both instructional tools had similar information, the textbook information about gymnosperms is dominated by a diagram of the pine reproductive cycle, while most of the other information is in the text. In contrast, in the CD-ROM, there is less text, no information about reproduction, and more images, some of which are very similar to some of the figures in the textbook. The results observed for the angiosperm were expected, since the CD-ROM provides plenty of information about the vascular plant families. Students were asked to explore three flowering plant families and share the information with a partner. Again, the trend of a higher number of responses with a reproduction theme was observed in the textbook group, while the CD-ROM group had a broader variety of themes. This open-ended question allowed students to follow an individual guided-inquiry and share their learning with a classmate. This also allowed the students to explore in a short period of time a minimum of three to six different plant families, since they shared with a partner, and to be exposed to information about a few
species of each of these families. Participants provided a brief description of the family and a fact that attracted their interest; some of these facts are exposed here:

- **Carla**: Food plants in the Asteracea include lettuce, artichoke, and sunflower. Used for minor sources of rubber and medicines. [partnered with Cyrenec]
- **Caleb**: Anacardiaceae has the same type of resin in poison ivy is present in mangos and cashews. [partnered with another male student]
- **Cyrenec**: Poacea or Gramminea [which shows] co-evolution with grazing animals. Provides major crops, alcoholic beverage ingredients, paper, building supplies, essential oils, ornamental plantings.

In the textbook group, students were encouraged to browse plant-related chapters in the textbook and look for plant examples that would offer them a broader view of the flowering plants. In addition, field guides and other plant-related books were made available in the classroom for students to use. However, students tended to limit their searches to places or examples they already had been exposed to in this lesson’s lecture or in a previous lesson. Students did not even “wander off” to other plant chapters or browse their textbook or any of the other available sources. This possibly explains their responses being more limited in themes and number:

- **Question**: Are all flowering plants alike? Using your textbook and additional references, explore characteristics and what grabs your attention to different plants. Provide some examples to support your answer. Provide reference.
- **Tanya**: You have monocots and dicots. [proceeded with explaining structural differences]…some flowers are smart in the way they dump pollen on bees [referring to lupines example]; long red flowers that attract hummingbirds in the tropics.
- **Thiab**: Differences in size, like duckweeds and eucalyptus. Some live on trees, like the Spanish moss [class, not textbook example], but others live on the ground, or water [lilies, lecture and on-campus example]. Different plants produce many things like spearmint, spices, nicotine, caffeine, which are things we use.
- **Trevic**: Different kinds of flowers attract different pollinators. Plants provide hummingbirds with nectar, and the hummingbirds get the pollen.

Regarding the flowering plants, the CD-ROM allowed students to be exposed to a broader view of the plant kingdom, beyond what is offered in the textbook. This potentially stimulated them to ask questions, which was the next step to which they were directed in the classroom.
Overall, responses from the CD-ROM group had more (16) different themes as compared to the responses from the textbook group (12) (see Figure 6).

Figure 6. Typology of the Characteristics of the Plant Kingdom Based on Responses for Lesson Three, Activity Four.

*Note.* See text for code descriptions.

**Classroom Observations** – The lecture proceeded more actively than previous ones. Students were attentive to the materials coming out of the researcher’s bucket full of live material and demonstration box. There were comments like:

- **Student** Never thought that was a plant! [sample of real moss] (female, textbook group)
- **Trevic** This thing has flowers! [referring to a sample of Spanish moss]
- **Carla** I don’t want to touch that... it’s going to make me itchy! [sample of real moss]

These comments point to the unawareness, or plant blindness, with which students reach college biology classes and the importance of experiences in their course to make them aware of the plants they interact with everyday.
During the activities, students in the textbook group used Chapter 21 and figures in other chapters to give them the closest experience to what the CD-ROM group was experiencing with the CEB CD-ROM. Students in the textbook group seemed to be not as upset as the first time they were required to use other chapters to complete the activity. As students in the textbook group completed the activity, there were student-student interactions. In both groups the researcher had to clarify what was expected with the application question “kind” of plant, meaning to which phyla it belonged, suggesting the wording of this question should be revised before using the activity again. Before, students in the CD-ROM group worked independently, but this time the activity called for interacting with a partner; therefore, there were more student-student interactions. One student still decided to complete the work by himself.

Quiz #2, Chapter 21 – This quiz included factual questions and some application questions (see Appendix W). Three evaluators established face validity of the quiz. All questions came from the material discussed in the textbook and lecture, and 12 of the 25 quiz questions were reinforced through the material covered in the activities. In addition, some questions were based on figures that were projected during the test. This allowed some questions to be in an environment as close as possible to the lecture environment. As with the first quiz, students in either group had the potential of performing at the same level. Differences in performance could be attributed to the tool that was used for concept reinforcement, the textbook and the CD-ROM.

Class-wide and at the participant level, students in the CD-ROM group tended to perform better on the quiz than students in the textbook group did as indicated by the mean percent scores (see Table 15). Although inferential statistics are to be used and interpreted with caution, due to the experimental design of this research, an independent samples \( t \)-test was performed (MS Excel \( \text{\textregistered} \), 2003). Class-wide results suggest there is no statistically significant difference between the mean percent scores for the textbook group (58.0) and for the CD-ROM group (66.1) \( (t = -1.373, \text{...} \)
p = 0.091). The trend remains the same when considering the subset of participants. There is no statistically significant difference between the mean percent scores for the textbook group’s participants (63.3) and for the CD-ROM group’s participants (66.0) (t = -0.917, p = 0.205).

These findings suggest that the use of the CEB CD-ROM had a slight effect on student learning about characteristics of plants and the different phyla of the plant groups. This could have positively affected the student’s quiz scores. The subtle tendency for a difference between the textbook and the CD-ROM groups could be attributed to the exposure of the CD-ROM students to other themes that allowed them to experience different perspectives about plants, in addition to their exposure to the same material as the students in the textbook group. Caleb achieved the highest score (70), and was the only one with a “passing” score. Cyrenec and Thiab followed with a score of 66. The lower end scores were shared by the textbook and the CD-ROM groups in the following order: Tanya (64), Carla (62), and Trevic (60). Looking at the range of scores, the differences are small. Alternatively, the difference in scores between participants in the CD-ROM and the textbook groups could be attributed to other factors such as students preparing better for the test or merely being better test takers.

**Clinical Interviews** – Participants were interviewed after quiz #2. This interview was compared to interview #3 with the purpose of revealing any learning gains as a result of lesson
three. The interview protocol is in Appendix D; Appendix L, Tables L13-L18 shows the concept proposition analysis. The examples provided by the participants along with their propositions were identified according to the source: textbook, CD-ROM, both of these, lecture, all (lecture + textbook + CD-ROM), and general knowledge. Table 16 presents a summary of the results for participants across treatments.

The total number of learning gains and examples was slightly higher in the CD-ROM group than in the textbook group. Cyrenec showed the highest number of gains of all participants. Regarding unique plant characteristics, Tanya and Trevic appear to lose the misconception of plant movement; both had stated “can’t move” in Interview #3 but did not re-state this in Interview #4. In Chapter 18, plants are actually described as not having movement. However, in the lecture when the general characteristics of the kingdom were discussed, the argument was presented and it was explained that plants move at a scale different from ours and by changing the size of cells rather than by muscular contraction. In addition, translocation is possible with help. Thiab retained her misconception in this regard: “They don’t move.” Tanya showed another misconception in relation to general plant characteristics, stating, “they give us water.” In explaining this statement during the interview process, she seemed confused, probably from the essay read in class. When the researcher asked, “Can you tell more about why or how plants give us water?,” although she did not seem to be quite sure of what she was saying, she proceeded to answer: “Through photosynthesis, and they affect then the cycle of water…produce water vapor, and take more water from the soil.” The previous semester, Tanya had taken the other introductory biology course. She knew about the use of carbon dioxide, water, and sunlight, but here she was confused with the outcomes of photosynthesis. Since photosynthesis was not the main topic of this research, nor she would encounter textbook material in the
Table 16
Results of Concept Propositional Analysis for Interviews #3 and #4.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Learning Gains</th>
<th>Examples</th>
<th>Learning Losses</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mc+  +  tl</td>
<td>T  CD  B  L  A  G  Other</td>
<td>mc-  mc  -  tl</td>
<td>mc0  0  tl</td>
</tr>
<tr>
<td>Tanya</td>
<td>1  24  25</td>
<td>4  2  1</td>
<td>7  1  2  3</td>
<td>2  2</td>
</tr>
<tr>
<td>Thiab</td>
<td>1  19  20</td>
<td>7  1  1</td>
<td>9  1  1  1  1</td>
<td>2</td>
</tr>
<tr>
<td>Trevic</td>
<td>21  21</td>
<td>3</td>
<td>3  3  3  3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2  64  66</td>
<td>14  3  2  1  19</td>
<td>6  7  1  6  7</td>
<td></td>
</tr>
<tr>
<td>Carla</td>
<td>1  21  22</td>
<td>1  6  2</td>
<td>9  2  2</td>
<td></td>
</tr>
<tr>
<td>Caleb</td>
<td>21  21</td>
<td>4  2  2</td>
<td>M*  9  4  4  1  4  5</td>
<td></td>
</tr>
<tr>
<td>Cyrenec</td>
<td>27  27</td>
<td>6  3  1</td>
<td>2M* 12</td>
<td>2  2</td>
</tr>
<tr>
<td>Total</td>
<td>1  69  70</td>
<td>1  16  7  1  2  3  30</td>
<td>6  6  1  6  7</td>
<td></td>
</tr>
</tbody>
</table>

Note. Values represent participants’ learning gains, examples contributed, and learning losses for pre- and postinstruction for lesson three.

Note. Codes are: mc+, incorrect proposition changed correctly; “+”, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- an correct proposition changed to incorrect; mc, changed from none or vague to incorrect; “-”, a correct proposition changed to none, vague, or correct proposition but not adequate to the instruction; tl, total. Examples: T, textbook; CD, CD-ROM; B, both CD and T; L, lecture; A, all, T+CD+L; G, general knowledge. Examples: T, textbook; CD, CD-ROM; B, both CD and T; L, lecture; A, all, T+CD+L; G, general knowledge; other: M*, use of a metaphor.
upcoming lessons that would help her remediate the misconception, the researcher helped her clarify it after the interview was over.

Regarding the evolution of the plant kingdom, Tanya, Thiab, and Carla were able to modify their conceptions through the lesson. They ended up correctly identifying green algae as the possible common ancestor for the plant kingdom. The researcher acknowledges evolution in structures was not followed-up as a theme under evolution (i.e., change from rhizoids to roots and from no stems to true leaves and stems) in as much detail as changes in reproductive structures. The main reason was not much emphasis was given to this aspect in either instructional tool.

Participants from both groups used different sources of examples during the interviews. During the interviews participants in the textbook group provided examples mainly from the textbook and a few examples from the lecture or general knowledge in support for their statements. In contrast, participants in the CD-ROM group used examples mainly from the CD-ROM, followed by examples that were both from the CD-ROM and the textbook or present in all sources, and then followed by just a few examples that were from the lecture only. Interestingly, Caleb and Cyrenec used metaphors as examples:

**Caleb**
Ferns are like a middle class plant; they are vascular but seedless.

**Cyrenec**
They [plants] function like a bridge with the sun for all organisms. Many [plants] have roots for absorption and vessels that are like a circulatory system with no need for pumps, and that support upright growth.

It is important to note that for the basic plant characteristics, the researcher did not distinguish examples as from the textbook or from the CD-ROM because both sources presented very similar information and it was not possible to discern the source. For all other questions, if the participants used an example, the source was determined according to the example and the treatment they were exposed to. It was observed throughout the interview process, that the majority of the participants tended to limit or restrict their responses after being exposed to the
lesson. They wanted to recall what they were exposed to in the lesson but had not “matured” in the sense that instead of building upon correct statements that usually came from their general knowledge and possibly making them more complete, these statements were just discarded or substituted (learning losses, “-”). It almost gives the impression that “what I know” and “what I know for class” are two different things, which can run the risk of making “what is known for class” just stay there. In other words, if learning is taking place, it is not being transferred to other scenarios other than the classroom. Alternatively, the original statements may not really form part of their knowledge; they could have been mere guesses, which would then make it likely the participants would not remember them the second time. In other words, the information could just be committed to short-term memory, and is not learned in a meaningful way. For examples, there were some participants’ statements during Interview #3, in reference to the role of plants in the ecosystems or the use of plants that were not re-visited in Interview #4:

- **Tanya** [Plants]Give off carbon dioxide when they are burned causing pollution. [role in Ecosystem – part of biogeochemical cycle]
  Aloe Vera that has medicinal use, but others like marihuana, is not good. [Uses of plants]
- **Thiab** Make oxygen for us to breathe. [role in ecosystem]
- **Trevic** People in other countries use trees to build their houses and plants to weave baskets, some make their garments out of leaves. [Uses of plants]
- **Carla** Shelter. [role in ecosystem]
- **Caleb** Some serve to control erosion. [role in ecosystem]

The researcher failed to have a transcript of the previous interview (Interview #3), which could have helped in assessing these losses *in situ* and then trying to find out from the participant what was going on. This opens an area to explore and be aware of in a future study.

**Concept Maps** – Following lesson three and the clinical interviews, participants created a third concept map (CM3) (see examples in Appendix X). This concept map was based on 26 concepts, three more concepts than previous maps. Of the 26 concepts, six were new concepts, which were added to account for the topics presented in the current lesson; 9 concepts had been
repeated once (i.e., were in CM2); and 11 concepts had been repeated twice (i.e., were in CM1 and CM2). The average CM3 scores for the textbook group tended to be higher than for the CD-ROM group (see Table 17). A look at the spread of the values, suggests that the means are not different from each other, as there is a chance for some values of the two samples to overlap.

Concept map scores seem to support the trend observed in the activity, where the number of responses for the textbook group were higher in three out of five groups of questions: plant characteristics, application questions, and vascular plants. This is different from the trend observed for the quizzes scores, but in that case, the mean score for the CD-ROM group was only slightly higher than the mean score for the textbook group.

<table>
<thead>
<tr>
<th>Group</th>
<th>CM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbook (3)</td>
<td>78.7 ± 27.7</td>
</tr>
<tr>
<td>CD-ROM (3)</td>
<td>66.7 ± 20.8</td>
</tr>
<tr>
<td>Total # concepts</td>
<td>26</td>
</tr>
<tr>
<td>% old/% new</td>
<td>77/23</td>
</tr>
</tbody>
</table>

Table 17

Average Scores for Concept Map 3.

Note. Scores expressed as mean ± SD

Contributions from the participants varied. When considering the contributions of each participant, Thiab had the greatest contribution to the higher mean score of the textbook group, 102 points, which represented 35 points over what she scored in CM2. Trevic had the second highest contribution to the mean score (86), but he had the highest gain from CM2, 42 points, while Tanya scored 48 and had a gain of 27 points. This was an interesting outcome, as it suggests that Tanya’s learning about plant biodiversity at this point was the lowest for her group, although the achievement level at which she entered the research was the highest. In contrast, Cyreneec had the highest score of the CD-ROM group (85) with a gain of 15 points, and Carla
followed with a score of 71, which represented a gain of 18 points from CM2. Caleb’s score was the lowest (44) and represented a loss of 34 points. This trend suggests that two-thirds of the participants in the textbook group show a higher achievement in their learning regarding characteristics of the plant kingdom and diversity of the different plant phyla. Caleb’s loss might be a result of the effort he put into the concept map, not necessarily meaning he has not earned knowledge, as reflected by his quiz score (70%), which was the highest from all participants in both groups.

Summary of Lesson Three

Lesson three help expose students to the different levels of diversity in the plant kingdom. This was achieved by experiencing concepts related to the basic characteristics of plants, possible evolutionary origin of the kingdom, characteristics of the major phyla in the kingdom, role of plants in the ecosystem, and benefits we obtain from plants.

Results from the activity were mixed. For a group of questions on general plant characteristics and vascular plants, the textbook participants had a higher number of responses and a broader variety of themes. However, for the questions related to gymnosperms and angiosperms, the participants in the CD-ROM group had a higher number of responses and a broader variety of themes. This reflected the amount of material present in the instructional tool as well as the effort required to access and collect the information. The basic information presented in both tools was similar regarding general plant characteristics. However, the textbook information was more extensive and gave more emphasis to the reproductive cycle of the plants. Whereas, the CEB CD-ROM provided brief information regarding general plant characteristics and focused more on descriptive characteristics of the phyla, ecological role, use, and number of species for the vascular plants.
The trend observed for the activity was also reflected in the results for the quiz. Class-wide and for participants, the quiz score tended to be higher in the CD-ROM group than in the textbook group, but only by a marginal difference. The textbook group had higher concept map scores than the CD-ROM. This finding was strongly influenced by Thiab’s performance. The trend was reversed in the concept propositional analysis, and the CD-ROM group did better than the textbook group.

Findings suggest that the tools differentially affect participants’ understanding. There was inconsistency of either group on having higher scores or responses throughout the different assessments (activity, quiz, concept map, interview). It is possible that the CD-ROM participants received moderate influence from the instructional tool to which they were exposed, but they were not negatively impacted by it. It also suggests that rather than having a strong group effect, which made one group or the other perform clearly better across all activities, individual participants in either group were performing better or worse in relation to the other participants.

After reviewing each participant’s propositions for Interview #4, quiz #2, and concept map #3, the researcher believes all participants reached level three of the PBLR, Raven. To different extents, they all seem to have a basic understanding of plant biodiversity in terms of recognizing at least some of the characteristics of the different groups of plants and the role of plants in the ecosystems.

Lesson four was the starting point for the group inquiry project and was assessed with the group presentations. Therefore, lesson four is discussed in Chapter 5, along with research question number two. Discussion of lesson five follows.

Lesson Five

For this lesson, sections of Chapter 41, Earth’s Diverse Ecosystems and the essay “Crops, Livestock, and Wild Genes” were covered in lecture (Audesirk, Audesirk, & Byers, 2002). As
part of the lecture, students were exposed to more in-depth information about some of the local ecosystems: wetlands and long leaf pine savannas. The lesson plan and objectives are in Appendix Y. Following the lecture, both groups worked on activity number five. This experience was expected to support previous levels by giving students a deeper sense of the ecosystem level of biodiversity (PBLR level 2), as well as exposing them more to some of the goods and services provided by both the genetics and ecosystem level (PBLR level 4). As the students encountered information about ecosystems on a global and local scale, they also were exposed to information on the threats and conservation issues. Therefore, it was expected that this learning experience would introduce students to level five of the PBLR, Wilson. Participants were interviewed before lesson four. The follow up interview was the last event at the end of the study unit.

**Activity Five** – The purpose of this activity was to help students explore the diversity of ecosystems on a global scale and local scale. In this framework, students were exposed to the diversity of the plant kingdom, goods and services provided by plants in these ecosystems, and the role of genetic diversity. To the extent possible, the questions in the activity for the textbook group were designed to match those in the CD-ROM according to themes. There were some questions in the CD-ROM activity that had no corresponding items in the textbook but that were considered important to offering a global view of plant biodiversity. They are discussed separately (see activity example in Appendix Z).

A priori codes were selected according to the codes used for previous activities. New codes were added based on the themes presented in Chapter 41 of the textbook and on information provided in the CEB CD-ROM: CLIM, for prevalent climate (temperature and rainfall pattern) as recognized for an area and affecting the diversity of organisms there; GEOGLO, for any specific place or geographical location world-wide; GEOLOC, for local references, state or United States; THREAT, for general reference to threats to biodiversity; THRMAN, for any threats of
anthropogenic origin, (i.e., habitat destruction, exotic species, population growth, pollution, overharvesting); and THR NAT, for any threats, including those above but of natural origin, including natural disturbance of natural geological changes. At first, all codes were considered for the analysis. Codes that were not used as the responses were coded were eliminated from the results table. Only correct responses were coded. The percent of responses for each theme for each question was calculated dividing the responses for the theme by the total number of responses for that question.

The total number of responses was slightly higher in the CD-ROM group as compared to the textbook group (see Table 18). The textbook and the CD-ROM groups had almost the same number of responses, and the different themes were present in a similar pattern. This suggests there are no substantial differences in how students learn, or apply their learning, about Louisiana ecosystems by using either of the instructional tools. The CD-ROM allowed participants to be more specific, and they could zoom-in on the United States map to get a better view and to use a color-key to identify different types of ecosystems. All participants in the CD-ROM group identified the ecosystems in Louisiana as “temperate grass/shrubland savannas; temperate/tropical coniferous forest; temperate broad leaf mixed forest (dominant).” Participants in the textbook group used a world map color-key to identify the ecosystem. They described it as temperate deciduous forest, which almost corresponds to the temperate broad leaf mixed forest stated by the CD-ROM group. The information in the textbook map is less detailed, but the basic idea is there. In addition, the students could read the description of the biome and look at a picture of it along with common fauna and flora. The CD-ROM enhanced their responses by allowing the students to search more specifically in the map and by letting them more closely explore Louisiana as a geographical region.
<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (43)</th>
<th>CD-ROM (49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity</td>
<td>n = 4</td>
<td>n = 4</td>
</tr>
<tr>
<td>ECODIV</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>ECOINT</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>NSPP</td>
<td>50% 25%</td>
<td></td>
</tr>
<tr>
<td>THRMAN</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Biomes – named after plants predictors of diversity</td>
<td>n = 1</td>
<td>n = 1</td>
</tr>
<tr>
<td>ECOENE</td>
<td>100% 100%</td>
<td></td>
</tr>
<tr>
<td>Ecosystems and Biomes</td>
<td>n = 3</td>
<td>n = 5</td>
</tr>
<tr>
<td>CLIM</td>
<td>33% 20%</td>
<td></td>
</tr>
<tr>
<td>ECODIV</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>ECOINT</td>
<td>67% 20%</td>
<td></td>
</tr>
<tr>
<td>State Ecosystems</td>
<td>n = 9</td>
<td>n = 8</td>
</tr>
<tr>
<td>ECODIV</td>
<td>33% 38%</td>
<td></td>
</tr>
<tr>
<td>GEOLOC</td>
<td>33% 38%</td>
<td></td>
</tr>
<tr>
<td>THRMAN</td>
<td>33% 25%</td>
<td></td>
</tr>
<tr>
<td>Plants in areas of high diversity</td>
<td>n = 3</td>
<td>n = 6</td>
</tr>
<tr>
<td>ORGN</td>
<td>100% 100%</td>
<td></td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Most Diverse Ecosystem</th>
<th>n = 7</th>
<th>n = 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECODIV</td>
<td>43%</td>
<td>50%</td>
</tr>
<tr>
<td>GEOGLO</td>
<td>43%</td>
<td>50%</td>
</tr>
<tr>
<td>NSPP</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause for differences in species diversity in ecosystems</td>
<td>n = 4</td>
<td>n = 3</td>
</tr>
<tr>
<td>CLIM</td>
<td>50%</td>
<td>33%</td>
</tr>
<tr>
<td>GEOGLO</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>GEOLOC</td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>NSPP</td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>Hot spots</td>
<td>n = 6</td>
<td>n = 9</td>
</tr>
<tr>
<td>CONSERV</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>ECODIV</td>
<td>17%</td>
<td>11%</td>
</tr>
<tr>
<td>GENDIV</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>GENMAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEOGLO</td>
<td>50%</td>
<td>33%</td>
</tr>
<tr>
<td>THREAT</td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>Ecosystems and Genetic Diversity in plants</td>
<td>n = 6</td>
<td>n = 7</td>
</tr>
<tr>
<td>GENDIV</td>
<td>33%</td>
<td>14%</td>
</tr>
<tr>
<td>GENMAN</td>
<td>66%</td>
<td>43%</td>
</tr>
<tr>
<td>GEOLOC</td>
<td></td>
<td>43%</td>
</tr>
</tbody>
</table>

*Note. N = total number of responses per group; (Note continued)*
n = total number of responses per question (color-coded sections).

Note. Code meanings are NSPP - number of Species; ORGN – examples of organisms; ECOENE - energy flow or mode of acquiring this (producers, food chain); ECOINT- positive species interactions; GENDIV- genetic diversity organisms; GENMAN- reference to genetic manipulation; ECODIV- ecosystem diversity; CLIM – prevalent climate affecting the diversity of organisms in an area; GEOGLO - any specific place or geographical location world-wide; GEOLOC local references, state or United States; THRMAN - threats of anthropogenic origin, (i.e., habitat destruction, exotic species, population growth, pollution, overharvesting); THREAT - for general reference to threats to biodiversity.

At the global scale, there were differences in the patterns observed. For two groups of questions, the number of responses was the same: biodiversity and biomes named after plant predictors. The biodiversity question was the only one where the themes varied somewhat when the two groups were compared. This question required the participants to identify what aspect of biodiversity they considered important. The responses of Tanya and Thiab basically were in tune with the definition of biodiversity, but Caleb offered a vague response; therefore, it was not coded:

- Tanya: Total number of species and complex interactions.
- Thiab: How many species are in a place and how they interact.

The responses of the CD-ROM group overlap with the textbook group, suggesting both resources shared some of the same information but also exposed other themes (i.e., hot spots and food plant diversity) which were not covered in the textbook, offering a broader view of the importance of plant biodiversity. Since participants in the CD-ROM group were able to further explore these other themes, apparently for some participants, these themes became relevant in terms of the importance of plant biodiversity:
Carla  Habitat loss affects food plant diversity.
Caleb  Hot spots - very diverse areas in danger.

These responses suggest the CD-ROM participants are exposed to information that allows them to recognize a broader view of biodiversity, moving away from the basic definition for biodiversity.

In the category of hot spots, there was a higher number of responses for the CD-ROM group than for the textbook group. The responses for the textbook group were all based on definition and discussion offered in the lecture, as this topic was not included at all in the textbook. Therefore, all responses here from the CD-ROM group truly represent a gain from the CEB CD-ROM, especially in the themes of conservation and threats. Regarding location, the textbook participants could infer based on the definition that regions of the tropics were hot spots. For example, Thiab stated “Places that the humans are destroying that are really important to biodiversity [for example] tropical rain forest.” However, the CD-ROM participants could locate more specific areas in the hot spots map:

Carla  California floristic province.
Caleb  Tropical Andes, Polynesia and Micronesia.

Thus, the CD-ROM gave these students the advantage of knowing exactly where in the world some of these hot spots are located. It also help them gain additional information about any hot spot of their interest, (i.e., looking at pictures and learning about the efforts for conservation of species there).

Regarding ecosystems and genetic diversity in plants, the participants in the CD-ROM group had a slightly larger number of responses and themes as compared to the textbook group. Based on the information from the essays read in class, participants in the textbook group were able to answer questions about the importance of genetic diversity in plants and the role of
ecosystems as places where the wild species for some plants might exist. They gathered
information for corn, strawberries, blueberries, and meadowfoam. Some responses were:

- **Tanya** Some plants can be resistant to diseases, insects, or weeds. [GENDIV]
- **Thiab** [genetics] may produce plants with therapeutic benefits. [meadowfoam; GENMAN]

**Thiab** [genetics] Can make plants much bigger…which equals more food for us…and also [make plants] resistant to diseases, insects, [and] weeds. [GENMAN]

There were also several misconceptions identified in the textbook group:

- **Thiab** Genetic engineering can make certain biomes more diverse by cloning animals they already have and making plants resistant to nature.
- **Trevic** Genetic engineering is important to keep the ecosystems alive. Wild species play a role in the ecosystem.

It seems Thiab may have been confused with the number of species vs. number of organisms (density) and increasing density in an area through cloning. In the case of Trevic, he might have been confused with a statement in the essay in reference to the Calophyllum tree’s extract, which has been found effective against the Aids virus:

> “When the researcher returned to Borneo to collect more, the tree he has sampled has been cut down […] Preserving the genes of the resident plants and animal is an important, but little recognized, reason to preserve wilderness.” (Audesirk, Audesirk, & Byers, 2002, p. 233).

These misconceptions present in the textbook participants suggest they needed longer exposure to the topic of genetic engineering and genetic diversity in wild species, why it matters, and possibly more discussion and background information on these issues. While they seemed to grasp the concept of genetic diversity, they seemed to be confused about the role of the ecosystems. When compared to the participants in the CD-ROM group who were exposed to both the essay and the CEB CD-ROM, there were no misconceptions identified. Based on additional information from the CD-ROM, participants in the CD-ROM group were able to answer questions about the importance of genetic diversity in plants and the role of ecosystems as places where these exist. The information to which CD-ROM participants were exposed
included maps of the world distribution of species diversity, maps of the centers of food plant and genetic diversity, the species that provide most of the 90% of human food intake, and species that make up most of the human caloric intake. Some of the responses related to genetic diversity were:

Carla Is important for the future of scientific research for crop variety…add genes for pest resistance …there are some plants they take the genes from. [GENMAN]

Cyrenec As we use crops and alter their genetics for faster & larger crops…we also alter the crop…the corn of the past is not today’s corn, and the corn of the future will be different…pest resistance. [GENDIV] (quote continues) Is important to know where the plants that are domesticated come from. We use only 20 plants for food…and corn is used for many different things…oil, starch…if its affected, then many things are. Scientists need to know where to get more new genes…origin in Central America.

Caleb Important to know where rice comes from – or corn, potatoes… it’s the whole world food. You can find wild plants of the same kind, with genes that could save or make them better for us…is the area where they are most [genetically] diverse…where they originated. [centers of genetic diversity]

The responses from participants in the CD-ROM group were more elaborate than the responses from participants in the textbook group. This suggests the additional information probably helped the CD-ROM group obtain a better idea of the role of those ecosystems that are home for the wild relatives of important species and how genes from the wild relatives can help modify crop species. In addition, students were able to inquire and learn about the origins and additional information about the food plants of their choice. There was no counterpart for this activity for the textbook group, since no information in the course textbook rendered to origins of species, families, or use, except for the ones discussed as part of the essay. Some examples produced by the CD-ROM participants’ mini-inquiry were:

Carla Cacao; family Sterculiaceae; center of origin is Brazil and Paraguay; use seeds to obtain chocolate.

Caleb Coffee; family Rubiaceae; center of origin is Ethiopia; leaves were chewed to extract the caffeine.

Cyrenec Pepper; Piperaceae; center of origin is India; world’s most important spice.
In this regard, the CD-ROM enhanced student exposure to the plant biodiversity material by allowing them to explore their own inquiries. It was not determined within this lesson if these plants became part of the “learned” material, since assessment was not until the end of the study unit.

Regarding the misconceptions present in the textbook group participants, it will be interesting to determine if, in fact, these could be clarified by posterior exposure of these students to the CEB CD-ROM. This was not possible due to the experimental design and was also out of the scope of the present question. At this moment, based on the findings here, it can only be ascertained that the CD-ROM group showed no misconceptions in relation to global patterns of diversity, genetic diversity, and genetic engineering in plants.

The overall pattern of themes for both groups reflects the trend observed for the responses (see Figure 7). The number of themes tended to be slightly higher for the CD-ROM group (13) as compared to the textbook group (11). The dominant themes – ECOENE, GEOGLO, and ECODIV – were the same for both groups. This suggests these themes are present in both sources. The themes THRMAN, HAB, and CONSERV were present only in the responses for the CD-ROM group, while ECOENE was only present in the responses for the textbook group.

A Comparison of the Instructional Tools – The way information was organized and the availability of maps comparisons was one of the main differences between the textbook and the CEB CD-ROM regarding global patterns of plant biodiversity. In the textbook chapter, there was a map showing the worldwide distribution of the different ecosystems. In addition, descriptive information about the structure, diversity, and threats of the ecosystems was offered throughout the chapter. There were figures of the different biomes, many of which included inserts of fauna and flora. A small map (about 1 sq. in.) along with the descriptive information for each biome,
helped keep track of the world-wide distribution of that particular biome. In order to give students some perspective on the importance of different ecosystems, the researcher chose a supplemental essay.

In contrast, the CEB CD-ROM offered multiple maps in addition to the information on ecosystems and specific plant-diversity information. The students could gain additional information at a glance regarding the world distribution of different ecosystems. They could focus on one region of the world and select different maps for a customized comparison. For example, they could compare land cover, the species diversity, deforestation, food plant diversity, population density, and hot spots (see Appendix AA). Even more, students could go back to any of the original maps. If they chose, for example, the centers of food plant diversity, they could gain additional information about the plants that are part of the centers of food-plant
diversity map and then see figures of them. They could also use the hot spots map, gain
information about the specific hot spots, and then look at these in the figures. This feature gave
the opportunity for more interaction and inquiry-type questions. An equivalent experience for the
textbook group could have been possible by using additional sources of text-based information in
the classroom, like for example, the Encyclopedia of Biodiversity (Levin, 2001). A combined-
resource activity could be developed using the textbook’s biomes figures, for which there are no
counterparts in the CEB CD-ROM; the hot spots and food-plant diversity maps for which there
are no counterparts in the textbook; and several figures, tables, maps, graphs from the
encyclopedia. This would provide students the “best of both” instructional tools. This approach
was not investigated in this study, as the comparison between textual information and CD-ROM
was focused on the regular course textbook and if the use of the CEB CD-ROM would enhance
student learning compared to that specific tool, not if any other “text” tool, that was not
customary part of the general course requirements, would enhance learning.

Summary of Lesson Five

The scope of this activity was broad, allowing a “bird’s-eye” view of the multiple concepts
that are part of the construct of global patterns of biodiversity. The overall results indicate the
CD-ROM group had a slightly larger number of responses and themes as compared to the
textbook group. When broken down into groups of questions, the results are mixed.

The main differences between the instructional tools were observed in two areas – hot spots
and the importance of ecosystems for the maintenance of genetic diversity in plants. Hot spots is
a theme that is not covered in the textbook; therefore, it represented, in a sense, a 100% gain for
the students who were exposed to the information through the CEB CD-ROM. The textbook
group was exposed to the concept via class discussion with the instructor who only provided the
basic definition. It is acknowledged that this represents a bias, but the since the objective was to
determine the value added in this case, then that would be any information beyond the basic definition. Therefore, concerning hot spots, the CD-ROM group had a more well-rounded perspective, that included information about conservation and threats issues, in addition to more specific geographical information because of the maps. These three areas represented the value added beyond the definition.

The second major difference between the CD-ROM group and the textbook group was the importance of ecosystems for the maintenance of genetic diversity in plants. Participants in the CD-ROM group were able to draw information from maps and text in addition to the textbook essay that helped them in forming their ideas about both the importance of genetic diversity and the role of ecosystems in maintaining that diversity. No misconceptions were identified in the responses from participants in the CD-ROM group as compared to participants in the textbook who showed some. Therefore, in regard to developing an understanding of the local patterns of ecosystem diversity and global patterns – and specifically genetic diversity, ecosystems and hot spots the CD-ROM seems to enhance student learning.

Lesson Six

In this lesson, students read and discussed in class three essays, “On dodos, bats, and disrupted ecosystems”, “Exotic invaders”, and “Do recombinants hold promise or peril?” These essays were selected because they would expose students in both groups to themes related to threats to ecosystems, which were similar to the themes encountered by students who would be exposed to the CD-ROM. Students worked on activity number six during the following class period. The lesson plan and objectives are in Appendix BB; examples of activities are in Appendix CC.

It was anticipated that experiencing lesson six and the activity designed to go along with it would strengthen concepts introduced in lesson five, thereby helping students achieve PBLR
level 5, Wilsonian. In addition, it was expected that students would get a better-rounded personal perspective of biodiversity, supporting and extending personal connections they had established earlier in the study unit. Therefore, students would reach level 6, Biophilia. Participants were interviewed before lesson four (prelesson) and after the final activities (postlesson).

**Activity Six** – The purpose of this activity was to help students explore how the diversity of the plant kingdom may contribute to or may be affected by the different threats affecting plant biodiversity at all three levels: ecosystem, species, and genetics both at the global and local scales. To the extent possible, the questions in the activities for the textbook and CD-ROM groups were designed to match themes in the CEB CD-ROM, except for where information may not be available in the textbook.

In addition to the a priori codes selected for previous lessons, new codes were added to reflect the themes presented in the textbook and CEB CD-ROM. Description of these codes follows: NEGECON, for any situation, action, or process that has a negative impact on the economy, and CONSERV, for any theme directly addressing the issue of conserving ecosystems or species that are threatened. The code used for lesson five, THRMAN, was modified to distinguish among threats, since that was a major component of the PBLR level the students were expected to reach after being exposed to this lesson. These additional threat-related themes included: THRMPOLL, for pollution of air, water, soil; THRMHAB, for habitat destruction, as in deforestation, agriculture, clear cut, mining, or filling; THRMEXO, for invasive or exotic species; THRMPOP, for human population growth, sprawling; and THRMOVR, for overharvesting or overconsumption. As with previous activities, only correct responses were coded and codes that were not used were eliminated during the analysis to create the table of themes used in the responses for the activity.
An outstanding difference was found in the questions related to exotic species. The CD-ROM group had about five times the number of responses of the textbook group (see Table 19).

It is important to note that for this question, each example of a plant that was an exotic species or a plant that was affected by an exotic species was counted as one answer. Therefore, the percentage of responses for the theme ORGN reflects the number of examples provided by the participants.

It was observed that the participants in both groups were able to define exotic species correctly:

- Thiab: Species introduced into an ecosystem where they didn’t evolve. Sometimes find no predators or parasites in the new environment.
- Caleb: Introduced species. Have no natural enemies.

About the impact of exotic species on the economy, the textbook group participants’ responses were somewhat more specific than the CD-ROM group participants’ responses:

- Tanya: Billions of dollars spent to attempt to control destructive invaders.
- Thiab: The cost of the damage they do is estimated in more than $120 billions/yr.
- Carla: Cause economic damage. I know is billions of dollars.
- Cyrenec: [threats] Cause huge economic damage, billions of dollars are spent to solve this problem.

It is worth noting that the information regarding the economical impact of invasive species was more detailed in the textbook that is, “the amount of money”, as compared to the information available in the CD-ROM that is, “cause economic damage”. However, all CD-ROM group participants had been exposed to the textbook information (essay) and were able to use it to complement their answers. Another point of interest regarding exotic species and plant biodiversity is the difference in the focus of the information presented to the students in the instructional tools. The textbook group had information about species in different kingdoms, including how exotic fungi (i.e., chestnut blight) and different exotic animals and plants affect ecosystems. The essay “Exotic invaders” (Audersirk, Audersirk, & Byers, 2002) exposed eight
Table 19
Patterns of Responses for Threats to Biodiversity (Activity #6).

<table>
<thead>
<tr>
<th>Code</th>
<th>Textbook (42)</th>
<th>CD-ROM (80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most endangered ecosystem</td>
<td>n = 6</td>
<td>n = 6</td>
</tr>
<tr>
<td>GEOGLO</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>THRMAN</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Importance of saving the TRF</td>
<td>n = 4</td>
<td>n = 4</td>
</tr>
<tr>
<td>BENEMED</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>ECOSERV</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>NSPP</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>THRMAN</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Reasons for deforestation in LA/US</td>
<td>n = 8</td>
<td>n = 8</td>
</tr>
<tr>
<td>BENEFood</td>
<td>38%</td>
<td>25%</td>
</tr>
<tr>
<td>BENEMAT</td>
<td>62%</td>
<td>50%</td>
</tr>
<tr>
<td>THRMPPOP</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Threats LA ecosystems</td>
<td>n = 9</td>
<td>n = 1</td>
</tr>
<tr>
<td>THRMPOLL</td>
<td>11%</td>
<td>27%</td>
</tr>
<tr>
<td>THRMPHAB</td>
<td>33%</td>
<td>27%</td>
</tr>
<tr>
<td>THRMPLEXO</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>THRMPPOP</td>
<td>22%</td>
<td>9%</td>
</tr>
<tr>
<td>THRMOVVR</td>
<td>9%</td>
<td></td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Threats to diversity</th>
<th>n = 8</th>
<th>n = 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>THRMPOLL</td>
<td>13%</td>
<td>20%</td>
</tr>
<tr>
<td>THRMHAB</td>
<td>38%</td>
<td>60%</td>
</tr>
<tr>
<td>THRMESSO</td>
<td>38%</td>
<td>20%</td>
</tr>
<tr>
<td>THRMPPOP</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>

Note. N = total number of responses per group; n = total number of responses per question (color-coded sections).

Note. Code meanings are NSPP - number of species; EVOL - evolution (adaptations, dominance, ancestors); ORGN – examples of organisms; HARM - impact on other organisms through disease or other interaction; ECOINT- positive species interactions REPR- type of reproduction; BENEMED - medicines or drugs; BENEMAT- raw materials; BENEFOD - species as source (Note continued)
examples. Three of these examples were animals that affect plant species: fire ants, gypsy moth, and Asian long-horned beetle. Another three were exotic plants that affect other plants: kudzu, water hyacinths and climbing ferns. Figures were included for the first two. In contrast, the CEB CD-ROM exposed five case studies. Two of these were animals that affect plant species, and were also included in the textbook: fire ants and gypsy moth. One of the examples in the CD-ROM was an invasive plant that is, the wetland exotic purple loosestrife. This case study allowed the students to be able to observe the stands where the plant grows; thus possibly helping them develop a more realistic picture in regard to possible effect of exotics. The CD-ROM students also were able to explore other exotic species that affected plant biodiversity and were also given the option to pursue other exotic species inquiries time permitting. Cyrenec, in fact, did look for information on some of the other species as well. Some responses regarding the impact of the purple loosestrife included:

Carla Produce 2.5 millions of seeds a year, form dense monocultures, take over and affect bog turtle, spick rush, local bulrush.
Caleb Takes over and drowns out other species, like cattail, sedges, bulrushes, [and] horsetails.
Cyrenec Degrades wetland ecosystems, exclude the natural vegetation, for example, cattails, red canary grass, sedges, willows, bulrush, [and] horsetails.

In comparison, the responses of the students who were in the textbook group were less detailed in regard to the effect of the exotics on the plant biodiversity:
The chestnut fungus affects chestnut trees and made them disappear in the United States.

Gypsy moth affects hardwood trees and the fire ants affect agriculture, water hyacinths clog waterways.

In the specific case of the fire ants and gypsy moths, students using the CD-ROM were able to determine which plants are affected by it beyond the more inclusive terms of “agriculture” or “hardwoods” given by the textbook. They could also determine if the species was present in Louisiana based on its distribution:

Fire ants – affect corn, sorghum, soybeans, citrus, okra; present in Louisiana.
Gypsy moth – affects oaks, dogwoods, magnolias, hollies, yews, sycamores, cypress; not present in Louisiana.

Additional discussion comparing the two instructional tools in regard of exotic species is offered as part of the post-unit interview analysis at the end of this chapter.

The number of responses from participants in both groups varied according to the different themes. This suggests differences in the way the themes were treated in the textbook and in the CEB CD-ROM. Regarding tropical forests as the most endangered ecosystem and the importance of saving this ecosystem both groups had the same number of responses and themes. In contrast, the textbook group had a slightly higher number of responses for threats to local ecosystems and threats to diversity than the CD-ROM group. This information was inferred either from text or maps.

The typology of themes related to threats to biodiversity reveals a small difference in the number of themes between the two groups. The participants in the textbook group had 16 themes in their responses (12 main categories plus 4 combined in THRMAN), as compared to the responses by participants in the CD-ROM, which had 17 themes (11 main categories plus 6 combined in THRMAN) (see Figure 8). To allow for easier presentation in the graph, all threats were combined as THRMAN unless they were of natural cause, THRNAT.
These findings suggest that the textbook essay and the exotics species section of the CEB CD-ROM complement each other in helping students develop their conception of what an exotic species is. While the textbook covers all themes, the information that specifically addresses plant biodiversity was more detailed in the CD-ROM.

**Summary of Lesson Six**

This activity exposed students to threats to biodiversity such as habitat destruction, pollution, over harvesting, and exotic species. They were able to consider these threats both at the global and local scale. The textbook and CD-ROM seem to cover approximately the same themes, although the percent of responses varied according to the different themes. The most striking difference was observed in the examples of exotic species. Participants in the CD-ROM group were exposed to a much more diverse variety of plant species affected by exotic species.
This suggests that student exposure to threats to biodiversity is not only complemented, but also enhanced when using the CEB CD-ROM.

Post Study-Unit Activities

This last section of question one presents the findings for the different activities that were completed at the end of the study unit including the essay re-visit, the Golden List of Species, concept map, post quiz, postsurvey, and the final interview. Discussion of these follows.

Essay – As part of study unit lesson two, students wrote an essay on their personal reasons to conserve biodiversity. Students had the opportunity to re-visit this question at the end of the study unit. They read over their first essay and then wrote a mini-essay about what was their current position regarding conservation of plant biodiversity. This activity was analyzed using SVA and Kellert’s attitudinal categories as indicated in lesson two. Figure 9 shows the change over time in the pattern of themes observed for the essay. Appendix DD includes sample essays and revisit essays from some participants.

At the end of lesson two, the participants in both groups had a similar number of coded statements (see Figure 9). By the end of the study unit, participants in the CD-ROM group had about twice the number of coded statements (23) as compared to their initial essays and as compared to the textbook group’s essays (10). Given the second essay was not a re-write of the first, but rather the intention was for the students to think and add if they wanted to change anything, the number of statements from lesson two really represent a gain in number of responses, and they could be, in fact, added to the lesson two responses. If so, then, the pattern of higher responses from the CD-ROM group (36) as compared to the textbook group (25) is still maintained. Regarding the variety of themes, the CD-ROM conserved the same trend observed after lesson two and had a slight majority (9) in contrast to the textbook group (7). The themes “nature” and “aesthetic” appeared only in the responses from the CD-ROM group. The
incidence of the theme “Plants” was higher in the textbook group as compared to the CD-ROM group. However in the CD-ROM group the themes “ecology” and “nature” were well represented while the theme “nature” was, in fact, absent in the responses by participants in the textbook group.

The similarity in the number of themes suggests that by the end of lesson two, students had experienced most of the different plant-biodiversity “ideas” that were appealing to them as a reason for conservation. In addition, this also suggests that both instructional tools can provide
students with a similar framework on which to base their reasons to conserve biodiversity.

Regarding the number of coded statements, the findings suggest the exposure of the participants to the CEB CD-ROM possibly enhanced their arguments and depth of understanding.

The experience students in this study had by writing an essay coincides with the argument presented by Ballantyne and Packer (1996) where they believe that attitudes and values are two areas that should be integrated with knowledge construction to help students develop meaningful conceptions. In their view, the integration of an individual’s attitudes and values should not be the sole focus of environmental education but rather an integral part of it, helping the students develop their conceptions. Furthermore, they suggest a constructivist approach to developing those conceptions. The findings of the study presented here suggest the participants had the opportunity to integrate the attitudes and values in developing their conceptions about plant biodiversity. As judged by the number of responses, using both instructional tools, the CD-ROM and the textbook, seemed to enhance the development of attitude/value-based conceptions even more. Potentially, these will form part of the students’ whole conception of plant biodiversity as they were exposed to the other activities, for example the development of their plant inquiries. This study also represents a contribution to one of the areas Ballantyne and Packer pointed out that where in need of research – namely testing teaching strategies that address cognitive, affective, and behavioral components of the environmental conceptions. While both teaching strategies implemented here, the textbook and the CD-ROM, allowed students to develop a personal connection regarding conserving plant biodiversity, an enhancing effect of using the CEB CD-ROM in addition to the textbook was observed in the higher complexity of the statements from CD-ROM group’s participants.

**Golden List of Species** – The Golden List of Species is a plant list created by students as they were exposed to the unit of study. This on-going activity, which started with lesson two and
ended after lesson six, was intended to reflect the participants’ general interest in the plant kingdom. This activity emulates the species lists kept by other diversity-focused scientists that is, ornithologists, when keeping track of the bird species observed in an area or over a period of time. It was expected students would keep a list of the plant species that they encountered (physically or virtually throughout the CD-ROM, textbook, or their daily routine), which they found interesting for a particular reason, in other words, plants that were “attention grabbers”. Examples of the Golden List of Species are in Appendix EE. The information collected by the participants in each group was analyzed quantitatively for total number of species. In addition, a simple valence analysis was done for the reasons of interest expressed by the participants. The codes used were the same used for this analysis of other activities. Table 20, as well as figures 10a, 10b, and 11 summarize the information obtained.

Participants in the CD-ROM group listed three times the number of plant species listed by the participants in the textbook group. This suggests they did a better job in keeping up with this task (see Table 20).

<table>
<thead>
<tr>
<th>Group</th>
<th>Textbook</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>10</td>
<td>39</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>3 ± 2</td>
<td>13 ± 3</td>
</tr>
<tr>
<td>Median</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Range</td>
<td>2 – 6</td>
<td>10 – 15</td>
</tr>
</tbody>
</table>

The majority of the plant examples provided by the textbook group was from daily life encounters (70%; Figure 10a). Plant examples for the CD-ROM group were mostly from the CD-ROM (49%; Figure 10b). No examples listed by the textbook participants came from the
textbook. The participants in the CD-ROM group had almost four times the number of themes as compared to the textbook group.

Figure 10. Origin of Plant Examples Listed in The Golden List of Species for the Textbook Group (A, N = 10) and the CD-ROM Group (B, N = 39).

Figure 11 shows the pattern of themes observed in the interests listed by the participants in the list of species. It is interesting to note that while the aesthetic theme was present in the Golden List of Species for the participants in the textbook group, this theme was not present in their revised essays (see Figure 9). In contrast, the themes of the interests listed in the Golden List of Species were similar to the themes exposed in the essays by the CD-ROM group participants. For example, in the essay the increase observed over time in the attitudinal theme NATURE (for interest in experience with diversity and nature) in the essay could correspond to, and possibly be elicited by, the interest in the structure and reproduction of plants. Both of these themes had a high percentage in the lists from the CD-ROM participants.
Interest and performance in the Golden List of Species varied among the participants.

When participants in the textbook group were asked about the lower number of examples they had in their lists, some of their responses showed almost apathy towards the process of keeping the list:

Trevic: I did it kind of last minute.

Researcher: Why?

Trevic: I did not follow it much. I did not know what to include there. I had other things, stuff from other classes going on… and [the list] was not due ‘till now.

Researcher: From what you included in the list, anything that stands out to you for any particular reason?

Trevic: No ma’am, not really. To be honest with you… I added some at the end… because we had to do it.

Figure 11. Typology of Interests in Plants Listed in The Golden List of Species

Trevic did not seem motivated to keep track of the diversity he experienced in his daily life, including those plants to which he was exposed through the textbook or research.
For him, this was one more activity needed to complete his requisites for the course. Other participants cited lack of time or forgetting about the list. However, a CD-ROM group participant offered a contrasting comment, which was closer to the expected outcome:

**Cyrenec**
This was kind of weird, but it was fun. I put in there anything that caught my attention. I did not write everything down, and I saw some other classmates that only had like two…and I was wondering how come, I mean, we saw a bunch of species…so many you couldn’t write all of them down. I had to draw a line of what to write - I included those that I thought about them after class.

**Researcher**
When you were adding species to your golden list of species, are there any that stand out to you more than the others for any particular reason?

**Cyrenec**
I know I included some crops, like corn and wheat, because they are important for our future.

The differences observed in the number of species and the motivation drive to include these species on the list suggest that it is possible participants in the CD-ROM were able to connect their routine, inside or outside the class, with an awareness of plants in different contexts. In a sense, they have become “plant seers” rather than individuals who suffer from plant blindness.

The researcher believes this recognition stage is an outcome of the additional exposure to plant biodiversity in multiple contexts throughout the different lessons. Alternatively, these participants in the CD-ROM may have been intrinsically more motivated and responsible students to keep up with their work.

**Concept Maps** – All students created a concept map (CM 4) during the class period at the end of the study unit, post lessons four, five, and six. This concept map was compared to the concept map one, which all students constructed at the beginning of the study unit, before lesson one (CM 1; see Table 21). Of the 21 seed concepts for CM 4, nine of these were old seed concepts used in CM 1. All students (class-wide) had been exposed to all of the other concepts throughout lessons two to six, even though only the participants from each group constructed concept maps two and three using those concepts.
Table 21. Class-wide Average Scores for Concept Maps 1 and 4.

<table>
<thead>
<tr>
<th>Group</th>
<th>Average Scores (mean ± SD)</th>
<th>Score Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CM 1</td>
<td>CM 4</td>
</tr>
<tr>
<td>Textbook (9)</td>
<td>25.8 ± 17.5</td>
<td>71.1 ± 21.9</td>
</tr>
<tr>
<td>CD-ROM (14)</td>
<td>36.4 ± 17.2</td>
<td>68.5 ± 31.3</td>
</tr>
<tr>
<td>Total # concepts</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>% old</td>
<td>0</td>
<td>43</td>
</tr>
</tbody>
</table>

Note. Total number of samples per group is given in parentheses.

The CD-ROM group tended to have higher average scores for CM 1 as compared to the textbook group. However, a look at the spread of the values suggests some students’ scores could coincide. Although inferential statistics must be interpreted with caution due to the design of the study, a Mann-Whitney U test suggested there was no significance difference between the average concept map scores for the textbook and the CD-ROM groups at the start of the study unit (z = 1.58; U = 43.0; p = 0.0569). This may suggest it is possible all students were at the same base level of understanding at the start of the study unit. This trend was expected to change over time if the instructional tools had a differential effect over student learning. It was observed that the scores for CM 4 were higher for both groups as compared to the scores for CM 1. In addition, scores for CM 4 were slightly higher for the textbook group when compared to the CD-ROM group. Again, a look at the spread of the values around the means suggests some scores could coincide. A Mann-Whitney U test suggested there was no significant difference between the average concept map scores for the textbook and the CD-ROM groups at the end of the study unit (z = 1.26; U = 43.0; p = 0.1039). The textbook group also had a larger score change over time when compared to the CD-ROM group. These findings suggest the study unit had an effect
on the learning of all students. In addition, class-wide, this effect was slightly higher in the students exposed only to the textbook only as compared to the students exposed to the CEB CD-ROM + textbook.

Comparing the concept map scores for participants in both groups may offer a more accurate view of the effect of the study unit on student learning. Participants had been exposed to all the seed concepts presented for CM 4. Of these, nine concepts had been repeated three times before (i.e., were exposed in CM1, CM2, and CM3); nine concepts had been repeated twice (i.e., were exposed in CM2 and CM3); and three concepts had been repeated once (i.e., were exposed in CM3). Scores for CM 3 and CM 1 were compared to the scores for CM 4, and gains were calculated for each interval of time (see Table 22). Participants in both groups had the opportunity to re-visit during the last interview the map created earlier in class. Examples of concept maps are in Appendix FF.

| Table 22. Average Scores for Concept Maps 1, 3, and 4 for Participants in the Textbook and CD-ROM Groups. |
| --- | --- | --- | --- | --- | --- |
| Group | CM 1 | CM 3 | CM 4 | CM 3-4 | CM 1-4 |
| Textbook (3) | 39.1 ± 6.6 | 78.7 ± 27.7 | 90.7 ± 16.6 | +12.0 | +51.6 |
| CD-ROM (3) | 50.3 ± 9.3 | 66.7 ± 20.8 | 119.3 ± 14.2 | +52.7 | +69.0 |
| Total # concepts | 21 | 26 | 21 | | |
| % old concepts | 0 | 77 | 100 | | |

Concept map scores for participants reflect gains in the last period of the study unit, CM 3 vs. CM 4. This finding suggests lessons five and six affected the learning of the participants. There was a slight overlap in the scores for textbook and CD-ROM groups, suggesting the scores are not completely different. However, the tendency for higher scores observed in the CD-ROM group’s participants as compared to the textbook group’s participants suggests that the activities
of lesson five may have helped the participants in the CD-ROM group earn a better understanding about global and local scale of biodiversity, ecosystem diversity, and hot spots. In addition, the activities of lesson six may have enhanced the participants’ learning about threats to biodiversity.

The overall score change between CM 1 and CM 4 and the average concept map scores suggest an effect of the study unit over overall on the participants’ learning. The observed tendency for higher scores in concept maps created by participants in the CD-ROM as compared to the scores observed for concept maps of the participants in the textbook group suggests an enhancing effect of the CEB CD-ROM on student learning.

The higher scores observed for the participants compared to the overall class-wide scores may be explained by the exposure of the participants to some of the concepts and the opportunity to re-visit CM 4 during the last interview. The last interview for the participants took place after completing project presentations, taking the third quiz, and completing the postsurvey. Therefore, it is likely that these experiences influenced the opportunity participants had to revise their concept maps. It is possible concepts were re-enforced during this period, and even though the last interview was approximately a week after the end of the study unit, the participants may have had an opportunity to re-structure their knowledge.

Individual scores for participants are shown in Figure 12. Except for CM 3, there was an overall trend for concept map scores to be slightly higher for participants in the CD-ROM group. This suggests an overall enhancing effect of the CD-ROM for most of the activities to which participants were exposed. Where the scores were lower, there was no negative effect observed in the CD-ROM, suggesting the information might have been at least complementary to what the textbook offered.
This study corroborated the usefulness of concept maps as an assessment tool for the constructivist classroom as proposed earlier by Mintzes & Wandersee (1998) and Novak & Gowin (1984). In this study, the use of concept maps allowed to reveal differences in performance among the participants, thus suggesting an effect of the CD-ROM in enhancing student learning. As discussed in the next section, used alone, other forms of assessment would probably have missed the by effect. Another important point is that observation on how students struggled while creating the concept maps. There were many examples where concepts were connected but propositions for the links were missing. This suggest that the students had some idea of the concepts being related, but no exact conceptual knowledge of how they were related – that is no learning had occurred. Higher scores in the concept maps form the participants in the

![Figure 12. Concept Map Scores Over Time for All Participants](image-url)

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CD-ROM group, suggests these students possibly were more successful in establishing these connections. Therefore, suggesting an enhancing effect of the CD-ROM on learning (see Appendix FF).

**Quiz #3, Post-unit Quiz** – Quiz #3 included factual and application questions based on the material exposed to the students through lecture and the textbook (see Appendix GG). Three evaluators determined the face validity of the test. They agreed both the lecture and quiz accurately reflected the objectives of the lesson. More than half of the questions (64%) were reinforced through the textbook-based and CEB CD-ROM-based activities. About half of the questions (44%) had a visual component, which the students had been exposed to in lecture. Therefore, it was expected that students in either group had the potential of performing at the same level. Then, if differences were observed, these could be attributed to differences in the effect of the tools used for concept reinforcement, the textbook or the CEB CD-ROM.

Both class-wide and at the participant level, scores for students in the CD-ROM group tended to be better than the scores for students in the textbook group (see Table 23).

<table>
<thead>
<tr>
<th>Group</th>
<th>Textbook</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class-wide</td>
<td>82.0 ± 11.8 (10)</td>
<td>84.3 ± 11.4 (14)</td>
</tr>
<tr>
<td>Participants</td>
<td>88.0 ± 12.0 (3)</td>
<td>92.0 ± 16.0 (3)</td>
</tr>
</tbody>
</table>

*Note. Scores are expressed as the average of percent scores considering class as study unit and participants. Number of quizzes considered is given in parentheses.*

Class-wide results for an independent samples *t*-test suggest there is no statistical significant difference between the mean percent scores for the textbook group (82.0) and for the CD-ROM
group (84.3) \( (t = -0.477, p = 0.319) \) (MS Excel®, 2003). The trend remains the same when considering the subset of participants. There is no statistically significant difference between the mean percent scores for the textbook group’s participants (88.0) and for the CD-ROM group’s participants (92.0) \( (t = -0.346, p = 0.373) \). The tendency for the quiz scores of the textbook group to be relatively higher than the quiz scores of the CD-ROM group suggests exposure to the CEB CD-ROM had a minimal enhancing effect on the quiz performance.

There are two possible explanations for the observed trend. First, the quiz was based mostly on lecture and textbook material, and did not include those areas where there were differences between the two instructional tools. It was observed from the activities that the information presented in the CD-ROM and textbook was similar in some themes but not all. The textbook and the CD-ROM were different in some topics such as maps, hot spots, and plant biodiversity affected by threats. However, the way questions were posed in the multiple choice quiz did not assess these differences, therefore preventing the quiz from being a more effective instrument to differentiate between the possible effects of the instructional tools used in the research. In other words, if there was an enhancing effect on the students’ knowledge or understanding, the quiz was possibly not effective enough to measure it. An alternative would be assessing with a quiz that provided options for any or all of the following: short concept maps, short essay questions, and open-ended questions. This approach could give students an opportunity to expose their knowledge while differences in understanding could surface and be assessed. Second, there is a possibility that students in the textbook group could be better testers as compared to the students in the CD-ROM group.

A closer look at the individual participants’ scores for all quizzes suggests three things (see Figure 13). First, over time, there is an effect of the study unit on the performance of all
participants. Scores for both the textbook and the CD-ROM groups improved over time, possibly due to an overall enhancing effect of the study unit on all students’ learning about plant biodiversity and to the exposure the same kind of testing. Second, there was a slight tendency for the participants in the CD-ROM group to perform better as compared to the participants in the textbook group. Although quiz scores for the CD-ROM participants tended to be higher than the scores for the textbook participants for quiz 1, the scores or both groups were more similar for quizzes two and three. The participants’ scores suggest that for the first part of the study unit, lesson one, the CEB CD-ROM had an enhancing effect on learning. This trend tended to dissipate for quizzes two and three, where participants in the CD-ROM group performed only slightly better than the students of the textbook group did, thus supporting the class-wide findings and participants’ mean scores discussed earlier. However, when individual cases are considered, in almost all cases, the participants from the CD-ROM group performed better than
the participants at the same level of achievement in the textbook group. Third, contrary to the expected outcome, it seems that the participants’ achievement level is not a good predictor of their performance on the quizzes. Over time, a reverse in the trend of participants’ scores was observed in the CD-ROM group. The individual participants’ scores in both groups did not follow the expected trend. On quiz two, Caleb and Cyrenec had higher scores than Carla, while on quiz three, Cyrenec had the highest score and Carla still performed at the lowest level. In the textbook group, Thiab consistently had the higher score for the group, while Tanya was not consistent, being at the same level slightly above or well below Trevic, depending on which quiz.

Survey

All students completed the Student Assessment of Learning Gains (SALG) at the beginning (pre-SALG) and end of the study unit (post-SALG). The post-SALG was the last activity completed after the student presentations and the post-unit quiz. Both instruments consisted of the same questions, except for three clusters of questions at the end of the post-SALG. These clusters assessed the effectiveness of the instructional tools used and the perspectives students will carry-forward to their future. Organization of the items into clusters allowed classification of students’ responses along the main themes explored with the survey.

Tables 24 through 32 summarize the class-wide survey results as a percentage found for the items in the different clusters for each group. Responses were grouped as low level and high level. The low level includes the “not confident/little confident/somewhat” responses and “high level” includes the “highly confident” and “extremely confident” responses. Participants’ responses were measured as gains and provided a closer look of the class-wide trends (see Figure 14). For the purpose of this analysis, gains were calculated as the percent of responses that showed a change, where the change was calculated as difference between the number of responses for pre- and post- SALG for each level, low and high.
The weighted means per item were calculated and used to test for significance. The statistical tests were performed to help infer the significance of the trends observed for each group. However, claims on the significance of the trends were made with caution given the quasi-experimental design of this research which violates the assumption of random assignment or random draw from a population (Gall, Borg, & Gall, 1996; Gribbons & Herman, 1997). In addition, there is low statistical power. Under these conditions, these authors suggest restraining from using the test of statistical significance or using them with caution. The researcher acknowledges these pitfalls. However, in a study of a chemistry course at a community college, the learning gains were measured with the SALG after a Peer-Led Team Learning practice was implemented the course and the researchers used the two tailed t-test (Kuempel & Tien, 2004). In their case, they had no problems with sample size (more than fifty students). Therefore, the researcher chose to perform a two-tailed t-test or Mann-Whitney U test, depending on the normality of the data for the cluster, using the weighted means per item for each group, textbook (n = 10) and CD-ROM (n = 14), and follow the advise of interpreting these with caution.

**Cluster One, Science Understanding** – Student confidence in their general ability to understand science concepts related to plant biodiversity was assessed. Students in the textbook group responded similarly to each other and more positively than negatively, as reflected by a higher percentage of “highly to extremely confident” choices for all items (see Table 24). Students in the CD-ROM group responded similarly to each other but more negatively than positively as reflected by the lower percentage of “highly to extremely confident” choices for four out of the six questions explored.

Compared to the students in the textbook group, students in the CD-ROM group were consistently initially less confident about their science understanding as indicated by the lower percentages in the “highly/extremely” level for all questions. However, they seem to gain more
Table 24.
SALG Percent Responses for Cluster One, Science Understanding, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Confidence in Understanding General Science concepts</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Discussing PB concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Post</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Critical thinking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Post</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Give a presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Post</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Developing an inquiry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Post</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Science processes behind scientific issues in the media</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Post</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>PB content of the course</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Post</td>
<td>60%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Cluster Mean Gain (SD) - 5% (18) 27% (25)

Note. Mean gains in students’ responses are reported for the cluster. These were determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster. Data are presented as summary of three lower vs. two upper levels of response. PB = plant biodiversity confidence over time. This was suggested by the consistently higher CD-ROM group post-SALG percentages as compared to the pre-SALG, for all six questions in this cluster. In contrast, when comparing responses of the pre- and post SALG for students in the textbook group, they seem to remain the same in terms of their confidence to discuss plant biodiversity concepts, give a presentation, and develop an inquiry. Two findings were the most dramatic in the questions
examined in this cluster. First, the textbook group’s perceived loss in their confidence in understanding the plant biodiversity concepts of the course (90% pre-SALG to 40% post-SALG). This differs with the CD-ROM students who reflected a positive change, suggesting they improved their confidence in the understanding of the plant biodiversity content of the course. The second major finding was the increase in confidence CD-ROM students had in their ability to develop an inquiry (from 36% to 64%) and in their confidence to give a presentation (from 36% to 79%). The textbook students had no change in either case regarding these questions. The general trend of gain in confidence by students in the CD-ROM group is supported by the calculated cluster mean gain of 27% as compared to a loss in the textbook group of 5%. This trend, though, needs to be taken with caution, as the CD-ROM group actually had more room for change as compared to the textbook group.

For individual participants, gains were calculated as the percent of responses out of the six questions in the cluster that changed from one level to another, low to high or vice versa (see Figure 14). Findings for participants in the CD-ROM group showed a similar trend to those in the textbook group; only Caleb showed a slightly higher gain than Tanya. The gains observed for the participants do not reflect any salient differences among the textbook and CD-ROM participants, neither do they reflect a pattern of higher achievers having more or fewer gains when compared between groups.

A mean score provides a numerical measure of the general trend or level of preference of the students for each item. Weighted means were calculated per question and then for the cluster to have a measure relatively easy to compare and give an overall trend. The weighted mean scores should be interpreted carefully, as they may not necessarily reflect the majority of responses for a single question of interest. Independent samples \( t \)-test was conducted to obtain a general idea of how the science understanding of students in the CD-ROM group
Figure 14. Participants Learning Gains as Suggested by the SALG Survey

as compared to that of students in the textbook group. Overall, responses to the pre-SALG indicate students in the textbook group were significantly more confident (27%, 2) than students in the CD-ROM group (22%, 2) (t (10) = 4.379, p = 0.0014). However, when weighted means are compared for the post-SALG, the trend is reversed; students in the textbook group were significantly less confident (23%, 1) than students in the CD-ROM group (26%, 2) (t (10) = 4.379, p = .0014).

These findings along with the ones discussed earlier suggest that the addition of the CD-ROM-related activities to the course had an overall effect of improving the confidence of the students, with particular emphasis on their confidence about the plant biodiversity content of the course.
**Cluster Two, Interest in Science** – Students in the textbook group and in the CD-ROM group responded in more varied ways to each other for most questions as suggested by the similar percentages observed for the two levels of responses for the first two questions (see Table 25). In general, the majority of students in both groups were initially somewhat to not interested in reading about plant biodiversity or exploring careers in science. A majority of students in both groups also showed somewhat to no interest in teaching science, with the textbook group having a strong negative response (90%). Experiencing the study unit seems to have influenced the interest to teach science in students of both groups. The post-SALG shows more students were highly to extremely interested in teaching science as indicated by a higher percentage of responses as compared to the pre-SALG in both the textbook (10% to 40%) and CD-ROM groups (36% to 43%) (see Table 25). However, when comparing the textbook and CD-ROM groups, there does not seem to be much difference between the groups.

Overall, the CD-ROM group had a higher gain as compared to the textbook group (9% vs. 8%). Individual participants’ gains suggest that for students who were at the same achievement level, those in the CD-ROM group had consistently greater gains or no change as compared to the textbook group. Carla and Caleb became highly to extremely interested in the instances measured in this cluster. When looking at their individual responses, they changed in all of them to an upper level. Cyreneec showed no net change since the two questions she changed on the pre- to post- SALG changed in opposite directions; she became more interested in reading about plant biodiversity but less interested in exploring careers in science, while her teaching interest did not change. Tanya and Thiab became more interested as well, but had a lower gain, suggesting they had no change in some questions. In fact, Tanya became more interested in reading and teaching,
Table 25. SALG Percent Responses for Cluster Two, Interest in Science, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>General Interest in Science</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Reading about PB and relation to social issues</td>
<td>Pre</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>40%</td>
</tr>
<tr>
<td>Exploring careers in science</td>
<td>Pre</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>40%</td>
</tr>
<tr>
<td>Teaching science</td>
<td>Pre</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>60%</td>
</tr>
<tr>
<td>Cluster Mean Gain (SD)</td>
<td></td>
<td>8% (12)</td>
</tr>
</tbody>
</table>

*Note.* Mean gains in students’ responses are reported for the cluster. These were determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster. Data are presented as summary of three lower vs. two upper levels of response. PB = plant biodiversity

while Thiab became more interested only in reading about plant biodiversity. Trevic showed a loss or decrease in interest. Two of his questions did not change, but he became less interested in exploring careers in science (see Figure 14).

Weighted means were calculated and an independent samples *t*-test was conducted to obtain a general idea of how the CD-ROM group of students’ interest in science compared to that of students in the textbook group. Overall, responses to the pre-SALG suggest students in both groups had similar interests. There was a non-significant difference in the responses from students in the textbook group (18%, 7) and the CD-ROM group (14%, 13) (*t* (4) = 0.549, *p* = .6125). When weighted means are compared for the post-SALG, the trend is reversed; students in the textbook group were less confident (21%, 0) than students in the CD-ROM group (27%, 252).
0), but the difference observed in the weighted mean was still not significant \( t(4) = -2.164, p = .0965 \).

These findings suggest that regarding the general interest in science, the use of the CEB CD-ROM in addition to the textbook did not result in a tremendous improvement as compared to the textbook group, except for the interest in teaching science. Findings suggest an increase over time in both groups, with a slightly higher number of students in the CD-ROM being highly to extremely interested as compared to the textbook group.

*Cluster three, Personal Connection to Plant Biodiversity* – Students in both groups responded similarly to each other as indicated by higher percentages towards one of the extremes of the levels (see Table 26). Regarding their personal connection to biodiversity, initially there was a higher percentage of negative responses in both the textbook (70%) and CD-ROM (86%) groups. By the end of the study unit, both groups increased in the number of responses in the upper levels, suggesting a higher number of students were highly to extremely interested in changing their lifestyles to reduce the impact on plant biodiversity and highly to extremely interested in promoting knowledge about plant biodiversity. The cluster mean gains suggest that more students in the CD-ROM group changed more of their responses towards the upper levels than students in the textbook group, although both groups show gains.

When gains in the responses for individual participants were examined, all participants across both groups showed the same patterns (see Figure 14). In each group, two out of three participants – Carla & Caleb and Tanya & Trevic – had 100% gain. When looking at their individual responses, all four changed both questions to an upper level after the study unit. Thiab and Cyrenec showed the same change in responses. Thiab really had no change after the study unit. However, Cyrenec was more interested in changing her lifestyle but less interested than before in promoting knowledge about plant biodiversity, resulting in a no net change.
Table 26. SALG Percent Responses for Cluster Three, Personal Connections to Plant Biodiversity, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Personal connection to plant biodiversity</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Changing life style to Reduce impact in PB</td>
<td>Pre 70% 30% 86% 14%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post 20% 80% 29% 71%</td>
<td></td>
</tr>
<tr>
<td>Promoting knowledge about PB</td>
<td>Pre 70% 30% 86% 14%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post 20% 80% 29% 71%</td>
<td></td>
</tr>
<tr>
<td>Cluster Mean Gain (SD)</td>
<td>25% (24)</td>
<td>57% (10)</td>
</tr>
</tbody>
</table>

Note. Mean gains in students’ responses are reported for the cluster. These were determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster. Data are presented as summary of three lower vs. two upper levels of response. PB = plant biodiversity

Weighted means were calculated and checked for normality. Results for the independent samples t-test suggest there was not a significant difference in the weighted mean of responses for the textbook group (19%, 0) and the CD-ROM group (22%, 1) (t (2) = -4.00, p = .0572). When weighted means were compared for the student interest in the post-SALG, the trend was maintained. There was a significant difference in scores for students in the textbook group (26%, 0) when compared to scores of students in the CD-ROM group (36%, 0) (t (2) = -21.213, p = .0022).

These findings suggest an increase over time in the personal connections to plant biodiversity for both groups. It seems there was a slightly higher number of students in the CD-ROM group being highly to extremely interested as compared to the textbook group. There is an obvious change in interest after students are exposed to the study unit, which might be slightly higher in the CD-ROM group as compared to textbook group. These findings coincide with the
findings for the essay activity, where the participants in the CD-ROM group had a higher number of statements and themes regarding their reasons to conserve biodiversity as compared to the participants in the textbook group.

**Cluster Four, Activities that Facilitate Learning** – Students in the textbook group responded similarly to each other as indicated by higher percentages on either level for each question in the pre-SALG (see Table 27). Consistently, students in this group found the relevance of the course material, discussions, computer use, and studying for the test highly to extremely helpful in class activities that helped their learning. Regarding concept maps, their responses were equally split. Most of the students considered group work and projects somewhat to not helpful. In contrast, students in the CD-ROM group initially diverged in their responses in the pre-SALG, as indicated by most of the questions having a split equal or close to 50%-50% toward each level in the responses. Only the relevance of the course material and studying for the tests were found to be consistently highly to extremely helpful by a higher number of students.

After the study unit, students in the textbook group showed a logical decrease in how helpful they considered the use of the computer to learning (see Table 27). They had been exposed to in-class computer activities prior to the study unit but not during the study unit. When the project/group work question was examined, there was a slight increase in the textbook group students who considered this in-class activity highly to extremely helpful, but still, the majority of them found it somewhat to not helpful. The findings for these two questions are quite in contrast to what the CD-ROM group students expressed. For an outstanding majority of students in the CD-ROM group, the use of the computer was considered highly to extremely helpful, representing a 43% difference when compared with the pre-SALG responses (see Table 27). It may be argued that this was an expected finding, considering the students were exposed to
Table 27. SALG Percent Responses for Cluster Four, Activities that Facilitate Learning, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Class Activities that help student learning</th>
<th>TEXTBOOK N = 10</th>
<th></th>
<th>CD-ROM n = 14</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Relevance of course material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>30%</td>
<td>70%</td>
<td>36%</td>
<td>64%</td>
</tr>
<tr>
<td>Post</td>
<td>30%</td>
<td>70%</td>
<td>29%</td>
<td>71%</td>
</tr>
<tr>
<td>Discussions/lecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>40%</td>
<td>60%</td>
<td>51%</td>
<td>53%</td>
</tr>
<tr>
<td>Post</td>
<td>20%</td>
<td>80%</td>
<td>29%</td>
<td>74%</td>
</tr>
<tr>
<td>Computer use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>40%</td>
<td>60%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Post</td>
<td>60%</td>
<td>40%</td>
<td>7%</td>
<td>93%</td>
</tr>
<tr>
<td>Concept maps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>50%</td>
<td>50%</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>Post</td>
<td>10%</td>
<td>90%</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>Studying for test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>20%</td>
<td>80%</td>
<td>29%</td>
<td>71%</td>
</tr>
<tr>
<td>Post</td>
<td>40%</td>
<td>60%</td>
<td>14%</td>
<td>86%</td>
</tr>
<tr>
<td>Project/group work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>90%</td>
<td>10%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Post</td>
<td>70%</td>
<td>30%</td>
<td>44%</td>
<td>59%</td>
</tr>
</tbody>
</table>

Cluster Mean Gain (SD) [3% (17)] [16 % (24)]

*Note.* Mean gains in students’ responses are reported for the cluster. These were determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster. Data are presented as summary of three lower vs. two upper levels of response. PB = plant biodiversity

computer-based activities related to the CEB CD-ROM. However, exposure to the activity may not necessarily translate into students finding the activity helpful. This point of view may be supported by the contrast provided by the responses divided 50%-50% in the pre-SALG as compared to 7%-93% in the post-SALG. For the CD-ROM group, more students in the post-
SALG compared to the pre-SALG also thought that the project and group work were highly to extremely helpful in-class activities that helped their learning (see Table 27). The number of responses is also higher (double) when contrasted to the post-SALG responses for students in the textbook group.

Another noteworthy finding is that a higher number of students in the textbook group considered concept maps highly to extremely helpful after the study unit, in contrast to the more varied responses in the pre-SALG. Concept maps and discussions were the two most favored activities by the textbook group. The CD-ROM group students also considered concept maps a highly to extremely helpful activity; however, they kept the same trend as before the study unit. Their second favorite most helpful activity for their learning was studying for the test.

When the change in survey responses was examined for the participants, some reflected losses, but the majority reflected gains (see Figure 14). Both Carla and Trevic had losses after the study unit. Carla thought lecture was less helpful than at the beginning of the study unit. She had no change in other activities. Trevic found relevance, studying for tests, group work, and lecture less helpful than before, but concept maps and discussions were more helpful than before the study unit. Perhaps this was influenced by the approach of discussing the essays in class, which was different to having the Power point-based lecture. Cyrenec found all activities to be more helpful to her learning after the study unit. Caleb followed the same trend, except for one, group work, where he had no change from before the study unit. Tanya and Thiab had the same pattern of responses, although both had a smaller percent than their counterparts in the CD-ROM group. Both found discussion, concept maps, and group work more helpful after the study unit. Tanya also found relevance of lecture more helpful than before, but computer use less helpful than before, resulting in no net gain.
Weighted means were calculated and checked for normality. Results for an independent samples t-test suggest there was a significant difference in the weighted mean of responses for the textbook group (25%, 2) and the CD-ROM group (33%, 4) (t (12) = -5.31, p = .0001). When weighted means from the post-SALG were compared for the class activities that helped student learning, the same trend was observed. There was a significant difference in scores for students in the textbook group (26%, 3) as compared to scores of students in the CD-ROM group (38%, 3) (t (14) = -7.600, p = 0.0001).

These findings suggest first, that different students tend to favor different activities, as supported not only by the pre- and post-SALG data but also by the closer look into the changes experienced by the participants. It would be interesting to explore whether preference is associated to learning style, effort the students want to invest, or other learning-associated variables. Second, and more important to this research, is the possible effect of the study unit in the students’ preference of learning activities. The use of the computer was a primary activity used in support of the textbook-based lecture in the CD-ROM group. It seems the use of the computer was an activity students tended to consider helpful for their learning, regardless of the group they were in originally, but even more strongly so after being exposed to it repetitively. The CD-ROM group strongly favored it over any other activities. Given the closeness in the percent of responses in the pre-SALG for both groups and the dramatic change observed for the CD-ROM group, one could speculate the possibility of any group of students favoring this type of activity once exposed to it. These results are consistent with findings of Waittiaux & Crump (2006), who examined student responses when exposed to two different classroom interventions, lecture vs. discussion of pre-assigned reading material, using a modified SALG instrument. Two different cohorts of students responded differently to the learning environment. They argued the differences in responses among students for some selected items (i.e., preference for lecture,
learning with in-class discussions), may be due to student standing, levels of interests, and variation in the learning styles.

**Cluster Five, Resources that Facilitate Learning** – For most of the questions in this category, students in the textbook group responded similarly to each other as indicated by higher percentages on either level for each question (see Table 28). Students in the CD-ROM group also responded in similar ways as indicated by higher percentages on either level for most questions.

The split of the responses for videos (pre-SALG) and textbook (post-SALG) suggest the students’ responses varied about how they perceive videos as a resource that facilitates learning. Considering results for the cluster as a whole, there was not a dramatic change over time in how helpful students found different resources as suggested by both groups having a small and similar change: textbook (3%) and CD-ROM (4%) groups.

After the study unit, the majority of students in the textbook group considered the Internet and lecture notes as the top highly to extremely helpful resources that facilitated their learning (see Table 28). This was followed by the computer laboratory and videos. After the study unit, the majority of students in the CD-ROM group found the most highly to extremely helpful resource was the use of the computer lab-CEB, followed by the Internet and lecture notes. The observed increase in the percentage of students in the textbook group who found the use of computers-CEB as a highly to extremely helpful resource which facilitated their learning was not expected. The textbook group was not exposed in lecture during the plant biodiversity study unit to computer laboratory use-CEB, but they were exposed to it through other activities on evolution earlier in the semester as part of another unit. A possibility is that given the post-SALG was administered towards the later part of the semester, they considered SALG an evaluation for the course and not just for the study unit, even though the students were given instructions that this survey was assessing their experiences only from the study unit on plant biodiversity.
Table 28. SALG Percent Responses for Cluster Five, Resources that Facilitate Learning, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Resources that facilitate student learning</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Post</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Textbook</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Post</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Textbook-CD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Post</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Computer lab – CEB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Post</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Lecture / Power Point notes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Post</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Videos</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Post</td>
<td>40%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Cluster Mean Gain
(SD) | 3% (16) | 4% (22)

*Note.* Mean gains in students’ responses are reported for the cluster. These were determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster. Data are presented as summary of three lower vs. two upper levels of response. PB = plant biodiversity

Another possibility is that students are just evaluating computer-laboratory use in general (disregarding – CEB), and the increase observed for this in the textbook group (20%) may be correlated to the trend that strongly favored use of Internet as a highly to extremely helpful resource that facilitates learning (30% to 80%, see Table 28). Both the computer lab-CEB and
the Internet were resources that students could use to work and develop their guided-inquiry group projects, which were part of the study unit. No test of correlation between questions was included in the analysis for this research. However, it would be interesting to pursue this question.

An alternative explanation for the unexpected result may be that the data may have been biased to a certain option (i.e., “e”). The assessment was not tied to the course grade, and there may be students whom this researcher will call “easy riders”, defined as those students who make one initial choice of alternatives and fill out the whole survey, test, or questionnaire with the same answer. A quick look at the answer sheets revealed one possible case. It is acknowledged this may affect all data and maybe this student’s response should be considered an outlier, but the researcher had no real basis to remove it from the sample (i.e., was the student truly “highly to extremely” confident for the questions asked?). Perhaps a follow-up interview or focus group could help remove easy riders from samples in any future research.

The increase in the CD-ROM group’s students finding the computer laboratory as a highly to extremely helpful resource to facilitate their learning is not surprising. First, this is the tool they were exposed to throughout the study unit, and the results of the previous cluster already showed a dramatic increase in the number of students who considered the computer use as a class activity highly to extremely helpful to their learning. Secondly, this finding is related to the use of Internet access, which had a good percentage of students considering it a highly to extremely helpful resource (71%), although there was no change in the percentage of responses from pre- to post-SALG in its use as a resource to facilitate learning.

The number of students in the textbook group who considered the textbook a highly to extremely helpful resource declined from 70% to 50% over time. Likewise, their preference for
the textbook-CD was reduced by 10%. However, initially a higher percentage of students already considered it somewhat to not helpful (60%).

Some examples of students’ comments during the last interview support the findings about the textbook and CEB CD-ROM + textbook as resources that facilitate student learning. From the perspective of the participants who experienced the textbook only, the consensus is they would have preferred using the CD-ROM, in fact, one of them complained about the flipping the pages in the textbook compared to the “click” for information:

Researcher Let me show you what the students in the other group did and you did not experience as a learning tool. I will like to hear any comments you may have.

Tanya I like this [CD-ROM] is very nice. I really like the maps, like you can actually just click a button and then the different maps come up …you can look, you know, to the deforestation and …I just realized most of what we eat is grown here, but is not from here…the sugar cane, and coffee…and corn…and potatoes. Can you imagine? I thought we sent these [produce] to other places. Use that! It has more maps than the book. This is very nice! It will be cool to use it …probably more than doing those worksheets with the textbook! I’d rather go over notes…!

Thiab [Activity with numbers of species] Look at bacteria, they’re little [she was observing the size of the area representing the number of species identified, as students in the CD-ROM group did for activity 1 ]…and the flowering plants…yeah…a lot more than the others is like 6 time more ah?…ooh, wow! Insects. I hate them!…Why so many??! That’s neat.

After observing the description of kingdoms, Thiab added:

Thiab Oh, shut up…men! You know how much time it took for me to finish that Worksheet [activity]? Forever!! Going all over the book. I spent so much time doing it [working on it], I did not want to share with anyone! Not fair!

Trevic [While exploring the map of food diversity] Coffee plants originally come from Ethiopia…never thought of that, wheat…I see flax there too, I eat flax seeds […].

Researcher I am curious, why you never mentioned wheat, coffee, flax as plant examples if they are part of your daily life?

Trevic I guess because with salads and lettuce it looks like a plant and is green…I don’t think about plants with the other stuff, but now yes, I guess they are plants too.

Researcher Let me know what you think about this program.

Trevic I like it …the figures and maps are pretty nice. Looks like is easier to follow than flipping pages back and forth in the textbook. Interesting…I wish you had shown me earlier…I would have switch sections, ha!
The participants of the textbook group expressed interest in using the CEB CD-ROM. Some of the aspects of the program that captured their interest were the way the information was organized, the visuals (including figures and maps), and the easy access to the information. In the case of Trevic, seems that the program could have helped him develop a better conception of plant biodiversity. Trevic was able to discover using the CEB CD-ROM that there are plant-products he used which he did not associate with being plants, because they were not “green.”

The participants in the CD-ROM group expressed their preference for the CEB program as compared to the textbook and raised the issue of access to the program, which could be improve to make this tool more available to the students:

**Researcher** What can you tell me about the role the CEB might have on developing your understanding about plant biodiversity?

**Carla** It helped…a lot, a like the visuals, the videos, slide shows, the way the information was short – you know how it was organized like an outline.

**Caleb** Seeing the pictures helps me a lot to pull the information from my head. I remember pictures from class, or from the program and that helps me.

**Researcher** If you had a choice of using the textbook, program, or both to study plant biodiversity which one would you choose and why?

**Carla** The book is OK, but I’d rather use the program – it was more fun and something different, and the information was like all in one place. The only thing is …it would be better if you can have it, you know. Like the textbook, I have it at home. I can study from it anytime. The program I could only use it here…in class.

**Caleb** I definitely recommend this program. You have the information in the book, …hum…but no…you know, is good to know all of the information…it’s more organized, you know, kind of you can get it easily. I think the program explains biodiversity very well…like I could have studied from it a lot more, it helps a lot, it shows a lot. It lays everything out there for you.

**Cyrenec** I like the focus and short story format of the program, to the point, and it takes less time. In the textbook, …is a lot of reading and I get lost. [the CD-ROM] Is not so much technical stuff. I mean, don’t get me wrong, you do have words you don’t know [in the CD-ROM] but they are “one click” away. Is not like you got to find it out in the glossary. In the book they do have more “big words”, but the program was easier to understand. You also have to carry the book around, which is a lot easier to come here, you got the information out of the computer. But…I’ll tell you one thing… it would even better if I could have this program to work when I can.
Participants in both groups liked the visual aspect of the program, and its organization. Based on the findings of the SALG and the comments provided by the participants in the last interview, the researcher can pose several possible reasons for the change observed in students preferences of the resources that facilitate their learning: (a) Students would rather come to a lecture and go over notes than work on textbook-based activities. The themes covered in the activities sometimes made them go back and forth in the book to gather the information. This was something to which they expressed a negative attitude; (b) Students do not like carrying the textbook to class everyday. Many students either left their books home or would ask if they needed to bring it to the next class; (c) Students who used the program, would prefer to have access to it outside class time as compared to access to the CD-ROM limited to the computer laboratory (and class time). When considering the CD-ROM group, there was an increase in the number of students who consider textbook as a somewhat to not useful resource that facilitated their learning. Looking at both the textbook and textbook CD, in general students in the CD-ROM group did not favor these as useful resources for their learning (see Table 28).

The change in survey responses was examined, taking a closer look at the participants. It was found that the responses for the questions related to the resources that facilitate student learning had the least change as a group when compared to the change observed for other clusters (see Figure 14). Carla, Caleb, and Trevic had the same percentage of change in responses. Their change contrasted with that of Tanya and Thiab, which was smaller. Cyrenec had losses, defined as a change towards the lower level responses. For about 20% of the responses, Cyrenec considered the resources less helpful for her learning after the study unit than at the beginning. The Internet, videos, and the textbook were the resources that she considered somewhat to not helpful, as opposed to her responses before the study unit. While other participants also considered some of these resources somewhat to not helpful, they balanced the
loss by considering another resource more helpful in the post-SALG than in the pre-SALG, resulting in no change. This did not happen in Cyrenec’s case.

Weighted means were calculated and checked for normality. Results for the independent samples *t*-test suggest there was a significant difference in the weighted mean of responses for the textbook group (23%, 4) and the CD-ROM group (31%, 7) (*t* (8) = -2.865, *p* = .0205). When weighted means from the post-SALG were compared for the class activities that helped student learning, the same trend was observed. There was a significant difference in scores for students in the textbook group (25%, 2) as compared to scores of students in the CD-ROM group (32%, 7) (*t* (6) = -2.439, *p* = .0510).

The findings discussed above suggest that using the CEB CD-ROM in addition to the textbook possibly had a positive impact on how students perceived the usefulness of the CD-ROM resource as a learning tool contributing towards their learning. Of all possible resources that the CD-ROM group students evaluated, the use of the computer laboratory – CEB had the highest number of students who thought it was a highly to extremely helpful resource. It can also be argued that the textbook is not a preferred resource; students in both groups had varied responses at the end of the study unit, as suggested by the close to 50% on both levels of responses for both groups.

**Cluster Six, Biodiversity-Related Concepts** – The plant biodiversity-related concepts were divided into six sub-clusters based on SVA codes used earlier and on which of these concepts may be representative of the different levels of the PBLR. When examining the mean percentages for the textbook group pre-SALG, it seems for the majority of questions, students responded similarly to each other as indicated by the majority of students being somewhat to not confident in most sub-clusters of concepts (see Table 29). The top three sub-clusters where students were less confident about their understanding included plant structure and reproduction,
goods and services from plants, and conservation issues as indicated by percentages 70-88%.
Likewise, students in the CD-ROM group responded similarly to each other as indicated by the
majority of students being somewhat to not confident for almost all of the concepts’ sub-clusters
(threats being the only one below 60%). The top three sub-clusters where students were less
confident about their understanding included conservation issues, goods and services from
plants, and plant structure and reproduction, as indicated by percentages 76-86% (see Table 29).

After the study unit, the post-SALG for the textbook group indicates responses of the
students tended to be similar to each other, as indicated by the majority of sub-clusters having
above 60% in one of the levels of responses (see Table 29). Students in the textbook group
improved in their confidence in understanding plant biodiversity concepts. For all sub-clusters,
the percentage of “highly/extremely highly” confidence was at least doubled compared to the
pre-SALG percentages. Biodiversity and evolution, threats to plant biodiversity, and biodiversity
levels were the sub-clusters where the students showed the highest confidence (72-82%).
Responses from students in the CD-ROM group suggest students had more divergent responses
as half of the sub-clusters had close to 50-50% splits between the two levels of responses. The
percent of responses for biodiversity and evolution and biodiversity levels showed that at least
twice the number of students became highly to extremely confident about their understanding of
these concepts, and these percentages were higher in the CD-ROM group as compared to the
textbook group. The mean cluster-wise gain in the high to extremely confident category tended
to be higher for the CD-ROM group as compared to the textbook group. Thus suggesting that the
confidence in understanding plant biodiversity concepts was probably positively enhanced by the
use of the CEB CD-ROM overtime.
Table 29. SALG Percent Responses for Cluster Six, Biodiversity-Related Concepts, Over Time (Pre and Post) for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Confident about understanding and explaining concepts related to …</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not/ A little/ Somewhat</td>
<td>Highly/ Extremely</td>
</tr>
<tr>
<td>Biodiversity – Evolution (26-28, 31, 35) - PBLR L1</td>
<td>Pre 58% (28) 42% (28) 71% (18) 29% (18)</td>
<td>Post 18% (13) 82% (13) 13% (11) 87% (11)</td>
</tr>
<tr>
<td>Biodiversity levels: species, genetic, ecosystem (29, 30, 32, 34, 43) - PBLR L2</td>
<td>Pre 62% (18) 38% (18) 73% (12) 27% (12)</td>
<td>Post 28% (11) 72% (11) 27% (6) 73% (6)</td>
</tr>
<tr>
<td>Plant structure, reproduction, growth (36-38, 41, 44, 49-51) - PBLR L3</td>
<td>Pre 88% (13) 13% (13) 76% (16) 24% (16)</td>
<td>Post 40% (24) 60% (24) 48% (19) 52% (19)</td>
</tr>
<tr>
<td>Goods and services from plants (39, 40, 42, 48, 52) - PBLR L4</td>
<td>Pre 88% (8) 12% (8) 79% (13) 21% (13)</td>
<td>Post 42% (24) 58% (24) 59% (11) 41% (11)</td>
</tr>
<tr>
<td>Threats to plant biodiversity (33, 45, 53, 54) - PBLR L5</td>
<td>Pre 60% (28) 40% (28) 59% (16) 41% (16)</td>
<td>Post 23% (5) 78% (5) 29% (6) 71% (6)</td>
</tr>
<tr>
<td>Conservation issues (46, 47) - PBLR L6</td>
<td>Pre 70% (14) 30% (14) 86% (10) 14% (10)</td>
<td>Post 40% (42) 60% (42) 46% (15) 54% (15)</td>
</tr>
</tbody>
</table>

Cluster Mean Gain (SD) | 21% (17) | 30% (14)

Note. Mean gains in students’ responses, determined as the mean of the difference in frequencies (Post SALG – Pre SALG) for all items in the cluster, are reported for the cluster. Items were coded into six groups according to content. Data are presented as the mean and standard deviation for each group of items and as a summary of three lower vs. two upper levels of response categories. PB = plant biodiversity

The change in survey responses was examined, taking a closer look at the participants (see Figure 14). Findings indicate that responses for the questions related to students’ confidence in their understanding of plant biodiversity were varied. Cyrenec had the highest number of
responses that reflected an increase in confidence in understanding, having a gain in all clusters but the last one where she experienced a gain and a loss with no net gain in understanding. Tanya and Thiab had approximately a 70% change. Trevic had the least change. All participants in both groups had the most changes in the biodiversity-evolution sub-cluster, indicating they followed the trend of the class.

Weighted means were calculated and checked for normality. The distribution indicated the data violated the assumption of normality. Therefore, the weighted means for the two groups, pooling all clusters together, were compared with the Mann-Whitney U test. The findings suggest there is a significant difference in the weighted mean of responses for the pre-SALG for the textbook group (15%, 3) and the CD-ROM group (26%, 4) ($z = 4.98, p \leq .05$). For the post-SALG, there is a significant difference in the weighted mean of responses for the pre-SALG for the textbook group (21%, 2) and the CD-ROM group (36%, 6) ($z = 6.18, p \leq .05$).

The findings discussed above suggest that students in the CD-ROM group tended to be more confident in their understanding of concepts related to plant biodiversity than students in the textbook group. Although the use of the CEB CD-ROM for this unit of study did not seem to add substantially to the students’ confidence above the confidence provided by the use of the textbook, it also did not have any negative results (losing confidence). A question that was not explored in this research, but would be worth pursuing, is whether there is a correlation between confidence and actual achievement of the students in graded assessments. Can confidence be used as an index or predictor of actual learning? In that case, the concept-related questions should be paired per theme and possibly content between the two instruments. In addition, it should be explored with a much larger sample size than the one in this research.
Cluster Seven, CD-ROM as a Learning Tool – The higher percentage of responses in the highly to extremely helpful level for both groups indicates that the majority of students responded similarly to each other (see Table 30). The majority of students in the CD-ROM group (79-86%) thought they had made a lot to a great deal of learning gains regarding the relevance of plant biodiversity to real world issues, understanding plant biodiversity and the relationship between concepts, and the ideas that were presented in this course in relation to other courses. The lowest gain was observed for enthusiasm about plant biodiversity, at 64%, which still can be argued to be a positive response.

Unexpectedly, students in the textbook group also reported having a lot to a great deal of learning gains in all the areas when using the CEB CD-ROM (see Table 30). It is unclear whether the students in the textbook group were confused about evaluating other activities in the course or if they were evaluating the study unit as indicated. It is possible that the questions in the survey were confusing to them or that the students did not pay attention (or forgot) the instructions given at the start of the survey. Alternatively, students could have answered at random (the easy riders discussed earlier), affecting the outcome of the data. Unfortunately, this was not realized until it was too late to go back to the students and find out. It supports the idea of the need to follow up this type of data collection with interviews or focus groups, especially if dealing with a small sample size. With the additional information, and/or a larger sample size, the researcher would be more eager to identify and discard the easy riders.

A Mann-Whitney test suggests the weighted means for the textbook group (26%, 0) and CD-ROM groups (40%, 2) are significantly different (z = 3.194, p = .0007). These findings suggest that the use of the CEB CD-ROM throughout the study unit positively impacted the learning gains and attitudes of the students in the CD-ROM group regarding plant biodiversity.
Table 30. Post- SALG Percent Responses for Cluster Seven, CD-ROM as a Learning Tool, for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Learning gains and influence in attitude towards plant biodiversity as result of using CD-ROM as learning tool</th>
<th>TEXTBOOK n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding PB and relationship between concepts</td>
<td>Not at all/ A little/ Somewhat</td>
<td>A lot/ a great deal</td>
</tr>
<tr>
<td>Ideas in this course in relation to other courses</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Relevance of PB to real world issues</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Appreciating PB</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Can explain PB</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Enthusiastic about PB</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Mean cluster percent (SD)</td>
<td>28% (4)</td>
<td>72% (4)</td>
</tr>
</tbody>
</table>

Note. A summary of responses is given as mean cluster percent. Data are presented as summary of three lower vs. two upper levels of response categories; PB = plant biodiversity

To a good extent, participants clearly reflect the patterns observed class-wide regarding the gains they made by using the CEB CD-ROM (see Figure 15). A closer look at the responses Caleb and Cyrene selected reveals how they both felt the CD-ROM had an important role in their understanding and appreciation of the concepts related to plant biodiversity. Carla had a divided response; nevertheless, she still had a strong positive perception of the role the CD-ROM played in her learning gains regarding her understanding and perception of plant biodiversity. For the most part, Thiab presented the expected results for the textbook group, which was not exposed to the CEB CD-ROM during the study unit. Tanya and Trevic offered the typical responses found for other students in the textbook group. These results were puzzling and unexpected. Plausible
explanations (i.e., being confused with the use of the program earlier in the semester) were explained with the class-wide results, and there is no reason to believe they could be any different with the participants.

![Bar chart showing participant learning gains](image)

**Figure 15. Participants Learning Gains as a Result of Using CEB CD-ROM as Learning Tool**

The findings for cluster seven, students favoring the use of CD-ROM and computer, coincide with what Simon (2001) found for an introductory biology course regarding attitudes towards the use of the CD-ROM in lieu of textbook. Different to the study presented here, in that case, a website completely replaced the use of the course textbook. Students preferred the use of web site and CD-ROM to the textbook. Among the reasons those students stated cost-saving, conciseness of notes, facility to carry, and accessibility of the course material. In Simon’s study, students stated lack of high quality images, having to print notes, and the inability to annotate as a down side of the CD-ROM. None of the latter represented a problem or an issue in the study.
discussed here, since the CEB CD-ROM was used in addition, as supplementary material, to the course textbook. The CEB CD-ROM also has a plus side, in that the visual resources, from pictures, diagrams, maps, and videos were of excellent quality. Simon’s study did not address the effects on student learning.

**Cluster Eight, Textbook as a Learning Tool** – The higher percentage of responses in the highly to extremely helpful level for the textbook group indicates that the majority of students responded similarly to each other (see Table 31). The majority of students in the textbook group (70%) considered the textbook helped them a lot to a great deal in making learning gains in understanding plant biodiversity concepts, ideas in this course in relation to other courses, relevance of plant biodiversity to real world issues, explaining plant biodiversity, and being enthusiastic about plant biodiversity.

In contrast, responses offered by students in the CD-ROM group diverged more from each other, as suggested by the equal or close to 50-50% split between the lower and upper level of responses in all questions (see Table 31). This suggests most students did not consider the textbook to influence their learning gains. It also supports the finding for the previous cluster, where the majority of students in the CD-ROM group considered the CEB CD-ROM to influence their gains greatly. A Mann-Whitney test suggests the weighted means per for the textbook group (26%, 0) and CD-ROM groups (33%, 1) are significantly different ($z = 3.194, p = .0007$).

Participants reflected the class-wide results, where the textbook group tended to have stronger support for the use of the textbook as a learning tool as compared to a lower support from students in the CD-ROM group (see Figure 16). Tanya, Thiab, and Trevic showed a stronger support in using the textbook as a learning tool as compared to the CD-ROM group’s participants. Carla and Cyrenec considered that the textbook only offers some help in appreciation, enthusiasm, and understanding of plant biodiversity. In contrast, when evaluating
Table 31.

<table>
<thead>
<tr>
<th>Gains in student responses using Textbook as learning tool/ Influence in attitude towards plant biodiversity</th>
<th>TEXT n = 10</th>
<th>CD-ROM n = 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding PB and relationship between concepts</td>
<td>Not at all/ A little/ Somewhat</td>
<td>A lot/ a great deal</td>
</tr>
<tr>
<td>Ideas in this course in relation to other courses</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Relevance of PB to real world issues</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Appreciating PB</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Can explain PB</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Enthusiastic about PB</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Mean cluster percent (SD)</td>
<td>30% (0)</td>
<td>70% (0)</td>
</tr>
</tbody>
</table>

Note. A summary of responses is given as mean cluster percent. Data are presented as summary of three lower vs. two upper levels of response; PB = plant biodiversity.

these same concepts in light of the usefulness of the CEB CD-ROM, Carla and Cyrene considered that the CD-ROM represented an important tool and helped a lot to a great deal.

Findings for cluster 8 suggest that students in the CD-ROM group differ in how they perceive the use of textbook in helping their learning gains. The textbook was not strongly supported as a tool that helps a lot to a great deal in the students’ learning gains. While the textbook group students supported the use of the textbook to a higher extent as compared to the students in the CD-ROM group, it is worth noting the support was not as overwhelming as one might expect. Keep in mind, the textbook was the main tool they used throughout the study unit.

It would be interesting to follow up with a content analysis of the textbook used for the study.
unit and other introductory biology textbooks as well. These other textbooks could be used to expose students to activities like the study unit here, and examine the response of the students to different textbooks.

Figure 16. Participants Learning Gains Using Textbook as Learning Tool

Cluster Nine, Plant Biodiversity Understanding, Skills, and Attitude Towards Plant Biodiversity to Carry on After this Course – Both groups’ students tended to have responses similar to each other as indicated by the higher percentages in one response level (see Table 32). Regarding the question “understanding of plant biodiversity and relationship between concepts”, students tended to diverge in their choice of alternatives as suggested by the 45-55% split between the two levels of responses. In addition, a lower percentage of students agreed they would carry on a lot to a great deal compared to the percentage of students choosing this level in the CD-ROM group (79%) (see Table 32).
Table 32. Post- SALG Percent Responses for Cluster Nine, Understanding, Skills, and Attitude Towards Plant Biodiversity to Carry On, for Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Plant biodiversity understanding/ Skills/attitude to carry on After course</th>
<th>TEXT n = 10</th>
<th></th>
<th>CD-ROM n = 14</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all/ A little/ Somewhat</td>
<td>A lot/ a great deal</td>
<td>Not at all/ A little/ Somewhat</td>
<td>A lot/ a great deal</td>
<td></td>
</tr>
</tbody>
</table>

Understanding PB and relationship between concepts

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Ideas in this course in relation relation to other courses

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>43%</td>
<td>57%</td>
</tr>
</tbody>
</table>

Relevance of PB to real world issues

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Ability to think through a problem

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>36%</td>
<td>64%</td>
</tr>
</tbody>
</table>

I am part of biodiversity and have a role in its conservation

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>36%</td>
<td>64%</td>
</tr>
</tbody>
</table>

Enthusiastic about PB

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Feel comfortable with complex ideas

<table>
<thead>
<tr>
<th></th>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Mean cluster percent (SD)

<table>
<thead>
<tr>
<th>TEXT</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% (0)</td>
<td>70% (0)</td>
</tr>
<tr>
<td>30% (9)</td>
<td>70% (9)</td>
</tr>
</tbody>
</table>

Note. A summary of responses is given as mean cluster percent. Data are presented as summary of three lower vs. two upper levels of response; PB = plant biodiversity.

Looking at the pattern of responses for previous clusters, the majority of students in the textbook group thought that both textbook and CD-ROM as instructional tools helped their understanding of plant biodiversity concepts (see Tables 30 and 31). However, only about half of the students would carry on that understanding beyond the course. Assuming they are responding sincerely and to the best of their judgment, this possibly implies that only about half of the students learned the material in a meaningful way.

The majority of students in the CD-ROM group seem to respond similarly to each other as indicated by the higher percentage for one of the response levels (see Table 32). The question on
“ideas of the course” that the students will carry on to other courses had the lowest percentage of responses. It seems that students diverge in their choices for that question. In contrast, a high percentage of students in the CD-ROM group strongly believe (i.e., a lot to a great deal) though, that they will carry on “understanding of plant biodiversity concepts”, “the relevance of plant biodiversity to real world issues”, “being enthusiastic about plant biodiversity”, and “feeling comfortable about complex ideas”. The pattern observed from participants’ overall responses suggests the unit of study, had the same positive effect on both groups regardless of the instructional tool used (see Figure 17). A Mann-Whitney test suggests the weighted means for

![Figure 17. How Much Participants Will Carry on to Other Classes and Life](image)

the textbook (26%, 1) and CD-ROM (39%, 2) groups are significantly different (z = 3.361, p = .0004). The findings here suggest the use of the CEB CD-ROM throughout the study unit positively impacted the learning gains and attitude of the students in the CD-ROM group. It enhanced the learning of plant biodiversity. In the few cases where it did not had an impact, an
effect similar to the one due to the use of the textbook was observed. Therefore, as an
instructional tool it seems to help students in acquiring knowledge and maintaining interest in
plant biodiversity that is, learning about plant biodiversity in a more meaningful way.

Post-Interview

Participants were interviewed at the end of the study unit. This was the last event of data
collection for this research. In order to assess if there were any learning gains due to students’
exposure to lessons five and six, the participants’ propositions from Interview #4 were compared
to the propositions from Interview #5. The interview protocol is in Appendix D; the concept
proposition analysis is in Appendix L, Tables L19-L24. The propositions and examples provided
by the students were identified according to source as textbook, CD-ROM, both of these, lecture,
and finally all sources (textbook + CD-ROM + lecture). Table 33 presents a summary of the
results for participants across treatments.

The total number of learning gains for participants in the CD-ROM group was
approximately 39% higher as compared to the learning gains for participants in the textbook
group. Both groups reflected a similar percentage of learning gains as a result of participants
restructuring their knowledge, (CD-ROM, 8% vs. textbook, 10%). The number of examples used
by participants in the CD-ROM group was approximately 65% higher than the number of
examples used by participants in the textbook group. Participants in the textbook group mainly
provided examples from the textbook, while the majority of examples from the participants in
the CD-ROM group were from the CD-ROM followed by the lecture, and then the textbook.
These findings suggest use of the CD-ROM possibly helped students earn a better overall
understanding of concepts related to global patterns of diversity and threats to biodiversity.

Considering the participants from both groups, Cyrenec had the highest number of learning gains

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Table 33. Results of Concept Propositional Analysis for Interviews #4 and #5.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Learning Gains</th>
<th>Examples</th>
<th>Learning Losses</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mc+</td>
<td>+</td>
<td>tl</td>
<td>T</td>
</tr>
<tr>
<td>Tanya</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Thiab</td>
<td>4</td>
<td>14</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Trevic</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>35</td>
<td>39</td>
<td>22</td>
</tr>
<tr>
<td>Carla</td>
<td>2</td>
<td>14</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Caleb</td>
<td>3</td>
<td>18</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Cyrenec</td>
<td>26</td>
<td>26</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>58</td>
<td>63</td>
<td>7</td>
</tr>
</tbody>
</table>

*Note. Values represent participants’ learning gains, examples contributed, and learning losses for pre- and postinstruction for lessons five and six.*

*Note. Codes are: mc+, incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- an correct proposition changed to incorrect; mc, changed from none or vague to incorrect; -, a correct proposition changed to none, vague, or correct proposition but not adequate to the instruction; tl, total. Examples: T, textbook; CD, CD-ROM; B, both CD and T; L, lecture; A, all, T+CD+L; G, general knowledge. Examples T, textbook; CD, CD-ROM; B, both, CD and T; L, lecture; A, all, T+CD+L; G, general knowledge; other: CD!, from a non-required activity completed on own from the CD-ROM.*

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of all. In addition, she was the only participant with no misconceptions or learning losses. Her responses reflected how the instruction helped restructuring her knowledge about global patterns. Although Cyrenec’s original understanding of this concept was not incorrect; she was able to “fine-tune it” as stated below:

Cyrenec:  
Preinstruction  They [plants] only grow in certain places, so there is differences between continents, but there is diversity everywhere but the kinds of things are different.  
Instruction  Global patterns in Biodiversity at the ecosystem level. Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, desserts, [and] grasslands.  
Postinstruction  There is like 15 of them [ecosystems], some are temperate, with conifers, tropical, desserts, savannas.

In this case, the examples she offered were from both sources, CD-ROM and textbook. Thus suggesting both learning tools influenced her understanding of global pattern of ecosystem diversity possibly in the same way.

There were some global ecosystem-related concepts for which the CEB CD-ROM represented an advantage as compared to the textbook. One of this was the concept of hot spots. The outcome of the interviews supported the earlier findings for activity five. Developing an understanding about hot spots represented a clear learning gain from using the CD-ROM as the learning tool. As discussed earlier, this theme was not covered in the textbook and the only other source of instruction that the participants in the textbook group had was a brief introduction in lecture. The preinstruction represented what students understood before been exposed to the definition in class. In the case of Cyrenec, she was able to develop a better, more comprehensive understanding of hot spots as compared to participants in the textbook group after she was exposed to the CD-ROM:

Instruction  Hot spots are ecosystems of high species diversity that are endangered. These are located in ___.
Cyrenec

Preinstruction  Diverse areas, like in the tropics.
Postinstruction  Places where there is more man-made decline and the diversity there is higher. These need to be conserved, they are in trouble. Mainly tropical areas and subtropical have hot spots, like in South America.

Thiab provides an example, were actually she negotiated a misconception of what hot spots are:

Thiab

Preinstruction  Places with a lot of sunlight – the tropical areas.
Postinstruction  Areas that are very diverse but are most threatened by human impact. Tropical rain forests.

This reflects that Thiab gained a basic understanding of why hot spots are important ecosystems.

The difference between Thiab’s explanation and that of Cyrenec, was that Cyrenec went one more step in saying that these hot spots need to be conserved, and specifically where these tropical forests hot spots are located.

Not all textbook group participants were able to develop a clear understanding of hot spots. For example, Tanya and Trevic show misconceptions about hot spots that were not resolved with the instruction:

Preinstruction
Tanya  A place or area of real importance or characteristics.
Trevic  Beach.

Postinstruction
Tanya  Places that have abundance of plant diversity. Tropical areas.
Trevic  Ecosystems like the tropical rain forest, dying off at a very fast rate.

While they both changed their original responses, their responses after instruction showed they had a somewhat incomplete or vague idea of what hot spots are. In Tanya’s case, her response was considered a misconception because in the preinstruction she failed to state the reason why hot spots are “important”, although she was pretty close to a correct definition. Then, in the postinstruction, she stated biodiversity as the characteristic of these places, but still could not point out to why they are important. In Trevic’s case, his response was considered a misconception that was not completely removed, because even though he recognized tropical
rain forests as a hot spot, his answer remained vague as he failed to mention biodiversity as a key word. Like Tanya and Trevic, both Carla and Caleb also reflected misconceptions:

| Preinstruction | Carla          | No clue, maybe tropical areas, they are warmer. |
|                | Caleb          | Maybe is a result of evolution, places were evolution is faster, like the Galapagos. |

| Postinstruction | Carla          | Areas that need to be left alone, don’t mess with them because of the diversity they have like 50% of the world’s tropical forests—like in Brazil. |
|                | Caleb          | Places were biodiversity is seriously threatened, so they need to implement conservation in stronger way, like in some tropical rain forests, and in the US there is one in California. |

However, Carla’s and Caleb’s misconceptions were resolved after the instruction, suggesting the CD-ROM played a role in the specific examples they provided. It seems the CD-ROM possibly helped participants in the CD-ROM group create schemas of hot spots which were somewhat more complete or complex, consisting of five ideas: what kind place, where is located, importance of this ecosystems, cause for threat, and need for conservation. In contrast, the schemas formed by Thiab and Trevic were more simple consisting of only three ideas: what kind place, where is located (in general), and cause for threat. It could be argued that the responses given by the textbook participants were biased by the information to which they were exposed. However, both groups were exposed to the same definition in lecture. The difference in information is basically due to the lack of any information available in the textbook regarding hot spots, in comparison to CD-ROM where the maps show the global distribution of hot spots and students could access information related to each hot spot.

One way in which the study here represents a contribution to the education about hot spots, is in focusing on the value of the diversity of the flora of these important ecosystems in general. The map to which students were exposed not only provided them with the geographical location of the hot spot ecosystems, but also with the possibility of exploring additional information on
any of those that was of their interest. Only one study was found that addressed education about hot spots (Bizerril, 2004). The study revealed that the textbooks for 6th graders in Brazil focused more in the geographical and physical attributes of the Cerrado area, a hot spot ecosystem, rather than the biodiversity aspects of the region. In the case of the Brazilian students, Bizerril pointed his findings could affect the development of an identity of this students with that particular ecosystem. This conclusion could be extrapolated to the possible outcomes of the students in the introductory biology courses. Acknowledging the limited transferability of the findings of this study, one could argue that the CD-ROM represented a tool that allowed the students to develop both a global and local (national, California) perspective of hot spots. The enhanced learning gains for the participants in the CD-ROM group surfaced during the interviews that followed the activity.

Another aspect in which the CD-ROM represented a clear learning gain for the participants in that group was concerning exotic species as a threat to biodiversity. In contrast to the hot spots concept discussed earlier, the concept of exotic species is included in the textbook and all students read an article about exotic or invasive species. All participants in the textbook group contributed examples to which they were exposed through lecture or textbook. When participants were asked about the threats to biodiversity during the preinstruction interview, none of them included exotic or invasive species in their responses. Therefore, it seems all participants gain knowledge about invasive species as a threat to biodiversity after the instruction. The following examples reflect how participants differ in the responses provided:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Threats to diversity: Invasive species – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Japanese climbing fern, Chinese tallow; lecture and text - water hyacinths, kudzu; text only- ; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm].</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanya</td>
<td>Like some plants, the tree, in class, Chinese tallow that’s growing all...</td>
</tr>
</tbody>
</table>
over the place. [lecture]

Thiab
Exotic species are invading and overtaking our native species. [For example] Chinese tallow and the water hyacinths in the wetlands. [lecture and textbook]

Trevic
Exotic invaders [for example] Chinese tallow. [lecture]

Carla
Exotic invaders, like the one with heart shaped leaves [Chinese tallow] and the climbing ferns which are kind of everywhere, and the purple flowers that grow in wetlands of the east. [All]

Caleb
[Exotic species] loosestrife is one with purple flowers that grows in wetlands, but not in Louisiana, other wetlands. That plant is killing a lot of other plant life in other wetlands. Also the water lilies [hyacinths]- the purple flower. In Louisiana the fire ants are a problem everywhere, but they can affect soybeans, and corn, and okra- maybe this is the worst of all invasives. [All]

Cyrenec
Exotic species can wipe out everything – like the [Chinese] tallow that is spreading in Louisiana, is an exotic plant and there is also a purple one that spreads in other wetlands, not here. Fire ants and the zebra mussels are in Louisiana. The mosquito fish- is good and bad, controls mosquitoes but kills some minnows. [All]

After analyzing the responses, there were two main differences among participants from the both groups: the source of examples and the complexity of the response. Regarding the source of examples, it was interesting that all participants in both groups mentioned Chinese tallow as an example. Living material of this plant was brought to lecture and students had the opportunity to recognize this plant outside in their college campus. This finding possibly suggests the value of real-life experiences and the relevance of local examples providing the students an opportunity to establish a personal connection with the learning experience. Thiab was the only participant from the textbook group that used a textbook-based example. Her response was also the most elaborate from the textbook group, as she included the reason why invasive species may be important as a threat. In contrast, all the participants from the CD-ROM group included examples from all sources.

Caleb and Cyrenec gave the more elaborate responses, including various examples and, like Thiab included the effect of invasive species on biodiversity. Caleb’s response also shows a clear gain specifically in the learning of plant biodiversity. For example, the textbook provides
general information about fire ants in relation of their effect to plants, “Their mounds can ruin farm fields…” (Audersirk, Audesirk, & Byers, 2002, p. 830). However, Caleb was able to learn which crops in specific are affected by fire ants, and using his general understating of the crops he knows are grown in his state, to then infer what is the potential danger of fire ants as an invasive species in his state. In the case of Cyrenec, she not only developed an elaborate understanding of invasive species, but also searched for additional information, even though it was not plant-biodiversity related. Of all participants, she was the only one who explored other case studies when working on the activity. These results suggest the CD-ROM had an impact in the understanding that the participants could gain about patterns of biodiversity and threats to biodiversity. It allowed the students to gain additional information, which became part of the schemas they developed regarding the concept of invasive/exotic species as threat to plant biodiversity.

A Comment on the Instructional Tools-- As stated earlier in the discussion of activity six, the textbook and the CD-ROM differ in the focus and quantity of information regarding the concept of exotic species as a threat to biodiversity. The one-page essay “Exotic invaders” (Audersirk, Audersirk, & Byers, 2002) exposed eight examples. Three of these examples were animals that affect plant species: fire ants, gypsy moth, and Asian long-horned beetle. Another three were exotic plants that affect other plants: kudzu, water hyacinths and climbing ferns. The textbook included figures for the first two. In contrast, the CEB CD-ROM exposed five examples. Two of these were animals that affect plant species, and were also included in the textbook: fire ants and gypsy moth. One of the examples in the CD-ROM was an invasive plant. Based on these sources of examples, one may think the textbook could have a greater influence in how the participants developed their understanding. However, it was observed that the participants in the CD-ROM group were able to provide more examples than the participants in
the textbook group. A closer look at the information provided in the CD-ROM can help explain the outcome. While fire ants and gypsy moths are present in both instructional tools, through the case studies presented in the CD-ROM more detailed information is provided regarding what plants can be affected by these invasive species. Another point is that while in the textbook three plants are presented as invasive species, only general information is provided about their impact. In contrast, in the CD-ROM a detailed case study is presented regarding the importance of the loosestrife as an invasive species. In light of the pattern of themes observed in the responses of participants in both groups, it might seem that the more detailed information exposed through case studies may provide the students with a broader framework to develop their understanding, in this case, of the effect of exotic invaders on plant biodiversity.

This finding of the study coincides with the notion stated by Simon (2001) that computer use in the biology classroom is one way of keeping the students up to date in the advances of biology. Such advances are occurring at a faster rate than they are been publish in the textbooks.

Summary of Post-Study Unit

The first post-unit activity was re-visiting the essay question “What are my reasons to conserve biodiversity?” The essay re-visit was completed once lessons five and six and their activities were finished. The similar number of themes overtime within each group suggests students had experienced most of the different plant-biodiversity “ideas” that were appealing to them as a reason for conservation by the end of lesson two, picking only one or two more themes over the remainder of the study unit. The similar number of themes when the textbook and CD-ROM groups were compared suggests that both instructional tools can provide students with a similar framework upon which they could base their reasons to conserve biodiversity. Participants in the CD-ROM group exposed a higher number of statements as compared to the participants in the textbook group, thus suggesting exposure to the CD-ROM possibly enhanced
the arguments the participants could have for conserving plant biodiversity. This could also suggest the CD-ROM enhances the development of attitude/value-based conceptions, potentially influencing the attitude of the participants and the development of their whole conception of plant biodiversity.

The Golden List of Species showed that participants in the CD-ROM group listed three times the number of species as compared to the number of species listed by participants in the textbook group. While participants in the CD-ROM group included examples from the textbook and their own inquiries, the majority of the examples of plant species came from the CD-ROM. Ten different themes were identified among the reasons of interest given by the participants in the CD-ROM group to include the plants in the list. Of these, plant structure was the predominant theme. In contrasts, the textbook group had no examples from the textbook, but rather the majority (7 out of 10) were from daily life, and represented three themes on their interests for including the plants. Aesthetic value was the predominant theme in this case. This suggests that use of the CD-ROM in addition to the textbook had a greater positive impact on the awareness of plant biodiversity among the participants that were exposed to it.

The average scores and change in scores both for the post-study unit period (CM3 vs. CM4) and overall the study unit (CM1 vs. CM4) were higher for the participants in the CD-ROM group as compared to the participants in the textbook group. This suggests using the CEB CD-ROM in addition to the textbook as an instructional tool for teaching about patterns of biodiversity and the threats to biodiversity had a positive impact, thus possibly enhancing student learning of plant biodiversity.

A post-unit quiz was given to all students at the end of the study unit. Results indicate that both, class-wide and at the participant level, scores for students in the CD-ROM group tended to be better than the scores for students in the textbook group.
The SALG survey allowed exploring the change over time of different aspects of student learning that could be affected by the study unit and the instructional tools used, two versions were used one at the beginning of the study, pre-SALG and one at the end of the study, post-SALG. The survey was analyzed in nine main clusters. Analysis of the first cluster, science understanding, indicated students in the CD-ROM group increased in their confidence in understanding the plant biodiversity content of the course, while students in the textbook group lost confidence. Students in the CD-ROM group also gained confidence in developing their own inquiries and giving a presentation, while the students in the textbook group show no change.

Regarding their interest in science, cluster two, both groups showed an increase in an interest in teaching science. Results for cluster three, personal connection to plant biodiversity, indicated a slightly higher number of students in the CD-ROM group were interested in changing their life styles to reduce the impact to plant biodiversity and in promoting knowledge about plant biodiversity. Results for cluster four, activities that facilitate learning, indicated that students vary in their preferences of activities. Of interest for future exploration is if the preference is related to learning styles. Of particular interest to this research and not expected, was that both groups favored the use of computers, however, the CD-ROM group showed an outstanding majority in their preference for computers compared to the textbook group. It may be possible this finding was influenced by the continuous exposure of participants in the CD-ROM group to the use of this tool during in class-activities. This finding coincides with findings for cluster five, resources that facilitated learning, where the use of computer, and the CEB program in particular, was the identified as the preferred resource among the students in the CD-ROM group. In contrast, the number of students that preferred the textbook as a resource decline over time, and the majority of students in the textbook group considered Internet and lecture notes as the top-two highly to extremely helpful resources that facilitate their learning.
Results for cluster six indicate that overall students in the CD-ROM group gain more confidence in their understanding of plant biodiversity concepts compared to students in the textbook group. Mean cluster-wise gains in the high to extremely confident category tended to be higher for the CD-ROM group as compared to the textbook group. Over time, students in both groups gained confidence in plant biodiversity concepts concerning biodiversity and evolution, threats to plant biodiversity, and biodiversity levels. Students in the textbook group gained more confidence in concepts related to plant structure than students in the CD-ROM group did. Thus suggesting that overtime the confidence in understanding plant biodiversity concepts probably was enhanced by the use of the CEB CD-ROM.

Results for cluster seven indicate that overall the use of the CD-ROM influenced the learning gains and attitude towards plant biodiversity of the majority of students in the CD-ROM group. The percentage of responses for the textbook group also seems to favor the use of this tool, but this result is conflicting, since these students were not exposed to the CD-ROM as a learning tool during the study unit. In contrast, results for cluster eight, the textbook as a learning tool, clearly indicate that students in the textbook group found the textbook helped them making learning gains in understanding plant biodiversity concepts a lot to a great deal. However, students in the CD-ROM group diverged in their responses suggesting most students did not considered the textbook to influence their learning gains.

The mean responses for cluster nine of the post-SALG, indicate that students of the textbook and CD-ROM groups strongly belief that after the course they will carry on an understanding of plant biodiversity. Both groups also will carry on an enthusiastic attitude about plant biodiversity, and feeling comfortable about complex ideas. The CD-ROM group had higher percentages in four out of seven items, including understanding of plant biodiversity concepts, the relevance of plant biodiversity to real world issues, being enthusiastic about plant
biodiversity, and feeling comfortable about complex ideas. This suggests that both instructional tools used throughout the study unit had a positive impact on the understanding, skills, and attitudes related to plant biodiversity, while the CD-ROM possibly had an even stronger effect on some aspects.

The overall pattern observed in the results of the survey, where for clusters one through seven the CD-ROM group had higher cluster mean gains than the textbook group, suggest the use of the CD-ROM as an instructional tool in addition of the textbook has a positive effect on student learning. The textbook group had higher mean cluster gains than the CD-ROM group only in the cluster that assessed the textbook as a resource for learning. Cluster mean gains were the same for both groups in the last cluster that assessed what the students will carry on after the course. However, in this case the CD-ROM has higher percentages as well compared to the textbook group for the majority of items assessed, thus suggesting a stronger impact of the CD-ROM as an instructional tool.

Findings for the last interview indicate the total number of learning gains for participants in the CD-ROM group was higher than the learning gains for participants in the textbook group. The same trend was observed for the number of examples used by participants in the CD-ROM group. The origin of these examples came mostly from the CD-ROM followed by the lecture, and then textbook or both. These findings indicate that the use of the CD-ROM possibly helped students earn a better overall understanding of concepts related to global patterns of diversity and threats to biodiversity.

Furthermore, the patterns observed overall the different assessments at the end of the study unit coincide, thus suggesting the CD-ROM as an instructional tool enhances student learning.

Each participant’s propositions during the post-unit interview (Interview #5) and concept map #4 were considered to determine the PBLR level reached. Results suggests that Tanya
reached level 4 and might have some knowledge about threats to plant biodiversity, but some of her statements were vague in this regard. Thiab reached levels 4, 5, and 6, and may be in a good starting point to reach level 7, but needs further experience to do so. Trevic reached level 4, but his responses in relation to threats to biodiversity were vague, so the researcher considered he did not reached level 5. In the CD-ROM group, all three participants reached level 4, 5, and possibly 6. Some participants, Caleb, Cyrenec, and Thiab are in good standing to develop a better understanding of biocomplexity, however, being conservative, they are not at the level of integrating all the different concepts necessary to ascertain they are at this level.
CHAPTER 5

RESEARCH FINDINGS AND DISCUSSION FOR QUESTION TWO:
DOES THE USE OF THE CEB CD-ROM ENHANCE THE STUDENTS’ ABILITY TO
DEVELOP AND PURSUE SELECTED GUIDED-INQUIRY QUESTIONS ABOUT LOCAL
PLANT BIODIVERSITY WITH RESPECT TO THREATS TO BIODIVERSITY?

“Look deep into nature, and then you will understand everything better”
- Albert Einstein

This section summarizes the information to answer the second question explored in this research. The focus of this question was determining if the exposure to the CD-ROM in addition to the textbook may enhance the ability to develop a selected-guided inquiry as compared to students who were exposed only to the textbook.

The data collected to explore this question consisted of several documents. These included the student-prepared Power Point® presentations according to guidelines offered by the researcher, an individual conclusion, a Louisiana Plant Diversity table, a reflection completed after the class presentations, and the interview questions during the last interview.

The Presentations

The goal of the students’ presentations was to have them explore in-depth and apply plant concepts to a Louisiana plant of their choice. In addition, the presentations allowed the researcher to turn on the students’ button of curiosity and initiate the process of discovery (Good et al., 1993). The presentation had to be developed under a main theme applied to the plant of interest. Several themes were listed as options including: unique plants, plants as symbols, medicinal plants, plants of economical importance, ethnobotany, etc. However, the students could choose other topics as long as they checked with the researcher to confirm that it was a valid one. Once the information was shared in class, based on the information they gathered from the classmates’ presentations, the students completed the table “Plants that Contribute to
Louisiana’s Plant Diversity.” The purpose of the table was to help the students create an idea of the diversity and elicit their interest to learn about other plants.

The first three lessons of the study unit provided the students with background information they could apply in the development of the inquiry, (i.e., plant classification and reproduction). Lesson Four consisted of selected concepts from textbook chapters 23 and 24 (See Appendix HH). The researcher applied these selected concepts to a single plant in order to provide a model in the lecture on how to apply the information needed to a specific plant as students developed their inquiries. The lecture model included a section on how the theme-plant was important for plant biodiversity. Guidelines listing the concepts to be included in the presentation were distributed and discussed in class along with the model lecture. The researcher believed that the first part of the guided inquiry would help students open other windows and discover. The sections where students looked for information on classification, distribution, and different aspects of the structure and reproduction of the plants provided an entrance point to other themes or aspects. Students were expected to establish the unique role of their plant in the plant biodiversity of Louisiana by applying concepts such as value, services, threats, and/or genetic variation.

Students had two weeks to complete the projects. Two class periods were dedicated as time to meet in-class and work. In addition, groups were assigned a group page in Blackboard™ where students could exchange e-mail or files with other group members or with the researcher. The day of the class presentations, students completed the table of the Louisiana plants as well as turned in an individual conclusion and a reflection paragraph on their learning experience. All presentations were peer-evaluated, as students in the class had the opportunity to provide written comments about other presentations.
Observations and notes gathered by the researcher during lessons and questions during the final interview, as well as the conclusions and reflections, were used to describe the process of inquiry. In addition, the themes identified by the participants as “what makes the plant important to Louisiana’s plant biodiversity” (Louisiana Plant Diversity table) are summarized for easy comparison between the two groups in Table 34, at the end of the discussion of the inquiries.

The discussion of students’ presentations that follows is centered on the process of developing an inquiry, as described in the Mary Worth Science Inquiry Diagram. This diagram was developed for the Institute of Inquiry (Worth, 1999; see Appendix I I). It offers the picture of inquiry as a cyclical process, with the cycle occurring at different levels, almost spirally.

Tanya

Tanya and her partner’s inquiry project was Native Louisiana Plant: *Magnolia grandiflora*. They met together and started their work right away, deciding to look for possible plants on their own and meet at the start of the next class to come up with their project plant. At that time, they had three options, but both agreed on the magnolia. The partner liked the smell of magnolias, and for Tanya, it represented her botanical sense of place, a way in which people establish a personal connection to plants from a previous experience (Wandersee, Clary & Guzman, 2006). In the interview, Tanya explained her connection with the magnolia:

<table>
<thead>
<tr>
<th>Tanya</th>
<th>The Southern Magnolia, which I have a huge tree right on the side of my house. I did a school project on it – most like history, nothing like this project.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>How you feel about this plant?</td>
</tr>
<tr>
<td>Tanya</td>
<td>It is a pain...in the fall it drops the cones and it’s all a mess…the seeds are all over the place. Then it drops the leaves in the spring, and we have to be raking all the time. But, yes, it’s really pretty.</td>
</tr>
</tbody>
</table>

Once Tanya and her partner had identified the plant, they decided to look for information independently due to schedule conflicts. They used as their project theme “unique plant”, which was the same theme developed in the lecture model. They selected two main reasons why
magnolias were unique plants, choosing this as the theme of their presentation: (a) how they compared to the Asian magnolia, and (b) how it is the state flower. The researcher, however, did not consider the first reason a valid one to label under the theme of “unique”. In contrast, the second reason could be used both as a reason to develop the inquiry under the theme of “unique plants” or under the “plants as symbol” theme.

The process of focused observations and questions allowed Tanya and her partner to explore some of the topics. Each of these topics represented a new question to explore, taking the students from the most general to the most specific. This stage of focused explorations included the required information: classification, distribution in the United States, structure, growth, and reproduction. During this part of the inquiry process, the two worked individually, each focusing on different topics. In addition to information from the text, they collected data from several Internet sources, including images, drawings, and maps. As part of the graphical data, Tanya included an original photo of the tree by her house to show the structure of magnolia trees. In the presentation, they included a 3-D model, as they brought in living and artificial material. This suggests that they probably identified themselves with learning about plants with the hands-on experience they had in the class, and wanted the class to have the same experience with the magnolia.

The process of organizing the presentation and making meaning developed both inside the classroom and during an outside class meeting. Regarding the technology, Tanya was the expert who took control of creating the Power PointR. This process was minimally shared with her partner, so there was not as much novice-expert interaction as would be expected on a group project. About her experience in doing the project, Tanya stated: “I like working on the Power PointR. It gives a chance to be creative. The part that I did not like was going through all the information I had on the plant.” Tanya was also responsible for taking pictures of the magnolia
tree next to her house and bringing both the living and artificial material, in her reflection she also added: “The thing I liked the most was taking pictures of the magnolia tree next door.” Tanya felt overwhelmed about the amount of information she had to handle for the Power Point®. Part of this problem came from lack of support from the partner. As indicated in the project group/self evaluation, the role of the partner was mostly limited to providing some information but was not much help much in organizing it. They had a cooperative type of group learning since the data collection was shared (Linn & Burbules, 1993). However, although Tanya and her partner tried to have a cooperative type of group learning, Tanya felt she had been taken advantage of, as she had contributed most of the information. The interaction between her and her partner was minimal, not resulting in a positive group interaction.

During the process of developing the inquiry, Tanya and her partner did not consult with the researcher/instructor. Interactions with the researcher were limited to report on progress that is, how much had been accomplished, during the classroom sessions. It was mentioned earlier that they used the same theme as the lecture model. This was also evident in one of the slides of the presentation where they describe: “The Southern magnolia is not unique because of the fruit, [as was the case of the lecture-model plant] but for the flower.” In a sense, it was as if they wanted to follow strictly what was offered as a model. This statement was followed by a description of how magnolia flowers are used as a spice or condiment in English cuisine. Even thought they were not “original” in their theme, Tanya and her partner were applying the knowledge acquired in the classroom to a new plant.

Another iteration of the inquiry process led to the pair developing the idea of the Southern magnolia in its role in Louisiana’s plant diversity. Tanya and her partner identified ornamental value due to the beauty of the leaves and flowers. The partner might have found here her botanical sense of place, as she mentioned, “This makes it really interesting for me, because what
I do for business is decoration of social events. I like using the leaves and flowers for arrangements. I also like the smell of magnolias.”

As other reasons of importance, they considered the used of the wood for furniture, veneer, and cabinets. The extraction of an alcohol used to treat malaria, itch, and blood pressure was something unusual and unexpected, representing a discovery moment for Tanya. The use of magnolias as a medicinal plant was one of the examples that Tanya would use later on during the last interview, indicating it had become part of her meaningful learning.

Making meaning from the experience was not only accomplished at the personal level but also as a class. The presentation influenced Tanya positively:

Tanya I would say it gave me a clearer picture on important topics that were covered in class. This way, I could find a plant and research it on my own. It helped me understand better. This was more detailed. You learn stuff that is not in the book.

Her expressions, suggest she enjoyed using other tools that took her learning beyond the information offered by the textbook. In addition, Tanya’s reflection included themes going from the local to the global perspective. A list of the most important things she learned from the presentations included the plant’s medicinal value, how some plants are used for research, and that most plants come from other parts of the world. She also believed, “We can help diversity by planting more plants”.

Being exposed to other presentations allowed Tanya to make meaning at the social level and at a more comprehensive level, (i.e., considering different plants that are part of Louisiana’s plant biodiversity). As described in her presentation evaluations, Tanya liked the experience of listening to other students presentations. She identified the passion flower as her “other favorite”. She pointed out and regretted that other groups did not include more information on how their plants were important to Louisiana’s plant biodiversity: “This was one of the most important
things of the presentations. It is sad some missed it.” Other students considered Tanya’s
presentation thorough. Evaluators considered Tanya and her partner to have reached between
levels one and two of the PBLR with their presentation.

Thiab

The inquiry developed by Thiab and her partner was Diversity of Louisiana Native Plants:
Passiflora incarnata. They seemed to go back and forth a couple of times in the first stage of the
inquiry process (i.e., notice, wonder, explore) before they decided on one plant. They started the
inquiry’s exploring phase right after the first class and determined the subject of their inquiry
would be a native plant. However, they were somewhat frustrated after looking on the Internet
after their searches were not successful. So, by the next class period, they visited the researcher’s
office to ask for advice. At that time, they were advise to use of any of the sources brought to
class before, find from the LA Wildlife and Fisheries, the Horticultural Extension, visit the
College library’s and use the Encyclopedia of Biodiversity, or use the plant field guides in the
biology laboratory. During the next class period, they decided to use the field guides that were
available in the biology laboratory. They still were not feeling strongly about their decision and
went back to the researcher’s office, having noticed earlier that there was a plant poster there.
The researcher allowed them to browse it since it is a poster of Louisiana’s native wild flowers.
From the poster, they selected some names of “pretty plants” and then went to the computer
laboratory to look for plants on their own.

The second stage, take action and extend questions, began as they identified their project
plant and began looking for the information. The reflections of Thiab and her partner, as well as
the post-interview with Thiab revealed how aesthetic value (a visual cue) played a role in their
decision, along with the curiosity for the unknown:
Thiab  We did the passion flower. We picked it because it was very pretty, and my partner wanted to do a pretty plant that was not usual, so we could learn something different.

Partner  I wanted something unique that stood out from just plain trees, something that would stick in everyone’s mind. I really loved the colors and shape of the flower, really unique.

Later in the post interview:

Researcher  When looking at the other students’ evaluations for your group, it actually shows how others liked the plant for being pretty.

Thiab  Really! That’s awesome, because we worked really hard to get it done.

Unlike Tanya and her partner, Thiab and her partner collaborated more as a group; they also tutored each other in the needed technical skills, thus showing one of the ways in which students are benefited from group collaboration (Linn & Burbules, 1993). They looked for some information on their own but then met to go over it during the research period in class, making good use of their time. They also both met additional days to work on the computers in the College’s library in order to prepare the Power PointR presentation. A novice-expert interaction was observed at different levels. While Thiab was more of an expert in looking for information on the Internet and in selecting the important information, her partner was more of an expert in the Power PointR skills. However, interestingly, this did not exclude either one from doing some of the alternative tasks (i.e., Thiab trying some slides of the Power PointR). The researcher believes they benefited from trying to work together all the time and from their consultation with the researcher, who helped them as a mediator (Tobin & Tippins, 1993).

During the phases of focused observations and focused explorations, Thiab became frustrated. She pointed out she was finding a lot of information for other passifloras but almost nothing for the species she had: “There are so many different species of the same genus! There is interesting stuff, and you will be like, ‘oh yes, I’m using this’…but then you find out is a different species in the same genus.” The researcher spent some time with them – one-on-one
support – observing how they were looking for the information and what type of information they were finding. By inviting the researcher to the library to answer some questions while they were meeting, they allowed the researcher to be their mentor outside of the classroom. This opportunity allowed for two important aspects of constructivism to surface. First, the researcher in her teacher role was able to play a mentoring role stimulating the curiosity, research, and discovery that allowed Thiab and her partner to gain knowledge. This supports the perspectives about developing scientific knowledge presented by Good et al. (1993). Second, the researcher was able to guide Thiab and her partner’s discovery by using her expertise as a plant biologist, thus developing another level of expert-novice interaction. The researcher was able to help Thiab and her partner to somewhat “zoom-out” in their exploration’s focus, and reduce the frustration, as they discovered that characteristics they were finding at the family or genus level would also apply to their plant. In addition, it was reiterated there were other aspects of the required information that they could figure out by applying the concepts from the textbook to any image or description of their plant. This, in fact, was a general observation, not only for Thiab’s inquiry journey but also for other students in both classes as well. Many students expected to find a source with the exact information they needed to complete their presentations, rather than applying some of the information from the textbook as expected. On more than one occasion, the researcher had to remind the students they had the general information in their textbooks, and along with either a good image of their plants and/or a good verbal description, they should be able to apply these concepts to their plants.

In their focused explorations Thiab and her partner included the concepts required according to the guidelines distributed. They included additional information on how to grow a healthy plant. In going one more round in the exploration-observation-take action phase, they were to address the issue of how the passion flower was important to Louisiana’s plant diversity.
However, at this stage, they stayed too broad. They included very interesting themes ranging from the perception of the shape of the flower as a religious symbol (crucifixion of Christ) to utilitarian services, such as its use in beauty products, food (fruit or juice), and inspiring art. The discovery of the flower as a religious symbol was an unexpected finding for Thiab, and she would use it as an example in following interviews. However, none of these directly addressed the role of the plant in Louisiana, which was the goal of the section. For example, they could have looked for more information about its role as a wild species and possible ecological interactions or functions. Perhaps time and the resources used were a factor. All their resources were from the Internet (17 references). This suggests the absence of such information specifically related to Louisiana’s native species in an important source of information that could be at hand to many students interested in learning about the native flora.

As part of the graphical information, they included maps, drawings, and pictures. None of these was original. The stage of making meaning was, in as sense, progressive as they made strides in completing the project. In her reflection, Thiab highlighted the importance of utilitarian uses of plants and plant distribution as part of her learning:

Thiab I like the most the interesting knowledge I gained. The fact that [passiflora] produces a fruit used in juice and also has medicinal value…it puts you to sleep and eases your tension and stress…The project helped me understand about the U.S.’ [United States] diversity, because I realized that many of the southern plants don’t grow in North U.S.

From her exposure to other class presentations, Thiab’s favorite was the magnolia (discussed earlier) and her second favorite was the water lily. About the presentations, she said, “I liked [how] they [magnolia group] passed around a model and you could see the characteristics up-close”. When asked about her perceptions about Louisiana’s plant biodiversity, she stressed the aesthetic value first but also the interdependence of plants to survive.
Other students considered Thiab’s presentation very good, and she captivated the students with the beauty of the flower and the fact that it was a religious symbol. Evaluators considered Thiab and her partner to have reached level one of the PBLR.

**Trevic**

The inquiry and theme developed by Trevic and his partner was Black gum (*Nyssa sylvatica*): a native Louisiana species. They started the first phase of the inquiry process in the first class period that was designated for group-project work. They felt kind of lost and sought advice. The researcher gave them several options, as with Thiab’s group:

Trevic We knew we needed a plant…a species to present, and had no idea where to look for. We asked for suggestions. That’s when we got a hold of the booklet, and we just picked one from there.

Trevic and his partner picked the black gum from the *Pocket Guide for Louisiana Native Trees* (Friends of Hilltop Arboretum, 1997).

Once Trevic and his partner had identified their plant, they moved on to the focus-exploration phase where they looked for the information according to the topics listed in the guidelines. Some topics were not covered for example, monocot vs. dicot type of leaf, suggesting that they were somewhat limited as they unfolded the inquiry. These questions probably emerged, and they could not find an answer, but unlike with Thiab, Trevic did not seek advice from the researcher/instructor. The interaction was limited in terms of informing the researcher about progress and how much had been accomplished. In addition to the required topics, Trevic and his partner looked for all the different common names for black gum. When asked during the presentation about what they found interesting about all the common names, Trevic’s partner stated: “[it] Tells you why the scientific name is important, you know, since the name for the same tree varies so much.” They also had information about the type of soil where black gum grows best.
It is not clear if Trevic and his partner developed the last required inquiry, identifying the role of black gum in Louisiana’s plant biodiversity. They discussed its value as an ornamental tree such as, color and density, how it attracts wildlife, and the disadvantages of the tree from an anthropogenic perspective (i.e., fruit litter, bird droppings, irregular and slow growth). However, they did not identify this set of information as such, neither did they have any specific comments about Louisiana. Other students in the class shared this perception.

The stage of making meaning from the experience was very succinct and shallow. Although Trevic and his partner used ten different websites to collect their data, it seems they just had an incomplete collection of facts but did not “mentally” process them. When asked about the most important aspect of their plant, they did not answer. On a positive note, working on the presentation helped Trevic to polish his skills in PowerPoint. In the reflection, Trevic stated he liked the most working on the PowerPoint presentation, but he did not like the process of collecting the data. In the last interview, Trevic stated, “I liked learning about my plant and about others too. I liked the passion flower because it was pretty.” The statement about liking learning about his plant was somewhat puzzling, in light of his reflection’s comments, where he had stated not liking finding the information. It suggests he is possibly used to receive information, rather than taking an active role in inquiry approach to learning. Trevic and his partner worked in a collaborative type of group learning (Linn & Burbules, 1993).

Other students considered Trevic’s presentation good; three said that it could be improved. The class missed their contribution on the importance of this plant to the diversity of plants in Louisiana, although it could be argued Trevic and his partner stated it as being an ornamental plant. Evaluators considered Trevic and his partner to have reached level one of the PBLR.
Carla and Cyrenec

This group was different because it consisted of two participants and a third partner. Although groups of three were discouraged, the two participants had worked in two different groups for another class project and felt other group members had taken advantage of them. They were allowed to work in a group of three but had to look for information on two plants.

They began their inquiry process by meeting in the library after class to explore possibilities. By the next class, they had a list of three plants, including strawberries, iris, and aloe vera. Their curiosity was driven because of the beauty of the iris, the medicinal value of aloe vera, and their love of eating strawberries, which are grown in Louisiana. They managed to keep strawberries since another group already took the iris, and aloe vera is not a Louisiana plant, so it was eliminated from the list. They asked for advice on where to look for information, so they were directed to the same possible sources as participants in the textbook group (Thiab and Trevic). An Internet search led them to the poppy mallow plant, which was approved for being a Louisiana wildflower. Therefore, they decided to develop two themes: native Louisiana wildlife and a species of economic importance to Louisiana.

Once they had their plants identified, Carla and Cyrenec moved to the phase of focused observations and questions, breaking down the material they needed to research. They made a plan to find some information on their own and get together to organize it. They used meeting time to put the information together into the required Power Point presentation. In this skill, Cyrenec was the expert helping Carla. They both shared good organizational skills. They work progressively; after meetings, they would make a list of what was left to do so they could focus on the next step. Carla and Cyrenec developed a cooperative-collaborative group interaction, while their interaction with the third partner was more of a cooperative interaction, which fell short towards the end of the project.
In trying to establish the importance of strawberries to the plant diversity in Louisiana, they decided to do something unique and contacted a strawberry farm. They also interviewed Louisiana’s strawberry ambassador. This experience gave them more information than they ever imagined:

Carla  This was [Cyrenec’s] idea. But meeting Ms. Lucy, who’s 87 years, was a great experience! She received us with warm homemade bread and strawberry preserves. She went out to the field with us and told us everything about growing strawberries.

Cyrenec We were able to take pictures and learn about the whole plant, leaves, flowers, fruit, runners…everything. We learned it first-hand. Having this experience was much more than getting information from the books or Internet.

This was a unique novice-expert interaction that provided both participants with the learning experience of a lifetime. When asked what motivated them to go to the farm, they answered,

Cyrenec  Never have been to one, thought this was a good opportunity to do it. Also, we wanted to do something unique, high quality, for our presentation. Originally, we even wanted to even include a video, my husband was going to help me, but it got kind of complicated.

Carla  We looked for a day that will accommodate everyone and contacted Ms. Lucy. Got together after school, Cyrenec got her baby, and we just went!

In their presentation, they provided the role strawberries have in Louisiana’s economy. In addition, they considered the medicinal and nutritional value of strawberries. The medicinal value and the tremendous impact on the economy were two unexpected discoveries in the information they gathered in their search for understanding. From their wildflower they learned about the projects to keep wildflowers in the roads, as they not only provide beauty but also interact with other species, even through they look insignificant.

As partners, and a part of the class, both Carla and Cyrenec were able to create meaning on their own. For Carla, it made her realize that biodiversity is everywhere:
Carla  We have more plant biodiversity than I expected in Louisiana. Maybe I did not notice it before. I realize I can contribute by making others aware we are part of biodiversity. We depend on it in many different ways, medicines, food, and the beauty of our wetlands.

Cyrenec stated a variety of themes in her reflection about Louisiana’s plant biodiversity, including aesthetic, economical, medicinal, and ecological. Carla’s other favorite plant was the Louisiana flag iris, and learning this was the wildflower state symbol was something new. Cyrenec’s other favorite plant was the water lily, which se learned you can pop and eat its seeds.

In her general view about the importance of plant biodiversity to Louisiana, Cyrenec stated, 

Cyrenec  [It]Is important because it attracts tourism for our beautiful state…

As we learned from our chosen plants, we learned to form a relationship with them, a connection. Some of us did not even use to notice what was around us. After this class experience, we will never see plants in the same way. I think we all gained consciousness of protecting them.

According to the group evaluation, both participants stated the process of data collection and organization was mostly shared by Cyrenec and Carla, with the third member contributing a minimum amount of the information. The third partner did not participate either in any of the meetings where they worked on the Power Point® because she was absent from class, nor could she attend the last session the other two had together. Carla and Cyrenec even took off from work to be able to meet and get the work done.

Other students in the class evaluated this presentation as excellent: “It was very thorough. I really liked they brought a plant and real strawberries. I learned stuff I did not know about strawberries.”

Evaluators considered they had reached level one of the PBLR.

Caleb  

The inquiry and theme developed by Caleb and his partner was Duckweed: “Extreme Case”. Caleb knew that he had to work on a plant project as part of this study unit, and he had
identified his theme when he was exposed to his plant of choice in a previous lesson. As soon as the guidelines were distributed, he found a partner and presented the theme to his partner, who agreed to it. Caleb was motivated by his botanical sense of place and a discovery made in class:

Caleb I chose duckweeds because I was thinking about what I see when I go to the house boat – in the swamp – it is everywhere, is part of my leisure time. I grew up with it. Now coming here and learning in class that was the smallest flowering plant in the whole world, that was something, I said, wow!...did not even know those things had flowers! I think that’s when I decided I wanted to know more about duckweeds.

Caleb and his partner divided the work and proceeded with the phase of focused explorations immediately. This stage allowed them to explore the different topics to be covered in the presentation. Caleb and his partner developed a cooperative-collaborative group (Linn & Burbules, 1993). Since Caleb had a demanding part-time job, it was important for him and his partner to come up with the necessary information and use class time to put the presentation together. In the computer laboratory, they were both involved part of the time in looking for information and part of the time in preparing slides that they merged afterwards. Their data collection was simple. They used one Internet site and two books. They included some of the information required in the guidelines, but also left some information out for example, details on the flower. However, they included additional specific information of the tissues, which was an important and relevant aspect of this aquatic plant. Their data included maps and images, none of which were original.

In the process of making meaning for Louisiana’s plant biodiversity, they pointed out the plant’s use and nutritional value, but they failed to specifically address the importance of duckweeds in Louisiana’s plant biodiversity in the Power Point®. At the end of their presentation, they were asked about this; Caleb responded:

Caleb Like I mentioned in the presentation they have a role in water purification in our swamps. I have noticed this when I am fishing. They also make the
whole are a very pretty, adding to the beauty of our swamps, along with the many other plant species that live there, the cypress and the Spanish moss. They are also part of the food webs; the egrets and some fish eat it, too.

The nutritional value was, in fact, a new discovery, unexpected information, that impacted him and other classmates as well. In his reflection of making meaning of Louisiana’s diversity, he stated he liked learning about other Louisiana plants. He had no idea how important for the state’s economy strawberries were, and he certainly enjoyed the samples. He also liked learning about other aquatic plants, like the yellow water lilies. He thought there were some presentations that were not as strong and could have been improved. He also pointed out how neat it was that the pink rainy lily group brought additional original pictures they took of their plant to pass around, which is something he did not think of.

Other students found Caleb’s presentation interesting, good but short, and that it needed more information. The protein content of the plant (as much as soybeans per area) caught the attention of other students as well. Evaluators considered Caleb and his partner had reached level one of the PBLR.

**Louisiana Plant Biodiversity**

The information gathered by the participants about the different Louisiana plants presented in class is summarized in Table 34. The importance of the species to Louisiana’s plant biodiversity was summarized as the themes the participants considered important for each plant presented in the class (all presentations). More than one theme could be attributed to the same plant. Students were also asked to identify if the plant represented a threat or was threatened.

In both groups, the class described six plants and families. The number of themes describing the importance of the plants for Louisiana’s plant diversity was similar in both groups. The responses from the textbook group’s participants included two more themes that is,
Table 34. Summary of Reasons of Plant’s Importance to Louisiana’s Plant Biodiversity for the Textbook and CD-ROM Groups.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Textbook</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td># families</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td># species</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Species represents a threat</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Species is threatened</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Importance to diversity</td>
<td>(n = 21)</td>
<td>(n = 28)</td>
</tr>
<tr>
<td>Ornamental value</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Folk medicine</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Ecosystem function</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Chemical – poison</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Symbol</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Economy</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

*Note.* N indicates the number of responses. Themes of importance are presented as sum of percent of participants responses.

chemical-poison and environmental problems, as compared to the responses from the CD-ROM group’s participants. All participants in the CD-ROM group were able to identify at least one reason for each plant to be important; however, one participant in the textbook group did not attributed importance to one of the plants. The frequency that any reason was given as importance of the plants for Louisiana’s plant diversity was calculated from the total times a value was identified divided by the total of responses offered in each group (N). For the reasons that were exposed by both groups, this frequency was always higher for the CD-ROM group as compared to the textbook group.
These findings suggest that possibly the CD-ROM group’s participants were able to identify more reasons of importance in the plants they were exposed to as compared to the participants in the textbook group. However, that may be due to the plants that were part of the presentations.

**Summary**

Gathering the information to prepare the Louisiana Unique Plant presentations allowed the students to experience human constructivism and to be empowered by taking a role in their own learning. It allowed them to explore a large quantity of material in a short period of time because it was focused on one species. The approach of reducing the amount of material in the curriculum is one of the recommendations of the AAAS (2001). The researcher also believes that focusing allowed exploring the most important aspects of the plant unit in a way that was meaningful to the students. The design of this activity also followed Bybee’s instructional model, providing all five stages: engaging, exploring, explaining, elaborating, and evaluating, which are part of the constructivist process (Bybee, 1966).

When comparing at both the textbook and CD-ROM groups, the way students were able to perceive the local biodiversity seems to be similar for both groups. They were exposed to the same number of families and species of Louisiana plants. The plants and information gathered was not conducive to explore in more depth the problem of threatened species. The theme “threats”, like other themes summarized in this section, was dependent upon the species that were originally selected by the students in both groups. When the data was examined, there is certainly no indication of a difference between the groups in regard to the species that are threatened or that represent a threat. Although the number (examples) in each of these categories varies, there were two, total, for each group.
Exploring the themes selected by the students as representative of plants that are part of Louisiana’s plant biodiversity could possibly give an idea of whether using the CD-ROM enhanced the student’s ability in the quest for this information. The number of themes identified by both groups was the same (n = 5), and each group had one theme that was not identified by the other group. The largest differences in the times a theme was identified were for the plants as symbols and medicinal value of plants. The theme of chemicals – toxin was identified in the textbook group, as one of the plants presented was poison ivy (not by a participant, but another student; therefore, inquiry not discussed). The other different theme was economy, for the impact of strawberries on the state’s economy. Therefore, it may be argued that students in the CD-ROM group did slightly better in identifying themes that make a plant important to Louisiana’s biodiversity, keeping in mind that the types of plants discussed can also affect this outcome. It is also important to point out here that all participants in the CD-ROM group were able to establish the importance of the selected plants to Louisiana’s plant diversity during the presentations. This was not the case in the textbook group, where only some of the participants established the role clearly, resulting in the lower number of instances that these were identified in the textbook group as compared to the CD-ROM group (see Table 34).

The patterns in performance of the range of participants through the different phases of the process of developing the inquiry can provide some insight on the possible effect, if any, of the instructional tools to which they were previously exposed. One should keep in mind the inquiry process is unique and personal. The first phase, “noticing wonder, and explore”, in other words, what drives the curiosity of participants in the textbook group, in one case was the botanical sense of place or a previous/existent relation with the plant. In the other two cases, it was a search that was not successful until guided by the researcher. In the CD-ROM group, there was also an instance of botanical sense of place. The other participants were part of the same group
and looked independently for their plants until they had to modify two of their three examples because it was already the theme for another group or was not a Louisiana plant. It seems in this phase, the CD-ROM group was slightly more independent than the textbook group.

The second phase can be summarized as “taking action, finding their own pathway, and developing an understanding”. In terms of group dynamics, for two of the three participants in the textbook group, this phase proceeded independently, or without much interaction with the researcher, except to indicate progress in the inquiry. Through the evaluations and reflections, it was noticed that in Tanya’s group, the work was mostly done by one person; another group (Trevic) left important information not covered; and Thiab’s group work diligently seeking advice from the researcher on one or more occasions. In the CD-ROM group, Caleb’s group worked independently some of the time, but this time, the participant and his partner shared the work fairly, unlike to Tanya’s situation. Carla and Cyrenec shared two plants in an original group of three. The third person in that group contributed minimally, like in Tanya’s group, but with two functional members, it did not hinder the development of the inquiry in spite of the overload. When comparing the process of unfolding the questions, following more focused explorations and collecting the data that was part of the presentation, there are some pieces of information that were the same across all participants, merely because these were part of the guidelines. Some themes, though, were developed as a choice of the participants, out of their curiosity (see Table 35). However, they do not reflect exceptional differences between the two groups.

Perhaps the differences are in the amount of text, the information used to describe these themes. To explore that possibility, a content analysis could be done, but this is a line of research that can be explored more in depth in the future. Another possibility concerns is the techniques employed during the process of data collection. In the case of Cyrenec and Carla, an interview as part of the
data collection was an interesting and unique ways of acquiring the data. In part, this also reflected their positive attitude towards their learning, again, even though they had a slightly bigger load.

Table 35
Summary of Themes Developed as Part of the Focused Exploration During the Process of Inquiry in Each Group.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Textbook</th>
<th>CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Origin/distribution</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>General characteristics</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Anatomy (structure)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tissues</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Reproduction</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Uses</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pest</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Symbol</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Economical value</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nutritional value</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Medicinal value</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Growth conditions</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

The phase of making meaning is attributed to the late stages in the project. This included getting ready to share the information with the class, presenting the themes, and making meaning about Louisiana’s plant biodiversity as a class (see Table 34). No outstanding differences were
observed here in terms of the themes. However, there were differences in the ability of the
participants and other students in entering a metacognitive phase and being able to identify the
role of the plants in Louisiana’s diversity. This type of information was not “readily available” to
them; they had to apply their findings and their knowledge in light of their previous experiences
in their learning of plant biodiversity throughout the study unit.

In any of the topics discussed above, the CD-ROM does not seem to be an activity that
negatively influences the learning. Instead, if an effect is present, as judged by the slight
differences, it is a positive one. If anything, it helps the students develop these themes rather than
act a negative influence in the process.

The argument regarding the use of educational technology in a constructivist approach has
gone in two directions. Some think it may limit social interactions, with the risk of becoming
didactic (Fraser & Deane, 1999). Others believe it actually supports constructivism (Gance,
2002). In the case of teaching about plant biodiversity in a constructivist environment, the
researcher will argue the computer technology served as an enhancer of the process of learning.
It supported student learning for all students as they developed their inquiries. Furthermore, for
those exposed to the CD-ROM as an instructional tool, it probably stimulated their search for
knowledge as suggested by the themes they explored and the themes that helped them establish
the role of plants in Louisiana’s plant biodiversity.
CHAPTER 6

RESEARCH FINDINGS AND DISCUSSION FOR QUESTION THREE: CAN A RUBRIC BE DEVELOPED AND VALIDATED, BASED ON THE HISTORY OF THE BIODIVERSITY CONCEPT, WHICH DIFFERENTIATES COLLEGE STUDENTS’ PROGRESS AND LEVELS OF UNDERSTANDING OF PLANT BIODIVERSITY?

“Scientists will welcome the history of science only when it has been demonstrated that this discipline can add to our understanding of science itself and thus help to produce, in some sense, better scientists.”

I. Bernard Cohen.

This section summarizes the information to answer the third question explored in this research. First, I created a time-line based on the historical development of the concept of biodiversity. Then, I present each level of the rubric and explain the basis for its development. The last section describes the findings of the rubric validation process by a panel of experts.

Time-line: History of the Idea of Biodiversity

When I decided to make the history of the concept of biodiversity the foundation for the plant biodiversity rubric, I was not aware of the challenges it would present. First, there is a very broad source of information related to biodiversity, including multiple Internet sites, books, encyclopedias, and official government documents, among others. Second, the concept itself is complex, nourished by many different branches of biology, so its interpretation and importance somewhat varies according to the area. Third, there are two different ways in which “history of biodiversity” can be approached: (a) from the evolutionary perspective of life or (b) as the history of the concept from an ecological perspective. The evolutionary perspective also offers two sides of a coin. Biodiversity can be examined as the history of the evolutionary development of life forms itself, or as the historical development of ideas for understanding and explaining such. The latter is the way most sources in the extensive literature review will approach it. Fourth, except for providing an approximate time when the concept was coined (1980s), its
complete development from the ecological perspective has not been historically accounted in a linear fashion by any single author. Therefore, I decided to create a time-line that summarizes the events that led to develop biodiversity as a concept. I started with an evolutionary perspective and integrated the ecological perspective throughout the development of the idea of biodiversity. In addition, I included the most current position and advancements related to this concept in the scientific discourse. Given that the focus of my research is on plant biodiversity, I included in the time-line events that specifically contributed to the accumulation of knowledge information about plant biodiversity. An alternative approach could be constructing a parallel time-line about the development of the diversity of life itself, including those changes taking place now and predicted for the near future. However, I limited the focus because I considered this more comprehensive alternative out of my scope.

In my search for information, I discovered biodiversity is a dynamic concept. It is nourished as new advances in technology offer new information comprising from the molecular level to organisms, from small areas to vast and previously unexplored regions of our planet, from threats to conservation. More than that, this concept has further evolved to become interdisciplinary, influencing and comprising not only the field of biology, but also the fields of geography, economics, and sociology. Following is a recompilation of dates, events, philosophers, and some of the scientists that have been important for the evolution of the idea of biodiversity.

The Ancient Greeks

500s B.C.E. – It was the Greek philosopher Anaximander who possibly provided the first insights into the origins of the diversity of life when he speculated that the world’s organic forms evolved from a formless condition (National Academy of Sciences [NAS], 1998). In addition, he believed there was a transformation of aquatic species into terrestrial ones.
400s to 300s B.C.E. – Plato and Aristotle recognized the diversity of life by acknowledging there were different species (Potts, 2004). They were the first to attempt describing all species and had a system to organize these into categories. Aristotle’s ideas of classification of species are developed in the area of metaphysics. The lowest level is the species, which were defined “by giving a genus (genos) and its differentia (diaphora)” (Smith, 2004, section 7.2, para. 1). The genus was the kind of the species and the differentia gives the particular characteristics of the species. Species are then organized into categories, katēgoria ("predication"). These categories would consider general information about something and could be of three types: (a) kinds of predicate (which could be divided into ten different classes); (b) relation of predicate to subject (i.e., “is human” is a different descriptor than “is literate”); and (c) the highest level in a list of genera, (i.e., “Socrates is a human, a mammal, an animal, a living being”) (Smith, 2004). In this example, “living being” would be the category. The categories were arranged in a linear, gradual fashion of growing superiority in Scala Naturae, with the human being the ultimate perfection (Potts, 2004).

Even though different species were recognized and categorized, Aristotle had a static view of diversity. Species were fixed and did not change; only linear relationships were conceived. In the view of the philosophers, nature was in perfect equilibrium or balance. Aristotle believed in a metaphysical harmony among species and their environment (Naeem, Loreau, & Inchausti, 2002). Nature was perceived as always being in perfect equilibrium. All entities were considered to be made up of earth, fire, water, air, and fifth essence. Therefore, environment, habitat, and individual were considered one (Naeem, Loreau, & Inchausti, 2002). This view was conserved until the seventeenth century. The concept of change did not appear until much later with Darwin (Potts, 2004). However, this comprehensive approach to biodiversity was not fully recognized.
and expanded into a multidisciplinary viewpoint until the start of the twenty first century, as the concept of biocomplexity arises (discussed later in this chapter).

Aristotle made important contributions to the idea of plant biodiversity from a practical and influential standpoint. He is attributed establishing the first known botanical garden (Brooklyn Botanical Garden [BBG], 2006). He was the teacher of Theophrastus, who lived from ca. 372 to about 287 B.C.E.. Theophrastus was the author of two books, *On the History of Plants* (*De historia plantarum*) and *On the Causes of Plants*, (*De causis plantarum*) (Sengbusch, 2003). The first one is considered the oldest thesis of pure botany and includes the description of 480 plants (BBG, 2006). These two books earned Theophrastus recognition as the "father of botany" and "father of taxonomy" (BBG, 2006; Sengbusch, 2003). Although Theophrastus used the species concept in a rudimentary way, he laid the ground to the developments in plant taxonomy that took place in the Common Era.

**Biodiversity in the Common Era**

**1600s to 1700s, Advances in Classifying Plant Biodiversity:** During this time several naturalists, like John Ray, Pitton de Tournefort, and Carl von Linné, made important contributions to the knowledge of plant diversity and the field of botany by establishing the classification of many plant species. John Ray, an English naturalist, was the first one to distinguish between monocots and dicots. In 1703 he published *Methodus Plantarum* where he proposed a classification for nearly 18,000 plant species. Pitton de Tournefort, a Swiss botanist, developed the concept of “genus” as used today. Up to this point, there was no systematic way of naming species. Later in this period Carl von Linné (Linnaeus) established a system of binomial nomenclature for plants and animals that broke the traditional viewpoint of linearity dating back to Aristotle’s *Scala Naturae*. For this reason, Linnaeus is considered the father of systematic
biology. His work, *Species Plantarum* (1753), was the starting point for the naming of plant species.

**1800s, The Foundation of Evolution as Source of Biodiversity:** This century witnessed major contributions in classification of plant biodiversity. The Swiss Augustin Pyramus de Candolle compiled the first seven volumes of *Prodromus Systematis Naturalis Regni Vegetabilis*, where he attempted to describe and classify all known species of seed plants (BBG, 2006). His son added ten more volumes to this work. Pyramus de Candolle is attributed with being the first to note the major trends of floral evolution in the flowering plants and to coin the term *taxonomy* in 1813.

More work in the classification of plant biodiversity comes from the French Antoine Laurent de Jussieu who differentiated the liverworts and mosses and separated them into two groups (BBG, 2006). He was also the first one to organize the classification of flowering plants by grouping genera into families. Laurent de Jussie is also known to be the founder of the Musée d'Histoire Naturelle de Paris, today the largest herbarium in the world (BBG, 2006).

Another contribution in classifying the diversity of the plant kingdom comes from Sir Joseph Dalton Hooker, who was the second director of the Royal Botanic Garden at Kew in England. He participated in the colossal compilation of *Genera Plantarum*. This work accounts for most of the plant families as we recognize them today (BBG, 2006).

It is in the 1800s when the studies of the diversity of life transcend the taxonomical perspective and profound influence of Aristotle’s postulates of fixed, perfect species and opens up to the perspective of evolution. The leading figures were Charles Darwin and Alfred Russell Wallace. They both noted that even the individuals of a single species will show differences, and this variation could be inherited. Wallace and Darwin jointly proposed evolution by natural selection as the mechanism to explain this variation among living organisms: the diversity of life.
Their ideas provoked controversy after Darwin’s published *On the Origin of Species* in 1859. However, Darwin’s work gave biologists a mechanism to explain that species were capable of change rather than being static entities. Since then, the diversity of life has been considered a result of evolution (NAS, 1998).

Darwin himself struggled with the idea of the source of variation among individuals and the mechanisms for passing the information from parents to offspring. The answer, never known to Darwin, had been in the work of Gregor Mendel, published in 1865. Mendel’s work with pea plants provided the necessary information about the mechanisms through which traits were inherited and passed on, the ultimate source of variation or diversity among living creatures. However, this information was not given proper attention until 1890 when its discovery prompted a renaissance in genetics.

Moreover, A. R. Wallace’s contribution to the knowledge of diversity provides a geographical perspective, which actually started what is currently known as the science of biogeography (Bryant, 2002). According to the principles of biogeography, the diversity of life varies in six to eight different regions of the world. Climate is one of the factors that, according to Wallace, played a major role in the accumulation of species. He argued that tropical areas had more species due to the constant climate present over long periods of time. In contrast, lower species diversity in the temperate areas or the poles were due to severe conditions, such as glaciations, which could lead to extinctions (Schluter & Ricklefs, 1993).

The Twentieth Century: Big Leaps for the Idea of Biodiversity

1920s, Evolution and Area – Early on, a geographical and evolutionary perspective for diversity is observed through the contribution of plant systematist J.C. Willis, who in 1922 published the book *Age and Area*. In this book he presents an interrelationship between diversity, the age of a geographical region, and the phenomenon of macromutations or saltation. Willis
argues that in a given geographical area species will accumulate over time. This phenomenon takes place as new species arise through macromutations. These new species will originally be rare, but as they adapt to the environment, they become more abundant and spread.

1930s, Re-discovering Mendel and the First Accounts From Ecology – Advances in the idea of diversity during this decade included the areas of evolution and genetics. In addition, for the first time, ecological thoughts started to play a role. In the area of genetics, approximately fifty years after the publication on Mendel’s paper, scientists finally established a connection between genetics and evolution, and recognized mutations as sources of variation among organisms (NAS, 1998). This helped to develop more understanding of the process of speciation itself.

During this decade, and perhaps throughout the first half of this century, the diversity idea was not a main focus in the field of ecology. However, there were important contributions coming from this field as new questions arose and more research was developed. One of such questions was what could explain the presence of different species in the ecosystem. Mathematical models were developed in the early 1930s by scientists such as Lotka, Volterra, Gause, and Nicholson, which helped explain the phenomena of species interaction. A significant contribution in the development of the concept of diversity in the ecosystem was the principle of competitive exclusion. According to the principle, species with very similar requirements would compete strongly and would not be able to coexist. This idea was tested and supported in the laboratory, but field-testing took place later (1950s to early 1960s).

1940s to 1950s, DNA: Ultimate source of diversity – The main contribution to the diversity concept during this time comes from the area of genetics. While diversity was not an important focus of the ecological discourse during this time, there were some contributions from this field.
Molecular genetics is considered the basic source of all variation, and ultimately evolution (NAS, 1998). DNA provides the necessary information to place organisms into a common evolutionary family tree, the “tree of life” which represents biodiversity (NAS, 1998; Potts, 2004). Therefore, an important event of these decades that needs to be considered is the scientific research that focused on gaining information about the molecule of DNA. Many scientists, such as Chargaff, Franklin, and Wilson contributed the pieces of the puzzle, which was solved when, in 1953, Francis Crick and James Watson proposed the model of the DNA molecule (Access Excellence, 1998; Buchanan, 2001).

During the 1940s and 1950s, species diversity was not highly regarded in ecology discourse. Ecologists then were more concerned about dynamics of populations and the functioning of ecosystems. In the 1940s, when Lack proposed the idea that resource partitioning between species allows their coexistence, some attention was given to diversity as species interactions in the context of community ecology (Schluter & Ricklefs, 1993). Another ecologist, Hutchinson, extended this idea in the late 1950s to include a multidimensional niche that allowed for the division of resources. These ideas were refined and field-tested by MacArthur during the latter part of the 1950s and in the 1960s.

**1960s to 1970s, Patterns and Phenomena: Beginning of an Ecological Perspective for Biodiversity** – During these two decades, the field of Ecology experienced great advances in the area of community and population ecology, fostering the development of the concept of species diversity. MacArthur applied Lack and Hutchison’s ideas to the problem of species diversity. Historically, species diversity has been considered the number of species in an area. MacArthur’s work, for the first time, gave a new perspective of species as functional, interacting entities of the community (Schluter & Ricklefs, 1993). Community interactions, mainly competition, and the complexity of the environment began to be considered as the driving factors shaping diversity.
There were three main ideas about species diversity supported by ecologists during this time: (a) higher species diversity is associated with less community stability and lower chance for invasions; (b) stronger interactions between species leads to higher stability of the communities; (c) random environmental changes reduce the coexistence of species (Schluter & Ricklefs, 1993).

In addition to MacArthur, many scientists played a role in the development of the species diversity concept during this time. These include Levin, Vandermeer, May, Tilman, Pacala, Pianka, Terborgh, and Diamond, among others. Their work in different areas led to a better understanding of the interactions between the complexity of the environment and species diversity (see Schluter & Ricklefs, 1993). Pianka, Terborgh, and Diamond related species richness to climate and altitudinal distributions. This idea took a stronger hold as Connell proposed the intermediate disturbance hypothesis as a possible explanation for the differences in species diversity resulting in regional mosaics (Schluter & Ricklefs, 1993, p. 2). A summary of the ecological phenomena considered influencing the number of species and their pattern of distribution is included in Table 36.

Towards the latter part of this period, the prevalent ideas of exclusion, character displacement, and competitive interaction shaping diversity were challenged. There was a shift in interest: rather than the nature of the interactions, scientists focused on the consequences of these interactions for the coexistence of species (Schluter & Ricklefs, 1993).

Wallace’s ideas about the geographical distribution of species resurfaced as some ecologists approached the study of species diversity as a comparison of species richness among different geographical regions. Research by Pianka, Karr, Cody, and others noted differences in diversity among similar regions (Schluter & Ricklefs, 1993). According to their findings, some areas showed convergence in species diversity across regions; however, in other cases, similar
Table 36.
Ecological Phenomena Proposed During the 1960s to 1970s That Likely Influenced the Number and Pattern of Species Diversity Concepts.

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Scientists</th>
<th>How it affects species diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat complexity</td>
<td>MacArthur 1961, Pianka 1967, Simpson 1964</td>
<td>Habitat heterogeneity along with resource partitioning among species with similar needs explains why desserts have higher diversity but lower productivity compared to salt marshes which are less diverse even though they are more productive.</td>
</tr>
<tr>
<td>Limiting similarity</td>
<td>MacArthur &amp; Levins 1967</td>
<td>Maximum degree of niche overlap that allows coexistence of species</td>
</tr>
<tr>
<td>Island equilibrium</td>
<td>MacArthur &amp; Wilson, 1963, 1967</td>
<td>Species diversity is determined by opposing forces of extinction and colonization. Diversity increases with island size, but decreases with distance from mainland.</td>
</tr>
<tr>
<td>Latitude</td>
<td>Connell &amp; Orias, 1964; Pianka, 1966; Ricklefs 1977</td>
<td>With some exceptions, the maximum number of species is greater toward the tropics than in temperate forests (i.e., 10 times more tree species in tropical forests).</td>
</tr>
<tr>
<td>Climate</td>
<td>Terborgh, 1973</td>
<td>For terrestrial ecosystems, warmer temperatures and higher precipitation are associated to higher species diversity</td>
</tr>
</tbody>
</table>

(Table continued)
Geographical distribution

Diamond, 1975

Ecological similar species are not distributed at random

Productivity

Whittaker & Niering, 1975 (and Tilman, 1982)

Higher diversity associated to intermediate levels of productivity because the extremes (habitat fertility too low or too high), results in lower diversity due to nutrient stress or simplified communities that result from competitive exclusion.

Note. All authors cited in Schluter & Ricklefs, 1993.

habitats would not support the same numbers of species. They found that the number of species is influenced by characteristics of the local habitats and the geological history of the area.

1980s, Coining a New Concept – In 1980, the concept “biological diversity” was first used by the tropical and conservation biologist Thomas Lovejoy. In that same year he presented the Global 2000 Report to the President stating predictions on the extinction rates of diversity. Five years later (1985), Rosen used the contraction “biodiversity” while the National Research Council was organizing the National Forum on Biological Diversity, which took place in 1986 (Wikipedia, 2006c). E.O. Wilson was the first to use the concept in a publication in 1988, when he used it in the title of the proceedings of that forum (Wilson & Perlman, 2002).

During the 1980s ecology continued to be a strong framework for the development of ideas about diversity. Scientists, like Terborgh, Diamond, Noon, Schluter, Connell, and Grant, continued to explore the role of competition and habitat complexity in the distribution of closely related species. A new idea explored during this time was habitat saturation, or the maximum number of species that could be found in an area. However, no clear arguments emerged because results from studies on birds and wasps were conflicting. A correlation between the local and
total island bird diversity was found, in addition to an upper limit to the total number of bird species in an island. However, this local region-total region correlation was not the case with the wasps (Schluter & Ricklefs, 1993). Towards the latter part of this decade, ecologists began to pay more attention to the effects of larger scale processes (i.e., immigration) on the local species diversity.

Two projects furthered knowledge of plant biodiversity during this decade. The Traditional Medicine for the Islands (TRAMIL) project, which started in 1982 in the Dominican Republic; the other was a project started by the National Cancer Institute in 1986. The former attempted to preserve the diversity of plant species and the indigenous medicine knowledge that goes with them. The latter project funded the extensive collection of more than 35,000 plant species. These species were screened for anti-AIDS and anti-cancer activity. This study resulted in 40 new species of plants, more than 800 species of plants known to have some anti-AIDS properties, and more than 60 species of plants with anti-cancer activity.

1990s, Paving the Way for Synthesis: Scale Issues, Functional Diversity, Debate and Socio-political advances – Because of the traditional-historical division between community and ecosystem ecologists, earlier biodiversity had been mostly the interest of community ecologists rather than ecosystem ecologists. During this decade the ecological discourse saw a larger interest in biodiversity from the ecosystem functioning perspective.

Findings from ecological research suggested how many processes working at different time and spatial scales influence patterns in species diversity. These include community interactions, migrations maintaining differences in local vs. regional diversity, evolution and diversification in similar habitats, influence of climate and geography, and unique events leading to extinctions (Ricklefs & Schluter, 1993).

In 1991, the International Conference on Biodiversity and Ecosystem function was organized in Germany. This conference was a result of the interest of the Scientific Committee
on the Problems of the Environment (SCOPE) on developing the International Geosphere Biosphere Programme. This programme had a special interest in global change and triggered interest in biodiversity-functioning research, thus merging the study of ecosystem functioning and biodiversity (Mooney, 2002; Naeem, Loreau, & Inchausti, 2002). The central idea of this new development was exploring the consequences that changes in species diversity (i.e., invasions vs. extinctions) could have on ecosystem function. In Mooney’s words this development would “help close the gap between knowledge on biological diversity and research on the functioning of ecosystems” (Mooney, 2002, p. 13). Following the conference, the experimental work moved at a faster pace than the development of theoretical work. Still, much debate went on about the relative importance of diversity for the ecosystems, mostly due to different interpretations of results in the scientific community. Of particular importance were the diverse hypotheses that had been proposed regarding the relationship between biodiversity and ecosystem processes. These were classified into three categories: redundant, singular, and idiosyncratic (see Naaem, Loreau, & Inchausti, 2002 for a summary of these). The redundant refers to the possible substitution of species, without major consequences. In contrast, the singular acknowledges the contribution of each species as unique. Last, the idiosyncratic considers contributions unique but dependent on extrinsic or intrinsic factors.

The critical importance of plant diversity to ecosystem functioning was demonstrated with experiments performed both in controlled and natural environments (Naaem, Loreau, & Inchausti, 2002). These experiments showed the effects of various levels of diversity on CO₂ and helped establish the importance of the role of plant diversity in maintaining the production, resistance, and resilience of prairie ecosystems (Naaem, Loreau, & Inchausti, 2002).

Much debate had been occurring among ecologists concerned with the role of diversity in ecosystem functioning. Most of this debate came from different interpretations of findings,
something not uncommon among the scientific community and, in fact, important to stimulate
good quality science. However, some find the debate to weaken the scientific standpoint among
the general public and policy makers (see Mooney, 2002). Even more the debate still
discourages younger ecologists from exploring questions in the realm of functioning-
biodiversity.

While the 1980s represented an emergence of biodiversity as an environmental issue, the
maximum expression of this perspective was the Earth Summit celebrated in Rio de Janeiro,
Brazil, in 1992. In this summit an international agreement, the Convention on Biological
Diversity (CBD), was proposed to protect the Earth’s biological resources (Bryant, 2002). The
three main goals of the Convention were: (a) conservation of biological diversity; (b) sustainable
use of biodiversity; and (c) fair and equitable use of resources derived from genetic resources.
Originally 150 governments signed the document, which became effective in December of 1993
(Bryant, 2004). By 2004, 188 countries had ratified the CBD, excluding the United States which
had not signed yet because “of clauses requiring profits from biodiversity be shared with the
species country of origin” (Bryant, 2002).

Following the CBD many countries have moved to identify their local issues related to
biodiversity and to improve the biodiversity literacy among their citizens in an effort to
implement the provisions of the CBD. Two examples come from Australia and the Netherlands.
In 1995, Australia’s Humane Society International established the Biodiversity Network (CBN),
which is a non-government, community-based network of organizations. The goals of this
network are to increase understanding, provide access to information, promote community
involvement in conservation, and ensure effective implementation of the national strategy for
conservation of biodiversity (Glanznig, 2001). In the Netherlands, the Ministry of Agriculture,
Nature Management, and Fisheries developed projects to explore the local meaning, value, and use of biodiversity. These projects will serve as guidelines to develop curricula for educational programs.

**Biodiversity in the New Millennium**

**2000 to Present** - It can be said that at the beginning of the new millennium biodiversity has evolved into a new idea, *biocomplexity*. This new term was introduced by the National Science Foundation in 2001 (Colwell, 2001). The complexity comes from the many functional interactions that are affected by the diversity of life, including biological, chemical, physical, and social interactions. It also expands to all levels of organization, all types of organisms, different spatio-temporal scales, and both social and economic factors, all of which are interrelated in a non-linear fashion (Greenler & Greenler, 2002a; Leveque & Mounolou, 2004).

The debates of the 1990s stimulated the organization of the *Biodiversity and ecosystem functioning: synthesis and perspective* conference, held in Paris, France in December 2000 (Naeem, Loreau, & Inchausti, 2002). This conference brought together biodiversity-functioning researchers who represented different areas of both theoretical and empirical expertise.

In June 2001, the Millennium Assessment was launched. It was designed to serve the needs of the Convention on Desertification, The Ramsar Convention, and the Convention on Biological Diversity (Mooney, 2002; United Nations Environment Programme [UNEP], 2001). This assessment focused on the goods and services upon which present and future societies depend. This assessment relied on the information provided concerning the role of biodiversity in ecosystem functioning. The first report card from the assessment came out in 2005. One of the main findings stated, “Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial
and largely irreversible loss in the diversity of life on Earth”. Furthermore, it specifically stated that “Species extinction rates are now 100-1,000 times above the background rate” (Wikipedia, 2006b).

Biodiversity is currently recognized as a theme in science and society. It is considered by some as an “ill-defined” concept, for it has no single definition and has multiple interpretations (Leveque & Mounolou, 2004; van Weelie & Wals, 2002).

In 2005 UNESCO hosted the International Scientific Conference on Biodiversity: Science and Governance. This conference appealed to scientists, governments, and the general public (including indigenous communities) and, because of a critical need for sustainability, urged these to significantly reduce the rate of biodiversity loss by 2010 (United Nations Educational Scientific and Cultural Organization [UNESCO], 2005).

The future trends of the concept of biodiversity are expanding. Levenque and Mounolou (2004) assert that the question of biodiversity should no longer be of interest to only a small group, but should be regarded as a major problem for society as a whole.

**Development of the Plant Biodiversity Literacy Rubric (PBLR)**

The Plant Biodiversity Literacy Rubric (see Appendix K) was developed to set the standards for each level of achievement and be able to assess students’ understanding of the concept of biodiversity. The rubric can be used to evaluate any artifact, for example, concept maps produced by the students (study subjects) for its overall quality. It can help judge the progress and overall performance of the students as they are exposed to a series of different learning activities or different interventions.

Several sources, as described in the methods chapter, were considered to define the qualities of each level. The time-line described earlier serves as a summary of the historical development of the concept of biodiversity, which constitutes the main background and
validation of the rubric. In addition, as one of the criteria to guide the order of the levels of the rubric, the researcher used four questions identified by the Center for Biodiversity and Conservation of the American Museum of Natural History. The Center identifies those four questions as necessary in providing information about biodiversity to the general public. The researcher believes these questions are basic to develop an understanding of plant biodiversity. In developing the rubric, levels one and two intend to address the information that a student should know in order to have an understanding of the first question posed by the AMNH: What is biodiversity? As the students are exposed to additional lessons it is expected that they will gain the necessary information to learn why biodiversity is important. Therefore, levels three and four of the rubric are consistent with the second question posed by the AMNH: Why is biodiversity important? Students who have achieved an understanding that places them at level five of the rubric will have the necessary knowledge that is consistent with the third question established by the AMNH: What are the threats to biodiversity? Last, students who achieve an understanding that places them at level six of the rubric will have the necessary knowledge that is consistent with the fourth and last question posed by the AMNH: What can we do to conserve biodiversity?

The discussion that follows presents the rationale for each level of the PBLR. It should be noted that even though it is recommended that rubrics are even-numbered, the PBLR consists of seven levels. The last level is provided as a challenging extension and is intended to be used in other non-introductory biology courses using the CEB CD ROM as an instructional tool.

**Plant Biodiversity Literacy Rubric**

**Level 0: Oblivious**

This is the most basic level and applies to a student that has no understanding of plant biodiversity. At this level, the student can not establish a connection between biodiversity and evolution. The student has no understanding of biodiversity as number of species in different
categories of organisms. The student lacks understanding of major groups of organisms and the use of hierarchical classification. The student is not aware of the genetic, species, or ecosystem levels of diversity.

Students at this level lack focus and may use biodiversity-related concepts at random, including loosely related information. The students have poor organization and have great difficulty establishing logical links between concepts. Students are unable to provide any definitions for concepts and fail to provide adequate examples.

**Level 1: Darwin**

The second level is named in honor of Charles Darwin, who proposed Natural Selection as the mechanism to explain the enormous variation of life. This level corresponds to the first tier in the communication model of the Community Biodiversity Network (CBN), representing awareness of biodiversity (Glanznig, 2001). This level is consistent with the following NRC Life Science Standards: (a) structure and function in living systems, (b) diversity and adaptations of organisms, (c) biological evolution, and (d) reproduction and heredity. These are also represented by the ASPB principles 1, 4 to 6, and 10 to 12 (see Appendixes A and B).

Students at this level recognize biodiversity as number of species and as a result of evolution. Students can recognize the role of systematics in organizing the diversity of life into hierarchical categories and the evolutionary relatedness among categories (domain through species levels). Students at this level recognize major groups of organisms at the domain and kingdom levels, and can specifically recognize plant kingdom. Students are able to use concepts that reflect their understanding, (i.e., taxonomical categories, broad categories of plant groups), and can establish logical links between them. The concepts are well organized and supported
with definitions and examples. Students may not use concepts that are beyond this level of understanding, and if included, there are no logical or appropriate connections, definitions, or examples for these.

**Level 2: Lovejoy**

The third level is named in honor of Thomas Lovejoy, who coined the concept of biological diversity and has made valuable contributions to the conservation of biodiversity. This level corresponds to the second tier in the communication model of the CBN, which establishes that there is understanding of the overall meaning of biodiversity, recognizing all three levels of diversity: genetic, species, ecosystem. This level is consistent with the following NRC Life Science Standards: (a) Molecular basis of heredity, (b) Biological evolution, and (c) Interdependence of organisms. This level is also consistent with the ASPB principles 1, 2, 4, 7, and 12 (see Appendixes A and B).

Students at this level recognize biodiversity beyond numbers of species by being aware of at least two of the three levels of biodiversity: genetic, species, and ecosystem. The student is aware that diversity at the genetic level is the basis for the variation at the other levels. The students may use concepts that recognize the role of plants in the ecosystems (i.e., producers, photosynthesis). Students may recognize different types of ecosystems and plants present in these. Students are aware with the importance of genetic diversity for plants.

The students can establish logical links between concepts that reflect this and lower levels of understanding. The concepts are well organized and supported with definitions and examples. The students may not use concepts beyond this level of understanding them. If included, there are no logical or appropriate connections, definitions, or examples.
Level 3: Raven

The third level is named in honor of Peter Raven for his contributions to the knowledge and conservation of plant diversity. This level is consistent with the following NRC Life Science Standards: (a) Reproduction and heredity, (b) Structure and function in living systems, (c) Interdependence of organisms, (d) Biological evolution, and (e) Diversity and adaptations of organisms. This level is also consistent with the ASPB principles 1, 3, 4, 7, and 12 (see Appendixes A and B).

The student understands plant biodiversity as number of species and as a representation of the main groups of the kingdom. The student recognizes the evolutionary origin of the plant kingdom and the unique characteristics of different groups within the plant kingdom. The student recognizes the diversity of plant life in terms of complexity, reproductive structures and strategies, size, and growth habits. The student recognizes the interdependence of plant life and organisms in other kingdoms. The student understands the role of plant diversity in the ecosystems.

The student uses concepts that reflect this level of understanding and those below it and establishes logical connections between the concepts. These are well organized and supported with definitions and examples. The student may not use concepts beyond this level of understanding. If included there are no logical or appropriate connections, definitions, or examples.

Level 4: Pimentel

The third level is named in honor of David Pimentel and his contributions in environmental accounting, which promulgated knowledge about the equivalent monetary value of the services we obtain from biodiversity. This level corresponds to the third tier in the communication model of the CBN. This level establishes that the individual can develop links between diversity and his
or her own life, ranging from the food he or she eats, health, to the services obtained from ecosystems. This level is consistent with the following NRC Life Science Standards: (a) Interdependence of organisms, (b) Populations and ecosystems, and (c) Matter, energy, and organization in living systems. This level is consistent with the ASPB principles 1, 6, 8, and 12 (see Appendixes A and B).

The student demonstrates understanding of the value of plant biodiversity. The student can recognize the diversity of goods and services provided by plant biodiversity at the species, genetics, or ecosystem levels. Examples could include but are not limited to: clean air, drinkable water, food-webs, pollination, shelter, dispersal, food, clothing, medicine, and fuel.

Concepts that reflect this level of understanding and below are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. The student may not use concepts beyond this level of understanding. If included, there are no logical or appropriate connections, definitions, or examples.

Level 5: Wilson

This level is named in honor of E. O. Wilson for his role in promoting the study and conservation of biodiversity. As part of his effort to promote conservation, Wilson has also worked to raise awareness of the HIPPO dilemma. The fifth level matches the fourth tier of the CBN communication model, which values consciousness about the importance and need to protect biodiversity. This level is consistent with the following NRC Life Science Standards: (a) Interdependence of organisms, (b) Population growth, (c) Populations and ecosystems, and (d) Matter, energy, and organization in living systems. This level is consistent with the ASPB principles 1, 6, 8, 9 and 12 (see Appendixes A and B).

The student demonstrates excellent knowledge of plant biodiversity. The student can identify at least one of the anti-conservation forces which endanger plant biodiversity and are
part of the HIPPO dilemma: Habitat destruction and degradation, Invasive species, Pollution, Population growth, and Overexploitation/Over consumption. The student is conscious about the need to protect and conserve.

The student is aware of controversial issues and sees the need to make choices. The student may show change in attitude. The student can connect concepts clearly and shows a logical organization of ideas. S/he demonstrates ability to use definitions and provides relevant examples in support of the concepts. The student may not use concepts beyond this level of understanding. If included, there are no logical or appropriate connections, definitions, or examples.

**Level 6: Biophilia**

This level is named in honor of a concept created by E. O. Wilson to identify the state in which humans gain consciousness about life and are moved to conserve it. The level matches the last tier of the CBN communication model, which targets a call to action, during which the individual changes actions that negatively impact biodiversity. This level is consistent with the NRC Life Science Standard - Interdependence of organisms. This level is consistent with the ASPB principles 1, 6, 8, 9 and 12 (see Appendixes A and B).

The student demonstrates outstanding and consistent understanding of plant biodiversity and can establish a personal connection with it, thus modifying personal beliefs. She/he can recognize how the diversity of goods and services provided by plant biodiversity are affected by personal life style and choices. The student recognizes her/himself as an integral part of the world community and can identify issues concerning local, national, or global biodiversity, assuming an informed position. Self-evaluation motivates the student to take some pro-biodiversity action.
The student articulates ideas clearly, using logical connections between concepts. The student demonstrates ability to use pertinent definitions and provide a variety of high quality examples in support of the concepts.

**Level 7: Biocomplexity**

This level is named in reference to the latest development in the evolution of the concept of biodiversity. Currently, biocomplexity is not a theme that is discussed in the textbook or CD-ROM. It is also not addressed by the NRC standards because it is a new concept, past the conception of the standards. The CD-ROM has the possibility of contacting scientists and discussing about this (or any other) topic. This was a feature not explored in this research, but that other students using the program could do. However, the student can be able to integrate understanding from several NRC standards for 9-12 level, including both Life Science standards, molecular basis of heredity and interdependence of organisms, and Science in Personal and Social Perspective standards Science and Technology in local, national, and global challenges and population growth. This level is consistent with the ASPB principles 1, 6, 8, 9 and 12 (see Appendixes A and B).

The student demonstrates superior and consistent awareness of plant biodiversity. The student is capable of integrating concepts from at least two different subjects/areas such as, geology, economics, sociology, agriculture, forestry, genetics, etc., and focuses these on plant biodiversity, establishing a co-relationship among different areas. The student may be able to distinguish her/his role in relation to one particular area of interest.

The student articulates ideas clearly and uses logical connections between major concepts. The student demonstrates ability to use adequate definitions and provides relevant examples in support of the concepts.
It is not expected that introductory biology level students master this level. However, it is the opinion of the researcher that this level could be reached with a thorough use of the instructional tool (CEB CD ROM). It is included here as an extension for the possible application of this rubric to other courses using the same tool as part of the course: e.g. introductory biology course (with sole focus on biodiversity), a conservation biology course, or an ecology course.

**Validity**

In addition to the validity based on the historical development of the concept of biodiversity, three experts validated the rubric. The panel of experts included two ecologists and a science educator, all with plant biology research and teaching experience. These evaluators rated the concept maps and the Louisiana Plant Diversity presentations.

The three evaluators show some consistency in the concept map’s ratings for the different participants. This was suggested by the concordance in the ranked rubric ratings (n=24; Kendall Coefficient of Concordance; \( W = 0.812, p = 0.0001 \)) (Miller, 2007). These findings suggested the rubric is a tool that could be use to determine the level of understanding reflected by the students in the concept maps they create (see Table 37).

The three evaluators had a more difficulty evaluating the presentations as suggested by their comments:

- **Evaluator #1** The presentations are good, but the scores may not reflect their quality. The topics do not easily lend themselves to the levels of the PBLR.

- **Evaluator #2** I had a little more difficult time applying the rubric to the presentations than I did with the concept maps, those were fine.

- **Evaluator #3** It was difficult to apply the PBLR to the presentations. Since there were guidelines, the students focused their presentations on the species and discussed similar topics (taxonomy, distribution, morphology, etc.). When discussing the importance of species they only considered benefits to humans and there were no references to the ecological roles.
When the scores are observed, there was a higher consistency between two of the evaluators (see Table 38). The coefficient of concordance reflected the discrepancy among evaluators’ ratings for the different participants \( n=24; \) Kendall Coefficient of Concordance; \( W = 0.525, p = .1635 \). These results suggest the either the rubric or the presentations should be modified. Evaluator #3 pointed out the similarities in structure and content of the presentations and the limited themes covered as possible factors making it difficult to apply the rubric. For the future, maybe providing less stringent guidelines could help. However, based on the findings here, and by the limitations that were imposed for this specific activity, the PBLR could provide mixed or
unclear results, and is not recommended. A suggestion for improvement would be having less restrictive guidelines, more open inquiry rather than guided-inquiry (see Table 38).

Table 38
Louisiana Plant Diversity Presentations Rated by Three Evaluators Using the PBLR

<table>
<thead>
<tr>
<th>Evaluator</th>
<th>Tanya</th>
<th>Thiab</th>
<th>Trevic</th>
<th>Carla</th>
<th>Caleb</th>
<th>Cyrenec</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>1</td>
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<td>B</td>
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</tr>
</tbody>
</table>
CONCLUSIONS AND IMPLICATIONS FOR PRACTICE AND FUTURE RESEARCH

“It is not enough for an artist to see, he must make others see”
E. Degas

Answering the Research Questions

This exploratory study addressed the value added to community college students’ understanding of biodiversity via supplementary use of an interactive biology CD-ROM in a non-majors introductory biology course. A mixed-methods, multiple case study, quasi-experimental design was used to solve this inquiry by examining three main questions. The paragraphs below discuss how this inquiry was solved.

First Question

What, if any, is the “value added” incrementally to introductory biology community college students’ baseline understanding of biodiversity by supplementary, sequenced use of an exemplary interactive CD-ROM on biodiversity, “Conserving Earth’s Biodiversity” (CEB) (Wilson & Perlman, 2000)?

The students’ incremental learning was measured as they were exposed to a plant biodiversity study. One course section was exposed to the CEB, which is an interactive, biodiversity-focused CD-ROM. A second course section was used as a comparison group. I examined how students understand the concept of biodiversity, and what, if any, conceptual change occurred when the CD-ROM was used in addition to the standard textbook-based instruction.

The findings of the study suggest that in most cases the implementation of the CEB CD-ROM enhanced the understanding of plant biodiversity concepts, considering all levels of diversity: species, genetics, and ecosystems. Evidence from the results of concept maps and clinical interviews support this notion. The results of the quizzes were mixed (no effect/positive
effect), and therefore not a strong basis to claim enhancement of learning by the CD-ROM. None of the assessments indicated a negative effect of the implementation of the CD-ROM.

Both the textbook and the CD-ROM exposed the majority of plant biodiversity concepts in a similar way concerning the themes included. However, the organization of the material, the way it was delivered, and the examples used in the CD-ROM as compared to the textbook seemed to have a differential effect on students’ understanding. The CD-ROM group’s participants elaborated more in their propositions as compared to the textbook group’s participants.

Both tools had a similar effect on student understanding of the concept of number of species. However, regarding the patterns in the distribution of species and contributions by the different organism, the participants in the CD-ROM group did somewhat better as compared to the participants in the textbook group. Concerning the diversity of the plant kingdom and the different groups, both instructional tools complemented each other, while the textbook emphasize structures and reproduction, the CD-ROM allowed the students to get a whole-organism and role-in-ecosystem view. These students were able to explore examples of plants in different families.

Another aspect of the CD-ROM that represented a complement to the textbook was the global patterns of ecosystem diversity. The textbook included brief descriptions of the flora of the different ecosystems. The CD-ROM focused on the geographical distribution of these and offered the possibility of exploring the relation of these ecosystems to threats, for example, population growth and deforestation. By being exposed to all aspects of this information, students in the CD-ROM group were able to develop more complex propositions. The CD-ROM also complemented the textbook in the information about exotic species. Both tools coincide in
some of the examples like, fire ants; however, the CD-ROM provided more specific information about how plant biodiversity was affected by these.

Second Question

**Does the use of the CEB CD-ROM enhance student ability to develop and pursue selected guided-inquiry questions about local plant biodiversity, with respect to threats to biodiversity?**

All students were able to experience constructivist approach as they discovered relevant information about the plants of their choice. It seems that students in both groups were able to experience Louisiana’s plant biodiversity in a similar way. If an enhancing effect of the CD-ROM is present in the CD-ROM group’s participants, it can be possibly attributed to the motivation to work and the independence to explore resources to effectively find the information at different stages of the inquiry process. Participants in the CD-ROM searched more independently for their plant-subject of study, as compared to the participants in the textbook group. One of the groups was willing to go beyond the “already collected information” (i.e., textbooks or Internet sources) to find “primary” source of information. However, the researcher believes the sample size was small, and any claims should be conservative. Even though no clear positive effect may be present, no negative effect of the CD-ROM was observed.

Third Question

**Can a rubric be developed and validated, based on the history of the biodiversity concept, which differentiates college students’ progress and levels of understanding of biodiversity?**

I developed an appropriate rubric, based on the actual history of the concept of Biodiversity. This rubric helped gauge students’ progress by assigning them to levels of understanding throughout the study. There were differences in perception of levels of literacy
between the evaluators and the researcher. This was possibly due to the exposure of the researcher to: (a) the clinical interviews and the process of concept map construction; (b) the process of development of the inquiry. The researcher agreed with the evaluators in that the rubric renders itself more useful for evaluating concept maps than the more complex plant presentations.

Implications for Practice

This study, in light of its limitations, represents a contribution to the interests of the Math and Science initiative’s goal of promoting research that can provide information on teaching methods and curricular material to improve the effectiveness of science instruction.

It also contributes to how instructional practices can be developed to help students achieve a better understanding of plant biodiversity. This is one of the most fundamental concepts in biology, especially in the field of ecology, and is a key topic in the science education reform movement. Therefore is imperative we develop the best practices possible to make this concept available, understandable, to all students.

The findings of this study suggest that the use of a supplemental, high quality, interactive CD-ROM can enhance learning of many of the plant biodiversity-related concepts. The task is not easy, and requires commitment from the instructor to design activities that can foster student-student, student-tool, and student-teacher interactions in order to make the most of the social setting. The constructivist approach allows to create the proper classroom environment for these interactions to take place. One aspect that the CD-ROM also affects is the attitude of the students towards the material. Rather than experiencing the same tool all the time, seemed that switching between tools, allowed the students to see the same material from different perspectives, or with different emphasis.
Another important aspect of the educational practice is the presence of misconceptions. It was noted that students that were exposed to the additional tool were able to negotiate more of these than the students that were exposed to the textbook only. However, the researcher considers this aspect deserves closer attention. It should be determined if they solve these “permanently” and not in a short term, and also how exactly the CD-ROM possibly helped. Perhaps by examining more closely the thinking process, it may shed some light on this regard.

Computer Technology in the Classroom

Students of the 21st century live in a world surrounded by many forms of technology and media. It is not strange then, that all of the students in this study approved and preferred exposure to the CD-ROM. However, differing from the present study, in a study in an introductory biology course the CD-ROM replaced all real-life simulations and printed material (Simon, 2001). In that case the researcher did not look into the effects of the CD-ROM technology on learning. Simon (2001) findings coincide with the findings in the present study in regard to the positive reasons to use the CD-ROM technology. This points towards the importance of establishing that some tools are not meant to be a substitute, but rather a complement of the traditional tool. In the specific case of the CEB, for many concepts as the sole source, however, if a complete substitution of the textbook was made, the students could miss information in other aspects. The focus of the course and an exhaustive evaluation of the material by the instructor is recommended before a decision is made in that regard. As a supplementary tool, it can help keep up with new developments in the area, since the CEB CD-ROM offers the advantage of consulting with experts. This was a feature of the program that was not explored in this study, since both tools being compared had the same publication date. However, is an obvious advantage for keeping the information up to date.
Again, as stated earlier, it is still on the hands of the instructor to use the program as a means to develop inquiry, discussion, and promote social interaction in the classroom. Otherwise, students might be at risk of loosing on these aspects due to the individualized interaction with the computer. This situation arose during the first computer session, bringing this problem to the attention of the researcher, who modified posterior activities, integrating group discussion. Implementing educational technology in the classroom runs the risk of becoming didactic and socially limiting (Cobb, 1999; Fraser & Deane, 1999; Gance 2002). Therefore, developing activities that included questions that allow students to exchange information with classmates (for example see Appendix U) was an important aspect of this study. This should be considered in the teaching practice if planning to make the CD-ROM part of the instructional tools in the classroom. In this study, the researcher was concerned with matching activities with the textbook to be able to compare the two groups exposed to the different instructional tools. However, it is important to note that the CD-ROM already has activities and questions that promote critical thinking and active engagement of the learner. It is up to the educator then, to promote in the classroom interaction among the learners.

Another point of importance in teaching about plant biodiversity is including real-world experiences. The CD-ROM does a good job in that by exposing students to real-world information in a virtual way. While there is nothing like the real-world experience, in the community college scenario, the virtual world offered by the CD-ROM opens the opportunity for students that attend night classes or that do not have additional time in their schedules to attend field trips to be exposed to other experiences. With this mind, in this study the researcher complemented both the textbook and CD-ROM information by bringing live samples and demonstration material to the classroom. Other studies had indicated that students preferred real
experiments and simulations over computer simulations in a human physiology class, and laboratory manual over CD-ROM in biology labs (Brickman, Ketter, & Pereira, 2005; Kirkwood, Sharp, de Vito, & Nimmo, 2002). However, different to the present study, where the CD-ROM was used to complement the textbook, in the human physiology and biology laboratory courses, the CD-ROM substituted all real life simulations and the printed material.

Learning Assessment

One important component of the theory of human constructivism, which sets it apart from similar theories, is assessment. This study corroborated the invaluable usefulness of concept mapping and clinical interviews in assessing student understanding, as has been suggested by others (Novak & Gowin, 1984; Mintzes & Wandersee, 1998). Concept mapping has in fact been proposed as the assessment that would help identify if educational practices are truly effective (Novak et. al., 2000). Even though the multiple choice quizzes designed for the study incorporated application questions and the use of images, these were not able to discern the differential effect of the instructional tools on students’ understanding of plant biodiversity. However, both the concept maps and interviews served this function. Both revealed aspects of the student understanding that were not so obvious when using the quizzes. Even though in this study the researcher made these quizzes not so-traditional but using image-based questions. Adding similar activities, perhaps through some open ended questions in lieu of interviews could help in assessing if true understanding is taking place. It would be beneficial to the learner, if in fact, the activities were incorporated as formative rather than summative assessment. In this way, the instructors can identify any misconceptions and help remediate them while in the unit.

For question two, meaningful learning of Louisiana’s plant biodiversity was possible through the metacognitive approach. The process of preparing the presentation gave students an
opportunity to experience this through the different phases of the development of their inquiries. In looking back at the activity, I suggest using the Mary Worth’s Inquiry Diagram with the students as part of their reflection process, and even possibly as part of the guidelines. I believe this will give them a way to organize their learning experience and see how they learn. From the instructor perspective, this could provide a basis to compare the students’ performance in their process of learning and help in providing more focused feedback that could benefit them in the future.

Another important aspect of the plant presentations was experiencing collaborative work. It was evident from the study that we are still in the process of making collaborative work a reality in the community college classroom. Some groups in this study corroborated what Linn and Burbules (1993) and Tobin and Tippins (1993) have said about collaborative work influencing and promoting cognitive, social, and work-pace skills. In these groups, the participants had the challenge of finding information to solve their guided inquiries, dealing with group dynamics, and presenting the information using the Power Point. Some students, for different reasons, were not fully part of the experience.

Having the students prepare a presentation also follows Dana and Davis (1993) recommendation of moving away form traditional assessment practices to ones that are more in accordance with constructivism in assessing the capability to apply the knowledge.

Plant Biodiversity Literacy Rubric

One aspect of this study was the development of the Plant Biodiversity Literacy Rubric to assess students’ level of literacy while they progressed in developing their understanding of plant biodiversity. The rubric was purposely not too specific or focused per level. The concept of plant biodiversity is very broad, and likewise was this exploratory study. However, the movement in
science education is towards a more focused science curriculum, where depth in knowledge and science-related critical-thinking skills are valued. Therefore, in light of that reform, any educator would be able to focus a study unit and still be able to measure student progress in becoming literate in plant biodiversity by using the PBLR.

Another characteristic of the rubric is that the highest level of understanding of plant biodiversity is achieved by understanding the concept of biocomplexity. This concept represents the most current development in the historical aspect of biodiversity. This concept is part of the current ecology discourse, at the expert’s level. However, a review of five current editions of introductory biology textbooks (2005-2008) revealed that although biodiversity is starting to make a bigger presence, even to an entire chapter in some textbooks, biocomplexity is yet to be discussed at the level of introductory biology. Therefore, the last level of the rubric may seem ahead at this time, and for this level. However, the researcher is confident of the usefulness of this level of the PBLR both in the near future of introductory biology courses as well as in upper level biology courses which may integrating the biocomplexity concept, (i.e., ecology, conservation biology, or majors biology).

Limitations of the Study

This study has limited generalizability and transferability for four main reasons. First, the small class size of both the treatment and comparison groups. Second, the sample of students reflected the gender proportion in the class, where there were more females than males. Third, as it is typical of the institution where the study was conducted, there was a low proportion of African-American students. One student in one class and three in the other class represented this ethnicity. Two of those students started as participants, but resigned. Fourth, participants were purposively selected.
The same instructor taught both course sections. All classrooms and the computer laboratory were in the same building. All students used the same textbook and were exposed to the same lectures. Therefore, if there were any differences observed they were attributed to intellectual ability of the participants and effects of the exposure to the CD-ROM. Having a M.S. in Biology, with focus on plant ecology, the instructor had expertise in the subject content examined.

Implications for Future Research

As an exploratory study, the main findings from this study suggest several inquiry pathways that could be pursued to build upon what we know at this moment about the role of CD-ROM in enhancing students’ learning of plant biodiversity.

First, throughout the study there were several times when participants expressed misconceptions. It would be of interest exploring in more in depth which thinking pathways allowed for the participants exposed to the CD-ROM negotiate their misconceptions, as compared to those students exposed to the textbook who kept theirs. By comparing a typology of emerging themes from the present study and the proposed idea, a theory of CD-ROM effects on negotiating misconception sand developing understanding could be developed.

Second, the incorporation of visual organizers such as the concept maps, helped in assessing student understanding in this study. It was observed that during the interviews many times the use of Power Point slides helped the participants in answering their questions. However, some of these students struggled while creating their concept maps. The researcher believes that possibly the combination of concepts and images associated to these could facilitate how students deal with the concept maps. It may be of interest finding out if image-concept
combination could help students in establishing links between concepts by eliciting their memory from additional visual cues. This is probably of interest in the context of the characteristics of the student population served by the rural community college in which this study was conducted. In this case, is an open admission institution, where a mixed student population includes students with learning disabilities such as, reading comprehension and dyslexia. Students may also have preparation deficiencies that is, are taking remedial math courses while enrolled in a biology course. These students are part of a biology-classroom community at this level that deserves attention and the best practices of teaching. The researcher believes that while their deficiencies in other areas may hinder the students from developing understanding of many concepts in biology, there could be ways to explore if this is true, and if so, how they could be help. The approach of the image-based concept map could possibly help these kinds of students. The current growth of the higher education institutions in this state and potentially of students with learning disabilities in the biology classroom merits prompt attention from the biology education researchers, if we are to responsibly contribute to developing science literacy.

Another aspect that surfaced with the students’ inquiries of Louisiana’s plant diversity is the lack of information in the Internet related to the role different plants may play in the local biodiversity. For many students in a rural setting, the Internet is perhaps an important source of information. In the future students’ projects could be used to start a collection of information that could help other students at the same or lower levels (K-12) in gathering information and learning about Louisiana’s plant biodiversity.

Perhaps the most unique contribution and exportable instrument developed for this dissertation was the Plant Biodiversity Literacy Rubric (PBLR). It may allow ecology educators at all levels to assess their students' levels of understanding plant biodiversity in a more sensitive
and sophisticated way than before. It may be worthy of presentation at the Ecological Society of America's annual meeting and worthy of National Science Foundation's funding for further development and application. After all, our plants are in peril. It is important the public understands that threats to plant biodiversity have important implications for their own lives and those of their children. This dissertation was no academic exercise. Effective ecology education is vital to the survival and well-being of the Earth's population. How can we improve it and increase levels of understanding if we cannot gauge our progress with an instrument like the PBLR?
LITERATURE CITED


Barataria-Terrebone National Estuary Program (1999). America’s Vanishing Treasure. (Video)


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APPENDIX A

LIST OF PRINCIPLES OF PLANT BIOLGY
Developed by the American Society of Plant Biologists

Source:http://www.aspb.org/education/foundation/principles.cfm

1. Plants contain the same biological processes and biochemistry as microbes and animals. However, plants are unique in that they have the ability to use energy from sunlight along with other chemical elements for growth. This process of photosynthesis provides the world's supply of food and energy.

2. Plants require certain inorganic elements for growth and play an essential role in the circulation of these nutrients within the biosphere.

3. Land plants evolved from ocean-dwelling, algae-like ancestors, and plants have played a role in the evolution of life, including the addition of oxygen and ozone to the atmosphere.

4. Reproduction in flowering plants takes place sexually, resulting in the production of a seed. Reproduction can also occur via asexual propagation.

5. Plants, like animals and many microbes, respire and utilize energy to grow and reproduce.

6. Cell walls provide structural support for the plant and also provide fibers and building materials for humans, insects, birds and many other organisms.

7. Plants exhibit diversity in size and shape ranging from single cells to gigantic trees.

8. Plants are a primary source of fiber, medicines, and countless other important products in everyday use.

9. Plants, like animals, are subject to injury and death due to infectious diseases caused by microorganisms. Plants have unique ways to defend themselves against pest and diseases.
10. Water is the major molecule present in plant cells and organs. In addition to an essential role in plant structure, development, and growth, water can be important for the internal circulation of organic molecules and salts.

11. Plant growth and development are under the control of hormones and can be affected by external signals such as light, gravity, touch, or environmental stresses.

12. Plants live and adapt to a wide variety of environments. Plants provide diverse habitats for birds, beneficial insects, and other wildlife in ecosystems.
To create the guide, first I examined each section of the program for concepts covered, paying particular attention to sections that incorporated plant biodiversity-related information. Then, wherever possible, I matched content to the Principles of Plant Biology (ASPB, 2001; for a list of principles see Appendix G), the Life Sciences (LS) and Science in Personal and Social Perspective (SPSP) standards (NRC, 1996), reference to Project 2061 (AAAS, 1989), and the chapters of the course textbook that are relevant for each CEB CD-ROM section. For both, LS and SPSP standards I considered grade levels 5-8 and 9-12. Selected sections of the guide are included in Appendix A. In the guide I use numbers, which could be used in lesson packets for the students and help with navigation in the program. The idea was suggested by students using the program with a given set of instructions during a pilot study. However, I will not use these numbers for the class activities because I will be projecting the different activities as they work on them in class, and I will be able to provide individual support if needed.

There are two important features of the guide. First, the content-specific match. Even though the ASPB had suggested earlier how all Principles of Plant Biology (except no. 3) can be integrated into the NRC Life Sciences standards (ASPB 2001), I particularly considered a match between the ASPB principles to the specific concepts and principles in each LS and SPSP standards as these apply to the specific concepts presented in the CD ROM section. Therefore, not all of the ASPB’s Principles of Plant Biology as matched to LS standards by the ASPB are reflected in this guide (i.e. they not necessarily consistent). Second, is the integration of the SPSP standards. These have not been previously matched the ASPB’s Principles of Plant Biology. However, I considered these standards very pertinent in promoting student’s
understanding of plant biodiversity. According to the National Research Council the objective of
the SPSP standards is giving students “a means to understand and act on personal and social
issues” and “help them developing decision-making skills” (NRC, 1996, p.107). In addition for
the grade level 9-12 it is stated that the SPSP standards “form a set of conceptual organizers,
fundamental understandings, and implied actions for most contemporary issues.” (NRC, 1996,
p.193). In many of the sections, the SPSP standards made a better match compared to the LS
standards. In addition, I highlighted the ASPB principles which are supported by references to
plant science in the AAAS Project 2061, Science for All Americans (all but 8, 9, and 11)
(http://www.project2061.org/publications/sfaa/online/sfaatoc.htm;) (see Appendix H for a list of
the plan-related references in Project 2061).
## CONSERVING EARTH’S BIODIVERSITY CONTENT GUIDE

### Sections Selected for Research Based on Basic Understanding of Biodiversity and Plant Biodiversity Content

<table>
<thead>
<tr>
<th>CEB</th>
<th>Concepts CD</th>
<th>ASPB Principle</th>
<th>NRC LS Stds 5-8, 9-12</th>
<th>NRC SPSP stds 5-8, 9-12</th>
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<tbody>
<tr>
<td>I. Introduction</td>
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<tr>
<td>1. Welcome T=1:20</td>
<td>Biodiversity, Threats Protection, Conservation</td>
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<tr>
<td>3. What is Biodiversity? T=1:35</td>
<td>Biodiversity, variety of: ecosystems, species, and genes, ecosystems, variation, Populations, communities, conservation</td>
<td>7, 9, 12</td>
<td>Populations and ecosystems</td>
<td>Population growth</td>
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<td>Diversity and adaptations of organisms</td>
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<td>Biological evolution</td>
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<td>Interdependence of organisms</td>
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<tr>
<td>4. Reasons for Conservation 4A. Introduction T=1:03</td>
<td>Wild species, Domesticated species Food, medicine, pests and disease, Ecosystem services, C storage, Nutrient cycling, Flood protection, Degraded planet, timber, fuel Ethical/spiritual issues</td>
<td>1, 2, 6, 8, 9, 12</td>
<td>Populations and ecosystems</td>
<td>Populations, resources, and environment</td>
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<td>Natural hazards</td>
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<td>Risks and benefits</td>
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<td>Science and technology in society</td>
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<td>Personal and community health</td>
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<td>Natural Resources</td>
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<td>Nat. &amp;human- induced hzds</td>
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<tr>
<th>CEB</th>
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<th>ASPB Principle</th>
<th>NRC LS Stds 5-8, 9-12</th>
<th>NRC SPSP stds 5-8, 9-12</th>
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<tr>
<td>4B. Ecosystems as resources</td>
<td>Ecosystem services</td>
<td>1, 2, 4, 6, 8, 9, 12</td>
<td>Populations and ecosystems Interdependence of organisms</td>
<td>Populations, resources, and environment Natural hazards Risks and benefits Natural resources Environmental quality Natural and human induced hazards Science and technology in local, national, and global challenges</td>
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<td>T₃= 8:55</td>
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<td>Tᵢ= 1:01</td>
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<td>4.B.1. Forest Services</td>
<td>Forests, timber, pulp, global warming, deforestation, flooding, erosion, pollination, pest control, wetlands, irrigation, flood pollution control, recreation, transportation, mycorrhizae, root nodules, mutualistic association, legumes, lichen, mosses, plant roots</td>
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<td>4.B.2. Pollination and pest control</td>
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<td>4.B.3. Wetlands freshwater ecosystems</td>
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<td>4.B.4. Soil production and nutrient cycling</td>
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<td>4.B.5. Marine systems</td>
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<tr>
<td>C. Species as resources</td>
<td>Natural fibers</td>
<td>6, 8</td>
<td>N/A Interdependence of organisms</td>
<td>Personal health¹ Science and technology in society Personal and community health Natural resources</td>
</tr>
<tr>
<td>T₄= 5:15</td>
<td>Natural fibers Building, recording history/information Clothing, ropes, building materials, cotton, wool, flax, hemp, sisal, jute, papyrus, wood, Natural chemicals, neem tree, toothpaste, antiseptics, insecticides,</td>
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<td>Tᵢ= 1:12</td>
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<td>4.C.1. Domesticated animals</td>
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<td>4.C.2. Natural Fibers</td>
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<td>4.C.3. Natural Chemicals</td>
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<td>4.C.4. Medicinal plants</td>
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<td>4.C.5. Crop species</td>
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¹ The NRC’s fundamental concepts and principles that underlie the “Personal health” standard include “natural environments may contain substances…that are harmful to human beings”. I interpret medicinal plants as an example of substances present in natural environments which in this case are beneficial rather than harmful to human beings.
<table>
<thead>
<tr>
<th>4D. Genes as resources</th>
<th>Medicinal plants, rosy periwinkle, cancer, yew trees, willow trees, aspirin, Crop species, wheat, corn, rice, diversify diet, amaranth</th>
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<td>4.D.1. Variation in wild species</td>
<td>American elm, Dutch elm disease, small populations, Crops disease resistance, cinchona trees, malaria, snake bites, tranquilizer, traditional healers, genetic diversity, homogeneity (reduced diversity), food, genetic engineering, cabbage, broccoli, cauliflower, kale, Brussels sprouts</td>
<td>1, 4, 8, 9</td>
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<td>4.D.2. Studying genetic variation</td>
<td>Structure and function in living systems</td>
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<td>4.D.5. Food varieties</td>
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<th>4E. Philosophical Reasons for Conservation</th>
<th>Existence values, Saranas (sacred groves), Fig trees, aesthetic value, Symbols, Canadian maple leaf, redwoods, Children’s rainforest, rice fields, transformative value, DDT, malaria</th>
<th>Personal Health</th>
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<td>4.E.1. Existence value</td>
<td>3 Risks and benefits</td>
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<tr>
<td>4.E.2. Aesthetic and symbolic value</td>
<td>Science and Technology in Society</td>
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<td>4.E.3. Religious or Spiritual Value</td>
<td>Interdependence of organisms</td>
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<td>4.E.4. Transformational value</td>
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<td>4.E.5. Stewardship and Intrinsic Value</td>
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<td>4.E.6. Intergenerational value</td>
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2 Interpreting human effects as the use of medicinal plants and genetic engineering of crops

3 DDT is interpreted as a harmful substance present in natural environments (by means of humans)
<table>
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<tr>
<th>CEB</th>
<th>Concepts CD</th>
<th>ASPB Principle</th>
<th>NRC LS Stds 5-8, 9-12</th>
<th>NRC SPSP stds 5-8, 9-12</th>
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<td>1. Introduction</td>
<td>Ecosystem types, forests, savannas, mangroves</td>
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<td>2. Global Patterns</td>
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<td>2.A. Introduction</td>
<td>Distribution of BDV, species richness, food plant diversity, species abundance, species rarity, hotspots, human pop growth, deforestation</td>
<td>7, 12</td>
<td>Populations and ecosystems, Diversity and adaptations of organisms, Biological evolution, Interdependence of organisms, Matter, energy, and organization in living systems</td>
<td>Populations, resources and environment, Natural hazards, Risks and benefits, Population growth, Natural resources, Environmental quality</td>
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<td>2.C. Biomes: Major Terrestrial Ecosystems</td>
<td>Biomes, ecosystems, tundra, temperate forest, tropical/subtropical forest, flooded grasslands, Mangroves</td>
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<td>Populations and ecosystems, Matter, energy, and organization in living systems</td>
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<td>2.C.2. Explorations</td>
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<td>2.C.3. Further Thought</td>
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</table>
| 2.F. Conservation Hot Spots (Conservation International)  
2.F.1. Overview  
2.F.2. Explorations  
2.F.3. Further Thought | Conservation hot spots, threatened, endemic species, 50% plant species, 2% world area, major tropical wilderness areas | Diversity and adaptations of organisms  
------------------------  
Biological evolution  
Interdependence of organisms  
Matter, energy, and organization in living systems | Populations, resources, and environment  
Natural hazards  
Risks and benefits  
------------------------  
Natural resources  
Natural and human-induced hazards  
Science and technology in local, national and global challenges |
| All other maps | | | |
| 2.H. World Deforestation  
2.H.1. Overview  
2.H.2. Explorations  
2.H.3. Further Thought (no?) | Intact forest, disturbed forest, original forest, land cover, deforestation rate | Population and ecosystems  
------------------------  
Interdependence of organisms | Populations, resources, and environment  
Natural hazards  
------------------------  
Natural resources  
Environmental quality  
Natural and human-induced hazards |
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<tr>
<th>CEB</th>
<th>Concepts CD</th>
<th>ASPB Principle</th>
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<th>NRC SPSP stds 5-8, 9-12</th>
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<tbody>
<tr>
<td>2.1. Centers of Food Plant Diversity</td>
<td>Center of diversity, 100 plant species, 90% world food, genetic diversity, pest resistance, wild species, crop species (Common and scientific names of plants as well as families)</td>
<td>1, 4, 7, 8, 9</td>
<td>Reproduction and heredity</td>
<td>N/A</td>
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<tr>
<td>2.1.1. Overview (do)</td>
<td></td>
<td></td>
<td>Diversity and adaptations of organisms</td>
<td>Natural resources</td>
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<td>2.1.2. Explorations (do)</td>
<td></td>
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<td>Biological evolution</td>
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<td>2.1.3. Further Thought (do)</td>
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<td>Interdependence of organisms</td>
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<td>All other maps</td>
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</tbody>
</table>

| 2.J. Plant Species Diversity | Area-species diversity relationship, low and high plant species diversity | 7 | Diversity and adaptations of organisms | N/A |
| 2.J.1. Overview | | | Biological evolution | |
| 2.J.2. Explorations | | | | |
| 2.J.3. Further Thought | | | | |
| All other maps | | | | |

| III. Diversity of Life | Phylum, new species taxonomy | Diversity and adaptations of organisms | N/A |
| 1. Introduction | | Biological evolution | |

| 2. Numbers of Species | Number of species, tree of life | 7, 12 | Diversity and adaptations of organisms | N/A |
| 2.A. Introduction | | Biological evolution | |

| 2.B. Described Species | Carolus Linnaeus, 1.6 mi species, scientific name, extant / extinct species, total number of described species | 7, 12 | Diversity and adaptations of organisms | N/A |
| 2.B.1. Explorations | | Biological evolution | |
| 2.B.2. Further Thought | | | |

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<tr>
<th>CEB</th>
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<th>NRC SPSP stds 5-8, 9-12</th>
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</thead>
<tbody>
<tr>
<td>3.A. Introduction</td>
<td>Taxa, taxonomy, Carolus Linnaeus, hierarchical taxonomy, phenotype, genotype, KPCOFGS, biological species concept, systematics, phylogenetics, cladistics, cladogram, common ancestors</td>
<td>7</td>
<td>Diversity and adaptations of organisms</td>
<td>Biological evolution</td>
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<td>3.E. Kingdom Plantae</td>
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<td>3. E.1. Vascular Plants</td>
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<td>3. E.2. Gymnosperms</td>
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<td>3. E.3. Angiosperms</td>
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<td>3.E.3.a.Dicotyledons</td>
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<td>3. E.3.a.1. Anacardiacea</td>
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<td>3. E.3.a.2. Asteracea</td>
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<td>3. E.3.a.3. Fabaceae</td>
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<td>3. E.3.a.4. Fagaceae</td>
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<td>3.E.3.a.5. Rosacea</td>
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<td>3.E.3.a.6. Rubiacea</td>
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<td>3.E.3.a.7. Solanacea</td>
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<td>3.E.3.b. Monocotyledons</td>
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<td>3.E.3.b.1. Areceaca</td>
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<td>3.E.3.b.2. Orchidacea</td>
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<td>3.E.3.b.3. Poacea</td>
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<tr>
<td></td>
<td>simple- opposite – whorled leaves, inflorescences, berry fruits, threats, habitat destruction, over collection, grain, grasslands, wind pollination</td>
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<td></td>
<td>Eukaryotic, vascular plants, non-vascular plants (bryophytes), seedless, ferns, horsetails, whisk ferns, non-flowering seed plants (gymnosperms), flowering (angiosperms), Ginko, eyads, conifers (pinaceae), dicots, monocots, econ. importance, rainforest, crop species, ornamental, herbs, symbiosis, N fixing bacteria, life forms, shrubs, trees xerophytes, aquatic, climbers, broadleaf, mycorrhizae, medicinal plants, petals, stamens, pollination, woody growth, herbaceous growth, thorns, dyes prickles, epiphytes, alkaloids, leaves, plant fiber,</td>
<td>2, 3, 4, 7, 8, 12</td>
<td>Structure and function in living systems</td>
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<td>Reproduction and heredity</td>
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<td>Diversity and adaptations of organisms</td>
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<td>Biological evolution</td>
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<td>Interdependence of organisms</td>
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<td></td>
<td></td>
<td>Matter, energy, and org of living systems</td>
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</tr>
</tbody>
</table>

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### V. Threats to Biodiversity

#### 1. Introduction
- Habitat loss, threats, exotic spp, excessive hunting and harvesting, pollution, human-caused habitat destruction, deforestation, habitat fragmentation, global climate change

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<tr>
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<th>NRC SPSP stds 5-8, 9-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>Habitat loss, threats, exotic spp, excessive hunting and harvesting, pollution, human-caused habitat destruction, deforestation, habitat fragmentation, global climate change</td>
<td>9, 11, 12</td>
<td>Populations and ecosystems Diversity and adaptations of organisms Interdependence of organisms Matter, energy, and org of living systems</td>
<td>Populations, resources, and environment Natural hazards Population growth Environmental quality Science and technology in local, national, and global challenges</td>
</tr>
</tbody>
</table>

#### 2. Habitat Loss

##### 2.A. Introduction

#### 2.B. Deforestation Rates

##### 2.B.1. Overview
- Recent rates of def

##### 2.B.2. Explorations
- Map comp: def rate/pop gr/gross domestic prod.

##### 2.B.3. Further Thought
- Social processes, def., Compare Land Cover + Def maps for E.– NA –Ind.- C.

| 2.B. Deforestation Rates | Deforestation rates, population growth, gross domestic product | 1, 6 | Populations and ecosystems Interdependence of organisms Matter, energy, and org of living systems | Populations, resources, and environment Natural hazards Population growth Environmental quality Science and technology in local, national, and global challenges |

#### 3. Habitat Fragmentation

##### 3.A. Introduction
- Forest fragments

##### 3.B. Effects of Habitat Fragmentation

##### 3.B.1. Explorations
- Habitat fragmentation, habitat loss, exotic species, small populations,

##### 3.B.2. Further Thought

| 3.B. Effects of Habitat Fragmentation | Habitat fragmentation, habitat loss, exotic species, small populations, | 1, 11, 12 | Populations and ecosystems Diversity and adaptations of organisms | Populations, resources, and environment Natural hazards Population growth |

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>4.A. Introduction</td>
<td>Exotic species, threats to biodiversity, habitat loss</td>
<td>Populations and ecosystems</td>
<td>Natural hazards</td>
<td>Natural and human-induced hazards</td>
</tr>
<tr>
<td>4.A.1. Explorations</td>
<td></td>
<td>Diversity and adaptations of organisms</td>
<td></td>
<td>Science and technology in local, national, and global challenges</td>
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<td>4.A.2. Further Though</td>
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<td>Interdependence of organisms</td>
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<tr>
<td>4.C. Purple Loosestrife</td>
<td>wetland degradation, control measures (efforts), native plants, threatened species, endangered species, biological control</td>
<td>Populations and ecosystems</td>
<td>Natural hazards</td>
<td>Natural and human-induced hazards</td>
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<td></td>
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<td>Diversity and adaptations of organisms</td>
<td>Risks and benefits</td>
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<td>Interdependence of organisms</td>
<td>Environmental quality</td>
<td>Science and technology in local, national, and global challenges</td>
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</table>
APPENDIX C

FLOW CHART OF RESEARCH

1. Literature Review 2000-2006
2. Preparation of prospectus Fall 2005-Spring 2006
3. Prospectus defense Spring 2006
4. Identification of study subjects and submission of IRB forms, Spring 2006
5. Development of Plant Biodiversity rubric based on history and science standards Fall 2005-Spring 2006
6. Data analysis, results, and discussion, implications for future study Summer 2006 – Spring 2007
8. Pilot study that explored specific activities of the CEB CD-ROM and research techniques with students Spring 2005
10. Classroom Research Late Spring-Summer 2006
11. Acquire CEB CD-ROM through grant and made it available in 22 computers in the computer lab of the institution where the research will take place Fall 2005
12. Biodiversity study lesson (lectures and CD-ROM activities) Collect documents, conduct pre-treatment interviews, concept mapping, assessment of attitudes and cognitive knowledge Summer 2006
13. Create a comprehensive guide for the CEB CD-ROM including: science standards, ASPB principles, concepts and textbook chapters Summer 2005
14. Explore the CEB CD-ROM in open inquiry activities with students 2002-2003
15. Pilot study that explored specific activities of the CEB CD-ROM and research techniques with students Spring 2005
17. Modify the CEB CD-ROM to assess student learning gains Fall 2005-Spring 2006
18. Literature Review 2000-2006
19. Collect documents, conduct pre-treatment interviews, concept mapping, assessment of attitudes and cognitive knowledge Summer 2006
20. Data analysis, results, and discussion, implications for future study Summer 2006 – Spring 2007
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28. Prospectus defense Spring 2006
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32. Dissertation Defense Summer 2007
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APPENDIX D

PROTOCOL FOR INTERVIEWS

First Interview Participant Code _______________

Following chapter 18 and before activities #1 and #2

1. **Introduction and purpose**
   - Participants complete consent form and questionnaire

2. **Understanding the concept of biodiversity**
   - To the best of your knowledge, what can you tell me about Biodiversity?
   - Have you learned about this concept prior to taking this course?
   - What can you say about the importance or relevance of this concept for your biology class?...to you as a biology student?...as a citizen?

3. **Evolution and hierarchical organization of Biodiversity**
   - What can you tell me about the role, if any, of evolution for understanding biodiversity?
   - *Show fig. 18.5 “Tree of Life” figure from the textbook. (domains and kingdoms names are covered)*
     - What can you tell me about this figure?
     - Can you tell me something about how these branches are organized?
     - Can you tell me something about what these branches represent?
     - Can you name these?
   - *Show fig. 18.6 “The eukaryotic tree of Life” figure from the textbook.*
     - What can you tell me about this other figure?
     - Can you tell me something about what these branches represent?

4. **Numbers of species** *(Show fig. 18.5)*
   - If you were to distribute the total diversity of life, a 100% percent budget, what percentage of species do you think each of the different groups (branches, kingdoms) contributes?

5. **Basic characteristics of organisms** *(Show fig. 18.6)*
   - What can you tell me about the criteria or characteristics that are used to group organisms into these categories?

6. **Information made available by recognizing relationship among organisms**
   - What can you tell about the importance, if any, of knowing about how organisms in the different groups may be related to each other?

7. **List of seed concepts provided for the pre-CM. Participants can revise and modify CM #1 (pre) if they want.**
   Concepts used represent a mixture of concepts that would be used throughout the research

   **Seed Concepts**
   - Angiosperms
   - Biocomplexity
   - Biodiversity
   - Bryophytes
   - deforestation
   - Domain
   - ecosystems
   - # of species
   - Pollution
   - Food
   - Evolution
   - Exotic species
   - Genetics
   - Gymnosperms
   - Hot spots
   - Habitat
   - destruction
   - Genetics
   - Threats
   - Population
   - Species
   - Systematics
   - Rainforest- LA
   - Costa Rica
   - Plants
Second Interview  Participant Code _______________

Following chapter 18 and activities #1 and #2; before lesson #2 on levels of diversity

I. Follow-up Biodiversity, organization, numbers of species, and characteristics of organisms

1. Concept of biodiversity and importance of species
   • What can you say about Biodiversity?
   • Could you reconstruct the tree of life? (like fig. 18.5 before)
     - What can you tell me about the different groups?
     - Can you say something about these groups in terms of evolution?

2. What was the effect of the activities post chapter 18?
   • Can you tell me something about the numbers of species in the different groups (kingdoms)?
     - What can you tell me about the total # of species that have been described?
     - Is that # the same as the estimate of the total # of species in the planet? For CD group: Any group that seem particular to you?
     - Can you say something about the numbers of plant species?
   • Can you say something about the characteristics and/or importance of the organisms in the different kingdoms?

3. Participant reflection on activities post chapter 18
   • What can you tell me about the worksheets/activities completed from the Textbook/CEB?
   • Can you say something about how they contributed to your understanding of these concepts?

II. Levels of Biodiversity – pre-lesson #2 scanning questions

4. Can you tell me something about the levels of biodiversity?
5. Can you say something about your reasons to conserve biodiversity?

III. Concept Map co-construction:
Use the list of seed concepts below to construct a concept map that will reflect how you think these concepts relate. Only use those concepts you are comfortable using (that you know). You can add any other concepts, related terms, or examples that you think are relevant. Work form the broadest term to the most specific ones. Use linking phrases between related concepts. List includes concepts present in lesson and some concepts of the next lessons

- Angiosperms
- Biocomplexity
- Biodiversity
- Bryophytes
- Genus
- Phylum

- Domain
- No. of species
- Kingdom
- Hot spots
- Wetlands- LA
- Evolution

- Exotic species
- Genetic-
diversity
- Gymnosperms
- Family
- Habitat-
destruction
- Endangered-
species
- Order
- Species
- Systematics
- Rainforest-
Costa Rica
- Class

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Third Interview

Following lesson #2, Levels of Biodiversity (worksheets and activity #3, and conservation essay); and before lesson #3 on chapter 21.

I. Follow-up levels of biodiversity and conservation

1. Understanding the concept of biodiversity
   - What can you say about Biodiversity now?
   - Do you think your idea of biodiversity has changed since the last interview? If so how?

2. What can you tell me about the levels of biodiversity (species, genetics, and ecosystems)?
   - Can you give me any examples?
   - Can you say something about the species level? genetics level? ecosystem level?

3. What can you say about conserving biodiversity?
   - Can you share some of your reasons to or not to conserve biodiversity?
   - What can you say about the causes for loss of biodiversity? [Question is also a scan for future threats activity]
   - What can you say about the consequences of losing biodiversity?

II. Pre-lesson #3 Ch 21: The Plant Kingdom – scanning questions

4. Plant kingdom characteristics and evolution
   - Show fig. 18.5 “Tree of Life” figure from the textbook. (domains and kingdoms names are covered). What can you tell me about this figure?
   - Show fig. 21.2 “Tree of Life” figure from the textbook. (Phyla and characteristics are covered) Do you think these two figures (18.5 and 21.2) may be related? If so, how?
     - What can you tell me about the criteria that organisms in this group share?
   - Can you say something about the diversity of the plant kingdom?

5. Assessing “Plant Blindness”
   - In your daily life do you tend to notice plants around you?
   - Did you ever have a hands-on experience with plants?
   - Can you say something about the importance of plants?
Fourth Interview

Participant Code _______________

Following lesson #3, chapter 21: The Plant Kingdom (worksheets and activity #4, and quiz chapter 21); and before lesson #4 (Louisiana Plants), lesson #5 (global patterns), and lesson #6 (threats).

I. Follow-up: Understanding the plant kingdom

1. Assessing knowledge about plants vs. “Plant Blindness”
   - Show interview Fig 1 - Flamingoes at Audubon zoo with plant background. What do you see in this picture? (PB: more questions on this topics later)

2. Biodiversity
   - What can you tell me about Biodiversity now?
   - Do you think your idea of biodiversity has changed since the last interview? If so how?
   - Can you say something about plant biodiversity?

3. Plant kingdom characteristics and evolution
   - Could you reconstruct the tree of life?
     - Show fig. 18.5 “Tree of Life” figure from the textbook. (domains and kingdoms names are covered). What can you tell me about this figure?
     - What can you tell me about the criteria that organisms in this group share? (Plant Kingdom)
   - Show fig. 21.2 “Tree of Life” figure from the textbook. (Phyla and characteristics are covered) Do you think these two figures (18.5 and 21.2) may be related? If so, how?
   - What can you tell me about the unique characteristics of this group? (Plant Kingdom)
     - Can plants move?
     - What do plants require to stay alive?
   - Could you elaborate on how evolution and plant diversity may be related?
     - Show interview Fig 2- Spirogyra
   - Are all plants the same? What can you tell me about the criteria used to group organisms here fig. 21.2)?
     - Can you tell me something about what you have learned about these plants here? (Show interview Figures 3 etc Bryophytes; horsetails; Ferns; Pines, cypress, etc.; flowering plant with butterfly, cactus with flower, iris, magnolia)

4. Role of plants in ecosystem
   - Can you tell me something about the type of plant community in which you live?
     - Can you say something about the plants that live there?
       - Reproduction, adaptations, other characteristics?
   - What can you say about plants and biogeochemical cycles?
     - Like carbon, nitrogen, water...
   - Could you comment and elaborate on these: (also a scanning question for next lesson)
     - Relation between ecosystems diversity and plant diversity
     - Relation between genetic diversity and plant diversity
   - What can you tell me about the role of plant species diversity in relation to
- Our food, other organisms, our health, other aspects of life

5. Botanical sense of place
   • In your daily life do you tend to notice plants around you?
   • Did you ever have a hands-on experience with plants?
   • Can you say something about the aesthetic value of plants?

6. About learning tools
   • Can you comment on the influence, if any, of lecture on chapter Ch 21 on your understanding of plant diversity?
   • What can you tell me about the influence of worksheets/CEB on your understanding of plant diversity?
     - Did you learned anything new by using the CD-ROM
     - Think pair share on plant families: How do you think this activity affected your learning about the plant families?
     - What things you liked and dislike about using the cd rom compare to textbook?

II. Pre-lesson #5 and #6 scanning questions

7. What can you tell me about the distribution of species in the world? Distribution of ecosystems?
8. Can you tell me something about factors that could affect biodiversity?

IV. Concept Map co-construction:
Use the list of seed concepts below to construct a concept map that will reflect how you think these concepts relate. Only use those concepts you are comfortable using (that you know). You can add any other concepts, related terms, or examples that you think are relevant. Work form the broadest term to the most specific ones. Use linking phrases between related concepts. List includes concepts present in earlier lesson and some concepts of this and the next lessons.

<table>
<thead>
<tr>
<th>Angiosperms</th>
<th>ecosystems</th>
<th>Exotic species</th>
<th>Habitat-</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocomplexity</td>
<td>No. of species</td>
<td>Genetics</td>
<td>destruction</td>
<td>Systematics</td>
</tr>
<tr>
<td>deforestation</td>
<td>Kingdom</td>
<td>Gymnosperms</td>
<td>food</td>
<td>Seeds</td>
</tr>
<tr>
<td>Plant-</td>
<td>threats</td>
<td>Endangered-</td>
<td>Bryophytes</td>
<td>Mosses</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Wetlands- LA</td>
<td>species</td>
<td>monocots</td>
<td>Family</td>
</tr>
<tr>
<td>Pollution</td>
<td>Evolution</td>
<td>pollination</td>
<td>medicines</td>
<td></td>
</tr>
</tbody>
</table>
Last interview, followed lessons #4, 5, and 6 (project, worksheets and activities #5 and #6; re-visit of conservation essay, post quiz, and post survey).

1. Follow-up previous interview (concepts) lessons #5 and #6

1. Global and local patterns
   - Could you comment and elaborate on the relation between ecosystems diversity and plant diversity
   - Use Fig. 41. 7 Global distribution of biomes. What can you tell me about the distribution of species in the world? About the distribution of ecosystems?
   - Use interview images: tropical rain forest, temperate forest, desert, and swamps
     - Do ecosystems differ in species diversity?
   - Can you say something about hot spots?

2. Role of plants
   - Could you comment and elaborate on the relation, if any, between genetic diversity and plant diversity
     - Can you say something about genetic engineering and species diversity? or ecosystem diversity?
   - Can you say something about the role of plants in medicine? Food?
     - Where do these come from?

3. Threats to plant biodiversity
   - What can you tell me about threats or things that negatively impact plant diversity?
     - Is any one in particular more important than another? Or of particular interest in the US? LA?
     - What can you say about loss of habitat as a threat to plant diversity?
     - What could be the consequences?
     - Show pictures of exotic (invasive) plant species. Can you tell me something about these plants here?

II. Follow up on project

4. You worked on a project about LA Native species. Can you share with me some comments you may have about this experience?
   - What can you say about in-class list of LA plant species diversity?

III. Follow up on other activities and post-unit activities

5. You wrote an essay on reasons for conserving plant species diversity. Do you have any comments on that?
   - What can you do to conserve plant species diversity?

6. Can you share with me some comments about the Golden List of Species?
7. How would you describe your overall experience of participating on this research?
   - This is what the students in the other group did (*Show worksheets to CEB group. Show CEB to textbok group*). Do you have any comments?
   - What can you tell me about the role of the CEB/textbook on developing your understanding about plant biodiversity?

**IV. Concept Map co-construction:**
Use the list of seed concepts below to construct a concept map that will reflect how you think these concepts relate. Only use those concepts you are comfortable using (that you know). You can add any other concepts, related terms, or examples that you think are relevant. Work from the broadest term to the most specific ones. Use linking phrases between related concepts. List includes concepts present in earlier lesson and some concepts of this and the next lessons.

<table>
<thead>
<tr>
<th>Flowering-plants</th>
<th>ecosystems</th>
<th>Exotic species</th>
<th>Genetics</th>
<th>Habitat-destruction</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocomplexity</td>
<td>threats</td>
<td></td>
<td>Endangered-species</td>
<td>medicines</td>
<td>Systematics</td>
</tr>
<tr>
<td>deforestation</td>
<td>conifers &amp;</td>
<td></td>
<td></td>
<td>hot spots</td>
<td>Mosses &amp;</td>
</tr>
<tr>
<td>Plant-biodiversity</td>
<td>cycads</td>
<td></td>
<td>Evolution</td>
<td>plants</td>
<td>liverworts</td>
</tr>
<tr>
<td></td>
<td>Family</td>
<td></td>
<td></td>
<td></td>
<td>Biodiversity</td>
</tr>
</tbody>
</table>
APPENDIX E

CLASSROOM AND COMPUTER LABORATORY OBSERVATION FORM

Section- ___________  Day of the week- ________

Attendance- _______ F _______ M

Setting: Classroom environment/atmosphere:
- Organized  Y  N  somewhat
- Cleanliness
- Temperature
- AV equipment working properly  Y  N

General attitude of the class

Incidents

<table>
<thead>
<tr>
<th>Student-student interactions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask questions</td>
<td></td>
</tr>
<tr>
<td>Works in group if instructed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student-teacher interaction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask questions</td>
<td></td>
</tr>
<tr>
<td>Completes notes/pays attention</td>
<td></td>
</tr>
<tr>
<td>Completes notes/not paying att</td>
<td></td>
</tr>
<tr>
<td>Sits and listens</td>
<td></td>
</tr>
<tr>
<td>Completes work as instructed/stays on task</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reads from text or computer</td>
<td></td>
</tr>
<tr>
<td>Completes work for another class while in lecture</td>
<td></td>
</tr>
<tr>
<td>Appears to daydream</td>
<td></td>
</tr>
<tr>
<td>Works on other sections of program not following instructions</td>
<td></td>
</tr>
<tr>
<td>Outside of computer program (other actv: e-mailing, web surfing)</td>
<td></td>
</tr>
</tbody>
</table>

My reflections for the day:
APPENDIX F

PRE – AND POST STUDENT ASSESSMENT OF LEARNING GAINS SURVEY

Student Assessment of Learning Gains
Pre-Survey

CODE:   M   F   Age ____    Course Sect – D0___      Last 2 digits social ___

* You are invited to answer the following survey. Please do so to the best of your current knowledge and as sincerely as possible. The information you provide will be used to improve science education. It will directly impact the teaching of biology at your institution.

* Please note, for most sections there is a separate set of alternatives from where to select your answer.

* The information collected here will remain anonymous

Use this set of words for sections I and II

a. Not (confident/interested)
b. A little (confident/interested)
c. Somewhat (confident/interested)
d. Highly (confident/interested)
e. Extremely (confident/interested)

I. Presently, I am _____ CONFIDENT I can ...
   ____ 1. Discuss scientific concepts related to plant biodiversity with my friends or family
   ____ 2. Think critically about scientific findings I read about in the media
   ____ 3. Give a presentation about plant biodiversity topic to my class
   ____ 4. Pose questions that can be addressed by collecting and evaluating scientific Evidence
   ____ 5. Understand scientific processes behind plant biodiversity issues in the media
   ____ 6. Understand the plant biodiversity content of this course

II. Presently, I am _____ interested in ...
   ____ 7. Reading about science and its relation to social issues
   ____ 8. Exploring career opportunities in science
   ____ 9. Teaching science
   ____10. Changing my life style to have a reduced impact on plant biodiversity
   ____11. Promoting knowledge about plant biodiversity
Use this set of words for sections III and IV

a. No help  
b. A little help  
c. Some help  
d. Highly helpful  
e. Extremely helpful

III. How much these aspects of the class help my learning of plant biodiversity?
___12. How the material is approached (relevance)
___13. Class activities: discussions
___14. Class activities: computer use
___15. Class activities: concept maps
___16. Class activities: studying for tests
___17. Collaboration, group work
___18. Working on a project
___19. Lecture

IV. How these Resources help your learning of plant biodiversity concepts in this class? (Please also circle & rank the ones you prefer)
___20. INTERNET
___21. Textbook
___22. Textbook CD
___23. Use of computer lab program (CEB)
___24. Instructor’s lecture notes
___25. Videos

Use this set of words for section V

a. Not confident  
b. A little confident  
c. Somewhat confident  
d. Highly confident  
e. Extremely confident

V. Based on the work you have completed on this class, presently, I feel confident I understand and can explain …
___26. Biodiversity is a term used to describe the variety of life on Earth
___27. Evolution can be defined as change in the genetic makeup of a population over time
___28. Evolution of life results in biodiversity
___29. Genetic diversity of wild plant species is important for disease resistance in crops like rice, potatoes, and corn
30. Diversity of life (Biodiversity) refers to the numbers of species on Earth, their genetic pool and the variety of ecosystems where they live
31. There are 1.6 million species described on earth
32. The diversity of species in a region of the world reflects the diversity of ecosystems in that place.
33. Environmental change is the most important cause of species extinction
34. Tropical rain forests have the greatest number of species
35. At the present time there are between 5 million and 30 million estimated species on Earth
36. Flowering plants, are the most diverse group of plants, and contribute the most species to the kingdom
37. Presence of flowers and cones is a major difference between gymnosperms and angiosperms
38. Bryophytes are land plants restricted to moist environments
39. The anti cancer drug Taxol is extracted from a gymnosperm, the yew tree
40. Plants, bacteria and fungi can form symbiotic relationships, like root nodules and mycorrhizae which helps plants grow
41. Plants have diverse growth habits (i.e. vines, epiphytes, grasses)
42. Plants are source of raw material (i.e. fiber).
43. Plants that we use for foods or other benefits may come from places distant to where they are cultivated or consumed
44. Some plants can have a negative impact on species diversity, like the wetland invasive purple loosestrife
45. The most important threat to plant biodiversity is growth of human population
46. There is no need to conserve plant biodiversity, we are not directly affected
47. It is possible and necessary to conserve plant biodiversity
48. Pollination and shelter are examples of ecosystem services provided by plants
49. Plants adapt to the environment, i.e. may loose leaves or store water
50. Some plants, like the American Holly, need male and female plants to reproduce
51. Plants are just as capable of responding to their environment as are animals
52. We rely in 20 plant species to provide over 80% of the world’s nutritional needs
53. Native plant diversity is affected mostly by development, habitat loss (i.e. deforestation), invasive species, human population growth, pollution, and overuse of natural resources
54. Endangered refers to a plant that can soon disappear from the planet
Student Assessment of Learning Gains
Post-Survey

CODE:  M  F  Age ____  Course Sect – D0___  Last 2 digits social ___

* You are invited to answer the following survey. Please do so to the best of your current knowledge and as sincerely as possible. The information you provide will be used to improve science education. It will directly impact the teaching of biology at your institution.

* Please note, for most sections there is a separate set of alternatives from where to select your answer.

* The information collected here will remain anonymous

Use this set of words for sections I and II

a. Not (confident/interested)
b. A little (confident/interested)
c. Somewhat (confident/interested)
d. Highly (confident/interested)
e. Extremely (confident/interested)

I. Presently, I am _____ CONFIDENT I can ...

_____ 1. Discuss scientific concepts related to plant biodiversity with my friends or family
_____ 2. Think critically about scientific findings I read about in the media
_____ 3. Give a presentation about plant biodiversity topic to my class
_____ 4. Pose questions that can be addressed by collecting and evaluating scientific Evidence
_____ 5. Understand scientific processes behind plant biodiversity issues in the media
_____ 6. Understand the plant biodiversity content of this course

II. Presently, I am _____ interested in ...

_____ 7. Reading about plant biodiversity and its relation to social issues
_____ 8. Exploring career opportunities in science
_____ 9. Teaching science
_____ 10. Changing my life style to have a reduced impact on plant biodiversity
_____ 11. Promoting knowledge about plant biodiversity
Use this set of words for sections III and IV

a. No help
b. A little help
c. Some help
d. Highly helpful
e. Extremely helpful

III. How much these aspects of the class help my learning of plant biodiversity?

12. How the material is approached
13. Class activities: discussions
14. Class activities: computer use
15. Class activities: concept maps
16. Class activities: studying for tests
17. Collaboration, group work
18. Working on a project
19. Lecture

IV. How these Resources help your learning of plant biodiversity concepts in this class (Please also circle & rank the ones you prefer)

20. INTERNET
21. Textbook
22. Textbook CD
23. Use of computer lab program (CEB)
24. Instructor’s lecture and notes
25. Videos

Use this set of words for section V

a. Not confident
b. A little confident
c. Somewhat confident
d. Highly confident
e. Extremely confident

V. Based on the work you have completed on this class, presently, I feel confident I understand and can explain …

26. Biodiversity is a term used to describe the variety of life on Earth
27. Evolution can be defined as change in the genetic makeup of a population over time
28. Evolution of life results in biodiversity
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400
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52. We rely in 20 plant species to provide over 80% of the world’s nutritional needs
53. Native plant diversity is affected mostly by development, habitat loss (i.e. deforestation), invasive species, human population growth, pollution, and overuse of natural resources
54. Endangered refers to a plant that can soon disappear from the planet

Use this set of words for sections VI -VIII

a. Not at all
b. A little
c. Somewhat
d. a lot
e. a great deal

VI. To what extent did you make gains in any of the following as a result of Using the Conserving Earth’s Biodiversity program?

55. Understanding plant biodiversity
56. Understanding the relationship between concepts related to plant biodiversity
57. Understanding how ideas in this class may relate to those in other science classes

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VII. To what extent did you make gains in any of the following as a result of Using the courses textbook?

62. Understanding plant biodiversity
63. Understanding the relationship between concepts related to plant biodiversity
64. Understanding how ideas in this class may relate to those in other science classes
65. Understanding the relevance of plant biodiversity to real world issues
66. Appreciating plant biodiversity
67. Feeling comfortable with explaining plant biodiversity
68. Enthusiasm for learning about plant biodiversity

VIII. How much of the following do you think you will remember and carry with you into other classes or aspects of your life?

69. Understanding main concepts about plant diversity
70. Understanding the relationship between concepts in biodiversity
71. Understanding how ideas in this class may relate to those in other science classes
72. Understanding the relevance of this field to real world issues, i.e. human population growth, loss of biodiversity, invasive species
73. Ability to think through a problem
74. Understanding of myself as part of the biodiversity and having a role in its conservation
75. Enthusiasm for subject
76. Feeling comfortable with complex ideas
## APPENDIX G

**STRENGTHS AND WEAKNESSES OF DATA COLLECTION METHODS.**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>O</th>
<th>I</th>
<th>DR</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helps uncovering participants’ perspectives</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fosters face-face interaction with participants</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Facilitates immediate follow-up for clarification</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Good for obtaining data on nonverbal behavior and communication</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Data easy to manipulate and categorize for analysis</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Easy to administer and manage</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easily quantifiable, use in statistical analysis</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Easy to establish generalizability</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Data collected in natural setting</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides for flexibility in formulating hypothesis</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides context information</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitates analysis, validity checks, and triangulation</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weakness</th>
<th>O</th>
<th>I</th>
<th>DR</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depends on cooperation of small group of individuals</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Data often subject to observer effects</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Dependent on openness and honesty of participants</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Difficult to replicate</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly dependent on the ability of the researcher to be resourceful, systematic, and honest</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Can lead researcher to “miss the forest while observing the trees</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

*Note.* Modified from Marshall and Rossman (1999), Tables 4.1 and 4.2. Strengths and weaknesses, as applicable to this research, are arranged in order of presence in one, two, three, or all four methods. Code meanings are: O= Observation; I= Interview; DR = document review; Q= questionnaire; X= presence
APPENDIX H

LSU INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH SUBJECT PROTECTION

LSU INSTITUTIONAL REVIEW BOARD (IRB)  5/12/2006
IRB APPLICATION: APPROVAL OF PROJECTS WHICH USE HUMAN SUBJECTS

The IRB uses this form to obtain succinct answers to questions it must consider. If incomplete, your application will be returned! You can download this form and all other IRB documents from http://www.lsu.edu/irb) & complete it with your word processor. Call Robert Mathews for assistance, 225-578-8692, or e-mail him at: irb@lsu.edu.

When this application is submitted to the IRB please include:
• Two copies of this completed form.
• A brief project description (adequate to evaluate risks to subjects)
• Copies of all instruments to be used. If this proposal is a part of a grant application include a copy of the grant proposal, the investigative brochure (if one exists) and any recruitment materials including advertisements intended to be seen or heard by potential subjects.
• The consent form that you will be using.
A copy of the Waiver of Signed Informed Consent is attached and must be completed only if you do not intend to use a signed consent form.
• Copies of your IRB stamped consent form must be used in obtaining consent.
• Certificate of Completion for Human Protection Training for all personnel involved in the project (including students who are involved with testing and handling data) at http://cme.cancer.gov/clinicaltrials/learning/humanparticipant-protections.asp (Unless already on file with the IRB.)

(IRB Use: IRB# _______ Review Type: Expedited___ Full ___)

Part 1: General Information

1. Principal Investigator: Dr. James H. Wandersee  Rank: Wm LeBlanc Alumni Prof.
   (PI Must be an LSU Faculty member)
   Dept.: Curriculum and Instruction  Ph: 225-578-2348
   E-mail: jwander@lsu.edu
   Co-investigators*: Sandra M. Guzman
   *Student? Yes  Thesis/dissertation/class project? Yes
   Dept.: Curriculum and Instruction  Ph: 225-578-2348
   E-mail: sguzma1@lsu.edu

2. Project Title: Community College Students’ Plant Biodiversity Learning Experience in an Introductory Biology Course: Exploring the Value Added by Using CD-ROM to Develop Inquiry Lessons

3. Proposed duration (months): approx. 4-5 wks  Start date: Summer 2006
4. Funding sought from: __none- (personal)________________________

5. LSU Proposal #: _______ 6. Number of subjects requested: 6 indv and approx. 40 max. total class

6. Are you obtaining any health information from a health care provider that contains any of the identifiers listed below? **NO**

A. Names

B. Address: street address, city, county, precinct, ZIP code, and their equivalent geocodes. Exception for ZIP codes: The initial three digits of the ZIP Code may be used, if according to current publicly available data from the Bureau of the Census: (1) The geographic unit formed by combining all ZIP codes with the same three initial digits contains more than 20,000 people; and (2) the initial three digits of a ZIP code for all such geographic units containing 20,000 or fewer people is changed to ‘000’. (Note: The 17 currently restricted 3-digit ZIP codes to be replaced with ‘000’ include: 036, 059, 063, 102, 203, 556, 692, 790, 821, 823, 830, 831, 878, 879, 884, 890, and 893.)

C. Dates related to individuals

i. Birth date

ii. Admission date

iii. Discharge date

iv. Date of death

v. And all ages over 89 and all elements of dates (including year) indicative of such age. Such ages and elements may be aggregated into a single category of age 90 or older.

D. Telephone numbers;

E. Fax numbers;

F. Electronic mail addresses;

G. Social security numbers;

H. Medical record numbers; (including prescription numbers and clinical trial numbers)

I. Health plan beneficiary numbers;

J. Account numbers;

K. Certificate/license numbers;

L. Vehicle identifiers and serial numbers including license plate numbers;

M. Device identifiers and serial numbers;

N. Web Universal Resource Locators (URLs);

O. Internet Protocol (IP) address numbers;

P. Biometric identifiers, including finger and voice prints;

Q. Full face photographic images and any comparable images; and

R. Any other unique identifying number, characteristic, or code; except a code used for re-identification purposes; and

S. The facility does not have actual knowledge that the information could be used alone or in combination with other information to identify an individual who is the subject of the information.

**YES**

Your study falls under the HIPAA (Health Information Privacy and Accountability Act) and you must obtain either a limited data set use agreement or a HIPPA authorization agreement from the health care provider. This agreement must be submitted with your IRB protocol.

**NO**
You do not need a HIPAA agreement.

Page 3

A. ASSURANCE: PRINCIPAL INVESTIGATOR – (Dr. James H. Wandersee)
I accept personal responsibility for the conduct of this study (including ensuring compliance of co-investigators/co-workers in accordance with the documents submitted herewith and the following guidelines for human subject protection: The Belmont Report, LSU's Assurance with OPRR, and 45 CFR 46 (Available from OSP or at http://www.lsu.edu/irb)

Signature of PI _________________________________ Date ______________

B. ASSURANCE OF STUDENT/PROJECT COORDINATOR (Sandra M. Guzman)
I agree to adhere to the terms of this document and am familiar with the documents referenced above.

Signature ______________________________ Date ______________

p.2

Part 2:
Project Abstract –
The objective of this research is to examine how the use of technology may affect the inquiry learning experience of the introductory biology students in a rural community college. By implement the use of an interactive biodiversity CD-ROM, I will examine how students understand the concept of biodiversity, and what are the learning gains when a CD-ROM is used in addition to the textbook-based instruction. By exposing students to lecture, virtual, and real experiences and data about plant biodiversity, this research will examine the students’ ability to pursue inquiries about biodiversity related concepts. In addition an appropriate rubric based on the history of the concept of biodiversity will be developed to evaluate students’ understanding.

Part 3:
Research Protocol
A: Describe study procedures
Describe study procedures with emphasis on those procedures affecting subjects and safety measure. Also provide script for telephone surveys.

During an approximate 4 week period participants will be exposed to learning about plant biodiversity. One group will be quasi experimental, and will be exposed to traditional textbook-based instruction supplemented by activities from the Conserving Earth’s Biodiversity CD-ROM. One group will be identified as comparison group and will complete textbook-based activities. All students will complete a pre-and post-survey, quizzes, and a group presentation. All of these activities will take part during class time, and they are part of the regularly required course work. Six students will be selected, three from each, treatment and comparison group. These six students will participate in interviews and concept map co-construction outside of class time, requiring approximately 6-7 hours of their time during the study period. All participants to be used as case studies will be assigned a code fictional name to guard their right of privacy. They will receive monetary compensation for the time invested out of the regular classroom activities.
B: Answer each of the following questions.
1. Why is the use of human subjects necessary? (v.s. animals/in vitro)

I will be testing hypotheses based on education practices and instruments used for such in the introductory biology college classroom. Therefore, this study calls for human students/learners.

2. Specify sites of data collection. – Introductory Biology courses at River Parishes Community College

3. If surgical or invasive procedures are used, give name, address, and telephone number of supervising physician and the qualifications of the person(s) performing the procedures. Comparable information when qualified participation or supervision is required or appropriate. N/A

4. Provide the names, dosage, and actions of any drugs or other materials administered to the subjects and the qualifications of the person(s) administering the drugs. N/A

5. Detail all the physical, psychological, and social risks to which the subjects may be exposed. N/A

6. What steps will be taken to minimize risks to subjects? This study represents no known risks to the participants

7. Describe the recruitment pool (community, institution, group) and the criteria used to select and exclude subjects. Students in an introductory biology courses at the institution where the research will take place.

8. List any vulnerable population whose members are included in this project (e.g., children under the age of 18; mentally impaired persons; pregnant women; prisoners; the aged.)- None

9. Describe the process through which informed consent will be obtained. (Informed consent usually requires an oral explanation, discussion, and opportunity for questions before seeking consent form signature.) All students will be explained the study to be conducted in their classroom. They will be given the opportunity to volunteer as a subject for the interview process. They will also be advised that even though the activities are part of the regular course work, if they do not wish to participate and their data collected, they can inform the instructor, and their information will not be used. In the same way, students will know they can withdraw from the study. However, they will still need to complete all course-related work in order to gain their course grade.

10. This study is confidential. Privacy of the study subjects and security of their data will be protected by using codes and fictional names.

Attachments:
1. Attach copies of All Instruments and questionnaires used. – **SALG included**
2. Any Relevant Grant Applications. – **none**
3. The investigative brochure (if one exists) and any recruitment materials, including advertisements intended to be seen or heard by potential subjects.
4. Attach documentation of application to IRB of collaborating institutions:
   (Documentation of application to the IRB of collaborating institution is required by LSU IRB before work begins on the study.)

Send original and 2 copies of application form & all attachments to IRB Office at 203 B-1 David Boyd Hall, (225) 578-8692, FAX 578-6792.

Expedited review usually takes 1-2 weeks. Full reviews are held at the bimonthly IRB meetings 2nd week of Feb, Apr, June, Aug, Oct, Dec. Carefully completed applications should be submitted 2 weeks before a meeting to ensure a prompt decision. Contact Dr. Robert Mathews, 225-578-8692, irb@lsu.edu if you need assistance. Additional important guidance and documents are at http://www.lsu.edu/irb/irbapp.wpd 05/12/2006

Institutional Review Board
203 B-1 David Boyd Hall
Louisiana State University and A&M College
Baton Rouge LA 70803
irb@lsu.edu
LSU IRB REQUEST FOR WAIVER OF SIGNED INFORMED CONSENT
*** A copy of the script you will use for oral consent should be included with this form. This script should contain the necessary elements for written informed consent (see http://appl003.lsu.edu/osp/osp.nsf/$content/LSU%20IRB%20Documents/$File/chklst.txt)

FROM: Name: _______________________________________
Department ___________________________________

TO:
Robert C. Mathews, Chairman
Institutional Review Board for Research with Human Subjects
DATE:

____________________________________________

RE:
IRB# ________________
TITLE:

______________________________________________________________________________

I am requesting waiver of signed Informed Consent because:
(a) The consent document would create the principal risk of participating in the study.
Or
(b) The research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context.
APPENDIX I

CONSENT FORM

Louisiana State University
Institutional Review Board for Human Research

1. STUDY TITLE:  Community College Students’ Plant Biodiversity Learning Experience in an Introductory Biology Course: Exploring the Value Added by Using a CD-ROM to Develop Inquiry Lessons

2. PERFORMANCE SITE:  River Parishes Community College, Sorrento, LA

3. INVESTIGATORS:  The following investigators are available for questions about this study, M-F, 8:00 a.m. - 4:30 p.m.

   Student Investigator:  Sandra M. Guzman, Doctoral Candidate of Biology Education, LSU
   P.O. Box 310, John LeBlanc Blvd., Sorrento, LA 70778
   (225) 675-0221, fax (225) 675-5478

   Faculty Advisor (PI):  Dr. James H. Wandersee, Wm LeBlanc Alumni Professor of Biology Education, Dept. Curriculum and Instruction, LSU.
   223-F Peabody Hall, Baton Rouge, LA 70803
   (225) 578-2348

4. PURPOSE OF THE STUDY:  The objective of this research is to examine how the use of technology may affect the inquiry learning experience of the introductory biology students in a rural community college.  By implement the use of an interactive biodiversity CD-ROM, I will examine how students understand the concept of biodiversity, and what are the learning gains when a CD-ROM is used in addition to the textbook-based instruction.  By exposing students to lecture, virtual, and real experiences and data about plant biodiversity, this research will examine the students’ ability to pursue inquiries about biodiversity related concepts.  In addition an appropriate rubric based on the history of the concept of biodiversity will be developed to evaluate students’ understanding.

5. SUBJECT INCLUSION:  Community college students taking introductory biology course for non-majors

6. NUMBER OF SUBJECTS:  Original number of subject is 6 (case studies) and 40 maximum (class wide)

7. STUDY PROCEDURES:  During a four to six week period participants will be exposed to learning about plant biodiversity.  One group will be experimental, and will be exposed to traditional textbook-based instruction supplemented by activities from the Conserving Earth’s Biodiversity CD-ROM.  One group will be identified as comparison group and will complete textbook-based activities.  All students will complete a pre-and post-survey, quizzes, and a group presentation.  All of these activities will take part during class time.  Six students will be selected, three from each, treatment and comparison group.  These six students will participate in
interviews and concept map co-construction outside of class time, requiring approximately 6-7 hours of their time during the study period.

8. BENEFITS: This study will yield valuable information about understanding of the biodiversity concept when students are exposed to computer-based instructional tools, in addition to the course textbook. In addition, the participants will directly benefit by being exposed to concepts of biological diversity, and hopefully learning these. As the majority of the activities are part of the course, all students will earn points towards their course grade. The participants who will be involved in additional out-of-class activities (i.e. interviews and concept map co-construction) will possibly earn a better understanding of the concepts. All students will be contributing to the effort of improving college biology education at RPCC and other similar institutions.

Monetary compensation will be awarded (at the Federal minimum wage rate) for the time used in interviews and working on additional activities.

9. RISKS: There are no risks associated to this research as known to the investigators.

10. RIGHT TO REFUSE: Even though some of the activities, and data collection will take place as part of the course requirements, participants may choose not to be part of the study or withdraw from the study at any time without penalty or loss of educational-related benefit, or monetary benefit to which they might be entitled at the time of withdrawal.

11. PRIVACY: This study is confidential. Results of the study may be presented at professional meetings (i.e. NABT, NARST, AERA, AIBS, or ESA), and may be published in science education research journals. However, no names will be included in the publication. Subject identity will remain confidential at all times, unless disclosure is required by law.

12. SIGNATURES:

The principal investigator has discussed this study with me. All my questions have been answered. I am informed that any additional questions regarding the study specifics can be directed to the investigators. If I have questions about subjects’ rights or other concerns, I can contact Robert C. Mathews, Institutional Review Board (225-578-8692).

I agree to participate in the study described above and acknowledge the investigator’s obligation to provide me with a signed copy of this consent form.

______________________________                      ____________________________
Participant       Investigator

____________              ___________
Date                  Date
APPENDIX J

PILOT STUDY METHODS

Setting

This pilot study took place at a rural area community college. This college is an open admission higher education institution. Study subjects were selected from two sections (D01 and D03) of the Introductory Biology course (BIOL 1020) using the criteria described in the next section. Biol 1020 is a course that covers the concepts of biological diversity, physiology, and behavior of living organisms threaded by the concept of evolution.

Criteria for Subject Selection

Two lecture sections for BIOL 1020 course, taught by the same instructor were selected to obtain a pool of research participants. The instructor requested information on BIOL 1020 students’ GPA from the registrar. Given the request was from an instructor at the institution no confidentiality rules on access to student records were broken. Four groups were established based on GPA as an index of student performance, using the following criteria:

Group 1: Excellent - “A” students – 3.33 – 4.00
Group 2: Good - “B” students – 2.70 – 3.32
Group 3: Satisfactory – “C” students – 2.00 -2.69
Group 4: Deficient & failing - “D” students – 0.67- 1.99
                   (≤1.99) “F” students - < 0.67

Then, for each group, the student names were placed in a brown bag and randomly selected. I selected a sample that included 2 males and 2 females in each group, for a total of 4 students per group or 16 study subjects. Students selected were invited to participate in the research and were told about the commitment it represented. If students did not agree to participate, they were substituted by others using that will meet the criteria, and selected on purpose. No consent forms were signed given this was a pilot study. Contact information for all participants has been kept in case signed forms are needed. In addition, all participants consented to be videotaped during the exit interview and agreed for any data based on the study to be used.

Out of the 4 students in each group (16 original study subjects), there was subject attrition in some groups,

- Group 1: -1 F
- Group 2: -1M & -1F
- Group 3: no attrition
- Group 4: -1M

Therefore the Pilot S’05 ended up with 12 study subjects. Information on these individuals follows. These subjects received extra credit points for the activities completed in class and were treated to pizza.
<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>4</td>
<td>F</td>
<td>F26521</td>
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</table>

Activities

The study started on April 4th, 2005 and extended through May 12th, 2005 with the higher concentration of activities taking place during the last week of April and first two weeks of May. During this time all students covered course material about biodiversity presented in chapters 18-22, and the plant unit, chapters 23-24, as discussed in *Biology: Life on Earth* (Audesirk, Audesirk, and Byers 2002).

Regular lecture with demos and Internet activities were used to expose the material in chapters 18 through 22 to the students. Student learning for these chapters was assessed by multiple choice tests with questions using projected visuals in Microsoft PowerPoint. The material in chapters 23 and 24, and a review of chapter 21 was presented through a guided inquiry activity, modeled by the instructor in lecture. Students were assessed using a group presentation on plant biodiversity using a focus theme of their choice from a list provided.

In addition to all regular-class activities, the 12 study subjects selected for the pilot study participated in a series of activities based on the CD-ROM *Conserving Earth’s Biodiversity* (Wilson and Perlman, 2000). These students completed all pilot study activities and met for

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4 A new edition of this textbook has been published in 2005 by Prentice Hall (7th edition). However at the study site students will still use the older 6th edition. Although some titles slightly change, the material presented in the chapters of interest for this research is exactly the same in both editions. Corresponding chapters for the 6th and 7th editions are listed below.

<table>
<thead>
<tr>
<th>6th ed</th>
<th>7th ed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch 18</td>
<td>Systematics: Seeking Order Amidst Diversity</td>
</tr>
<tr>
<td>Ch 21</td>
<td>The Diversity of Plants</td>
</tr>
<tr>
<td>Ch 23</td>
<td>Plant Form and Function</td>
</tr>
<tr>
<td>Ch 24</td>
<td>Plant Reproduction and Development</td>
</tr>
<tr>
<td>Ch 25</td>
<td>Plant Responses to the Environment</td>
</tr>
<tr>
<td>Ch 18</td>
<td>Systematics: Seeking Order Amidst Diversity</td>
</tr>
<tr>
<td>Ch 21</td>
<td>The Diversity of Plants</td>
</tr>
<tr>
<td>Ch 24</td>
<td>Plant Anatomy and Nutrient Transport</td>
</tr>
<tr>
<td>Ch 25</td>
<td>Plant Reproduction and Development</td>
</tr>
<tr>
<td>Ch 26</td>
<td>Plant Responses to the Environment</td>
</tr>
</tbody>
</table>

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413
interviews with the course instructor outside of regular classroom time. Students used two
computers located in the Learning Resource Center, were the researcher’s personal CD ROM
and the library copy were installed and made available to the study subjects. Discussion of the
activities that are part of the Plant Biodiversity Pilot Study follows.

Activity 1: Concept map (CM-I) construction and interview

This activity consisted of constructing a concept map using concepts from a list provided to
the students followed by an introductory interview. The objective of this activity was to obtain a
base line about the understanding students had about the concept of biodiversity. The
construction of concept map took place on April 6th, before students were exposed to the
chapters that present the concept of diversity and overview the different groups of the diversity
of life (18 through 22). All students from course section D01 (N=21, including 8 study subjects)
completed the activity during class time. Students selected as study subjects from section D02
(N=4) completed CM-I the day of the first interview, as it was not possible to dedicate a lecture
period for this activity in that course section. Most concepts included in the list provided are
present in the textbook used for this course and in the CD-ROM Conserving Earth Biodiversity
(See Appendix B). However, some concepts were deliberately chosen to be only from the
information in the CD, although they could have been exposed to those concepts in other
courses.

I provided students with the seed/main concept and throughout the construction process
provided feedback, i.e. about concepts and use of links. All students in both course sections had
previous experience in concept map construction. They all created concepts maps as an
assessment activity for material covered earlier in the course; and some students created a
concept map to summarize main aspects of the human body system for their Physiology Inquiry
Projects earlier in the semester.

The introductory interview took place from April 18th to 25th, after students were exposed
in class to Ch 21, “The Plant Kingdom” and before going on to the plant unit. This opportunity
was used to remind all study subjects of the importance of their commitment and they were
asked to give their best throughout the research. During the interview study subjects completed a
background questionnaire, a science background confidence survey (51 items; referred as
“confidence survey” from here on) and participated in an oral interview. The first questionnaire
provided general background information about student characteristics, academics, and science
background. Some study subjects completed this background questionnaire at home and brought
to school next day to go on with other sections of this activity. The confidence survey
provided base information about their current knowledge/self-appreciation of their knowledge of
science concepts related to biodiversity

The statements listed in the confidence survey were selected based on the content of their
class textbook. During the interview students were asked to expand in three of the concepts
listed in the “confidence survey” in order to verify their confidence. In addition, student’s visual
perception and understanding of the role of evolution on biodiversity was examined using two
figures from the textbook that represented the tree of life. Answers to all oral interview
questions were recorded in an answer sheet. Study subjects needed approximately 1.5 hrs to
complete these activities.
Activity 2: CEB: Diversity of Life: Numbers of species

Study subjects worked on the section *Diversity of Life* of the CEB CD-Rom from April 18th to 25th, that is after Interview #1 and before the plant unit was started. In this section, they completed two of the activities under the focus theme of *Numbers of Species*: Total Species on Earth and Described Species. The first activity provides the user with a general overview of the how many species in each different taxa have been described and the estimates of how many scientists think are out there. The second activity allows users to explore the relative contribution of each taxa to the total biodiversity, based on the numbers of described species.

The objective of this activity was exposing study subjects to a basic idea in building their understanding of the concept biodiversity, how the numbers of different taxa vary, and how these numbers may differ from what scientists estimate they should really be. In contrast to the textbook, where the information about numbers of species is scattered through different sections in different chapters, when using this section of the CEB CD ROM study subjects will be exposed to all the information at once. In addition, they are exposed to the notion of “estimated” numbers of species. Exposing study subjects to this section in the CEB CD ROM also allows me to explore how students learning may be affected with the visual aids that use area diagrams in contrast to the evolution tree of life presented in the course textbook.

Study subjects were provided with an activity sheet which guided them to listening the introduction narrated by E.O. Wilson, and then to completing the exploration activities on the Total Species on Earth and Described Species sections. Study subjects were asked to record start and finish times, in this way the approximate time needed to complete the activities can be estimated for future lesson plans. Once activities were completed, the study subjects were required to reflect on the section they had covered by evaluating the quality of the site (i.e. engagement, organization, evaluating accessibility of content) and listing specific ideas learned through the activities in that section.

Activity 3: CEB: Global Biodiversity: Global Patterns

Study subjects worked on the section *Global Biodiversity* of the CEB CD-Rom from April 22nd through 29th, after they had completed activity 2 and while working on their plant biodiversity inquiry projects. In this section they focused on the theme of *Global Patterns* and explored three activities: World Deforestation, Centers of Food Plant Diversity, and Plant Species Diversity. This section presents a series of world maps which allow the user to examine terrestrial ecosystems and 3 important fundamentals of biodiversity. The first activity exposed the study subjects to the present and past of forested areas as compared to land cover and human population density maps. The second activity exposed study subjects to the historical place of origin of different food plant, and how genetic diversity at these locations may be importance for the future of different crops. The third activity expose study subject to the idea of species richness, and how size (area) and number (of species) are both elements of this idea. In all three activities study subjects were able to explore the global perspective and compare the local (U.S.A.) to any other country of their choice. In addition, these map comparisons included in each case maps showing land cover and population density for the regions of their choice (US and another country).

The objective of this third research activity was bringing study subjects to a higher level in building their understanding of the concept biodiversity, specifically contributing to the idea of plant diversity as integrated at the population and ecosystem levels. After completing these
activities, study subjects should be able to comprehend that not only numbers of species but also their relation to area is important when referring to a region’s biodiversity. At the population level they should gain an understanding of the role of genetics in maintaining diversity of crop plant species and how this is related to their place of origin. At the ecosystem level, study subjects should gain a perspective of how plant diversity can be related to different types of ecosystems and how it is threatened by deforestation population density looking at both the global scale and at the local scale with examples of the US and other countries. Likewise with Activity 2 described above, the study subjects had an activity guide sheet and evaluation form.

**Activity 4: Concept Map construction**

This activity followed Activity 3 with the CD-ROM, and was completed between April 22nd and May 2nd. Students were asked to construct a second concept map, using the original list of concepts. An informal short interview allowed them to share their experiences with the program so far.

The objective of this activity was to produce a document that can be analyzed to assess the level of understanding of biodiversity of the students after been exposed to a series of CD ROM activities and regular lecture activities.

**Activity 5: CEB: Threats to Biodiversity: Exotic species**

This activity was completed between April 27th and May 6th. By this time, the lecture material has already being covered and study subjects were working on their final biodiversity inquiry class project with their groups. In this section they focused on the theme of *Exotic Species*, in specific the only case of an exotic plant included in the CEB program, the *Purple loosestrife*. Study subjects were also required to examine the *Case Study*, focusing on the information about *Costa Rica*.

The objective of this section is to help study subjects integrate another aspect of the concept of biodiversity, threats to its existence. This activity was selected as the last one to be completed in the series for two reasons. First, it allows study subjects to have a contrasting and specific case study of how an ecosystem that has lost plant diversity is affected. Second the Costa Rica case study may allow study subjects to integrate different views to which they have been exposed throughout the CD-ROM. By being exposed to the issues presented in the two activities selected here I expect study subjects to gain an initial understanding of the complexity of factors involved in conserving biodiversity, and to be introduced to the meaning of Biocomplexity⁵. Likewise with Activities 2 and 3, study subjects had an activity guide sheet and completed an evaluation sheet after finishing each activity.

**Activity 6: Concept Map and exit interview**

This activity was completed from May 4th to 11th. I required all study subjects to complete this activity before their final class presentations. This activity consisted of an exit interview, construction of concept map, and filling a confidence survey (same they completed at the beginning). This activity was used to recap and provide study subjects an opportunity to create a final concept map that summarizes their learning experience. This document can be compared to

⁵ Even though this concept is not included in the CD, all students are exposed to it in lecture.
previous ones in order to determine the progress of the learning study subjects. The interview was videotaped. Specific questions were asked during the interview regarding the general understanding of Biodiversity and the role of evolution, number of species, ecosystems, genetics, and threats. Study subjects were provided again with the opportunity to re-distribute a “budget” of species using figure 1. In addition, study subjects were given as a “take home” activity the challenge of creating a figure that represented Biocomplexity with plant biodiversity being at the center stage.

Activity 7: Post test and confidence survey

This was a class-wide activity. This activity took place on May 11th and May 12th, after students finished the group presentations of the inquiry project. All students and study subjects in BIOL 1020 D01 and D03 were asked to complete a Biodiversity post test. In addition to the post test, all non-research students in BIOL 1020 D03 were asked to complete the confidence survey study subjects had completed (as suggested by a study subject).
APPENDIX K

PLANT BIODIVERSITY LITERACY RUBRIC

Level 0: Beginners

Has no understanding of plant biodiversity. Can not establish a connection between biodiversity and evolution. No understanding of biodiversity as number of species in different categories of organisms. Has no understanding of major groups of organisms and the use of hierarchical classification. No understanding of the genetic, species, or ecosystem levels of diversity.

Uses concepts at random and includes loosely related information. Has high difficulty establishing logical links between concepts. Unable to provide any definitions and fails to provide adequate examples.

Level 1: Darwin

Recognizes biodiversity as number of species. Recognizes biodiversity as a result of evolution. Recognizes the role of systematics in organizing the diversity of life into hierarchical categories and the evolutionary relatedness among categories (Domain through species levels). Can recognize major groups of organisms at the domain and kingdom levels. Recognizes plant kingdom.

Concepts that reflect this level of understanding are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. For concepts beyond this level of understanding the student may not use them. If included there are no logical or appropriate connections, definitions, or examples.

Level 2: Lovejoy

Recognizes biodiversity beyond numbers of species by recognizing at least two of the three levels of biodiversity: genetic, species, and ecosystem. Aware that the diversity at genetic level is basis for the variation at the other levels. Recognizes the role or value of plants at the ecosystem level as producers.

Concepts that reflect this level and lower level of understanding are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. For concepts beyond this level of understanding the student may not use them. If included there are no logical or appropriate connections, definitions, or examples.
Level 3: Raven

Understands plant biodiversity as number of species and representation of the main groups of the kingdom. Recognizes the evolutionary origin of the plant kingdom. Understands unique characteristics of different groups within the plant kingdom. Recognizes the diversity of plant life in terms of complexity, reproductive structures and strategies, size, and growth habits. Recognize the interdependence of plant life and organisms in other kingdoms. Understands role of plant diversity in the ecosystems.

Concepts that reflect this level of understanding and below are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. For concepts beyond this level of understanding the student may not use them. If included there are no logical or appropriate connections, definitions, or examples.

Level 4: Pimentel

Student demonstrates understanding of the value of plant biodiversity by being able to recognize the diversity of goods and services provided by plant biodiversity at the species, genetics, or ecosystem levels. Examples could include but are not limited to: clean air, drinkable water, food-webs, pollination, shelter, dispersal, food, clothing, medicine, and fuel.

Concepts that reflect this level of understanding and below are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. For concepts beyond this level of understanding the student may not use them. If included there are no logical or appropriate connections, definitions, or examples.

Level 5: Wilson

Demonstrates knowledge of at least how one of the threats to conservation forces endangers plant biodiversity: habitat destruction and degradation, exotic/invasive species, pollution, population growth, and over hunting/over consumption. Among these threats recognize that human population growth has a major effect on plant biodiversity through the increased use of limited resources and modification of ecosystems. Demonstrates awareness of role of hotspots in conservation of plant biodiversity.

Concepts that reflect this level of understanding are included and logical connections between these are present. Concepts are well organized and supported with definitions and examples. For concepts beyond this level of understanding the student may not use them. If included there are no logical or appropriate connections, definitions, or examples.
Level 6  
**Biophilia**

Demonstrates consistent awareness of plant biodiversity and can establish a personal connection with it, influencing personal beliefs. S/he recognizes how the diversity of goods and services provided by plant biodiversity are affected by personal life style and choices. Can identify and be critical about issues concerning local, national, or global biodiversity.

Articulates ideas clearly and using logical connections between concepts that reflect this level and below. Demonstrates ability to use pertinent definitions and provide a variety of high quality examples in support of the concepts.

Level 7  
**Biocomplexity**

Demonstrates superior awareness of plant biodiversity. Can integrate concepts from different subjects/areas, (i.e. geology, politics, economics, sociology, agriculture, forestry, genetics, etc) or levels and focuses these on plant biodiversity establishing a co-relationship among different areas/levels.

Articulates ideas clearly and using logical connections between concepts that reflect this level and below. Demonstrates ability to use pertinent definitions and provide a variety of high quality examples in support of the concepts.
<table>
<thead>
<tr>
<th>Pre instruction – Interview #1</th>
<th>Instruction</th>
<th>Post instruction - Interview #2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>It shows how things started</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history.</td>
<td>They all come from a common organism.</td>
<td>+</td>
</tr>
<tr>
<td>How they have evolved over time.</td>
<td>TOL is (organization of) diversity of life.</td>
<td>They have evolved over time.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>TOL - All organisms share/evolved from a common ancestor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bacteria and Archaea are unicellular prokaryotes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eukarya have eukaryotic cells, multicellular except for protistas</td>
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<tr>
<td>Based on common things</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class,</td>
<td>Distinguish and break down or organize categories according to similarities of organisms.</td>
<td>mc+</td>
</tr>
<tr>
<td></td>
<td>order, family, genus, species</td>
<td>Largest is domain, then kingdom, class, order, family, genus, and species is smallest group.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Species is based in the capacity to interbreed</td>
<td></td>
</tr>
<tr>
<td>Archaea, Bacteria, and Eukarya</td>
<td>Domains are Bacteria, Archaea, and Eukarya</td>
<td>Archaea, Bacteria, and Eukarya</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Kingdoms are Protista, Plantae, Fungi, and Animalia</td>
<td>Plants, protists, fungus, animals</td>
<td></td>
</tr>
<tr>
<td>If cells do not have a nucleus.</td>
<td>Basic characteristics (identify some for each): Bacteria and Archaea are unicellular prokaryotes (no membrane-bound nucleus or organelles), live in diverse habitats, extreme in the case of Archaea, have diverse metabolisms.</td>
<td>Archaea and Bacteria have cells with no nucleus, prokaryotic, one cell</td>
<td>0 +, T</td>
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<tr>
<td>If cells have a nucleus</td>
<td>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</td>
<td>Eukarya have nucleus Protists are single cell, are photosynthetic like plants, the algae</td>
<td>0 +, T +, T</td>
</tr>
<tr>
<td>If they have leaves</td>
<td>Plants are multicellular eukaryotes, have cell wall (cellulose), photosynthesize</td>
<td>Are multicellular Photosynthetic</td>
<td>- +, T +, T</td>
</tr>
<tr>
<td>mushrooms look like light bulbs</td>
<td>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</td>
<td>Fungi can cause diseases, are heterotrophic Are multicellular</td>
<td>0 +, T +, T +, T</td>
</tr>
<tr>
<td>sea creatures, insects</td>
<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
<td>Are multicellular</td>
<td>+, T</td>
</tr>
<tr>
<td>Bio means life, then diversity must refer to different populations, species, living in the whole universe or world.</td>
<td>Biodiversity is total range of species diversity. Total number of species.</td>
<td>The variety of organisms that live in a place</td>
<td>+</td>
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<tr>
<td>Many – a high number</td>
<td>Numbers of species: named (categorized) 1.4 mi [textbook] 1.6 mi [CD] 1.4 mi-1.6 mi [lectura]</td>
<td>There are a lot of species, I think 1.4 mi</td>
<td>+, T</td>
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</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th><strong>Numbers of species:</strong></th>
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<tbody>
<tr>
<td>Number of species:</td>
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<tr>
<td>scientists estimate exist 7mi to 10mi, up to 100 mi [textbook]</td>
</tr>
<tr>
<td>More than 30 mi, up to 100 mi [CD]</td>
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<tr>
<td>There are more unknown than known species.</td>
</tr>
<tr>
<td>+, T</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>New species added each year 7,000 to 10,000</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to diversity by different groups: Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73%</td>
</tr>
<tr>
<td>[textbook] (Pr, A, B&lt;&lt;&lt;&lt;Pl &amp; F&lt;&lt;A)</td>
</tr>
<tr>
<td>[textbook] (A, B&lt;F&lt;Pr&lt;Pl&lt;&lt;A)</td>
</tr>
<tr>
<td>[CD] (look for trend, not exact numbers)</td>
</tr>
<tr>
<td>There are a lot, lot of insects, so animals have the most, Plants (come next)</td>
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<tr>
<td>Then Archaea and Bacteria, Fungi and Protists have the least [number of species]</td>
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<tr>
<td>mc+, T</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>About the same between bacteria and Archea, and Eukarya</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Know about habitat, food</strong></td>
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<tr>
<td>Information and benefits from knowledge of systematics: Understanding origin of pathogens (i.e. HIV, hantavirus) and find better ways to control/cure these</td>
</tr>
<tr>
<td>Common understanding among scientific community. Understanding natural history and ecology of organisms. Can help in genetic engineering of crop plants and finding active chemicals from medicinal plants</td>
</tr>
<tr>
<td>It can help us find cure for a lot of diseases, or know more, like HIV.</td>
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<tr>
<td>0</td>
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</tbody>
</table>

**Note.** mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed (Note continued)
correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-ROM was too extensive to include possible answers under the instruction column.

Table L-2  Comparison of Pre-instruction and Post-instruction Propositions for Thiab

<table>
<thead>
<tr>
<th>Preinstruction – Interview #1</th>
<th>Instruction</th>
<th>Postinstruction – Interview #2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>It has prokaryotic cells on one side and eukaryotic cells on the other. Archea are in the middle so they have both cells</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history. TOL is (organization of) diversity of life. TOL - All organisms share/evolved from a common ancestor. Bacteria and Archaea are unicellular prokaryotes Eukarya have eukaryotic cells, multicellular except for protista</td>
<td>All the diversity of living organisms Eukarya is broken down into different things How organisms are divided by their type of cells – if cells have no nucleus those are Bacteria and Archea Eukarya are the ones with nucleus Organized by common ancestors</td>
<td>mc+</td>
</tr>
<tr>
<td>Grouped by what they have in common</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class, order, family, genus, species</td>
<td>Domains at the top, that includes everything and then it goes more specific, kingdoms…all the way to species</td>
<td>0</td>
</tr>
<tr>
<td>Archea, Bacteria, Eukarya. Protist, Fungi, Animals, Plants</td>
<td>Domains are Bacteria, Archaea, and Eukarya Kingdoms are Protista, Plantae, Fungi, and Animalia</td>
<td>Domains Archea, Bacteria, Eukarya. Kingdoms Protists, Fungi, Animals, Plants</td>
<td>0</td>
</tr>
<tr>
<td>That they need to acquire to do what they need to do</td>
<td>Basic characteristics (identify some for each): Bacteria and Archaea are unicellular prokaryotes (no membrane-bound nucleus or organelles),</td>
<td>They are grouped together by what they have in common. Good bacteria, like those we need in the body for it to work right and bad bacteria that makes us sick.</td>
<td>+</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>live in diverse habitats, extreme in the case of Archaea, have diverse metabolisms.</th>
<th>Some bacteria are nitrogen fixers. Bacteria are single celled They have simpler cells.</th>
<th>0 +, T +, T +, T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</td>
<td>Protists have complex cells. Protists are unicellular. Protists form plankton</td>
<td>+, T +, T +, T</td>
</tr>
<tr>
<td>...like if their job is to make tomatoes, they need to photosynthesize Plants produce flowers</td>
<td>Plants are multicellular eukaryotes, have cell wall (cellulose), photosynthesize</td>
<td>0 +, T +, T -</td>
</tr>
<tr>
<td>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</td>
<td>Protists have complex cells. Protists are unicellular. Protists form plankton</td>
<td>+, T +, T +, T</td>
</tr>
<tr>
<td>Animals have sexual reproduction If they can reproduce with each other, they are same species.</td>
<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
<td>0 +, T +, T</td>
</tr>
<tr>
<td>Biodiversity is total range of species diversity. Total number of species.</td>
<td>All living things</td>
<td>0</td>
</tr>
<tr>
<td>Many, a lot, don’t know the number</td>
<td>Numbers of species: named (categorized) 1.4 mi [textbook] 1.6 mi [CD] 1.4 mi-1.6 mi [lecture]</td>
<td>There are 1.4 mi species mc+, T</td>
</tr>
<tr>
<td>(Table continued)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numbers of species: scientists estimate exist 7mi to 10mi, up to 100 mi [textbook] More than 30 mi, up to 100 mi [CD]</td>
<td>[scientists] think there is like even 100 mi +, T</td>
<td></td>
</tr>
<tr>
<td>New species added each year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution to diversity by different groups: Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73% (Pr, A, B&lt;&lt;Pl &amp; F&lt;&lt;A) [textbook] (A, B&lt;F&lt;Pr&lt;Pl&lt;&lt;A) [CD] (look for trend, not exact numbers)</td>
<td>Bacteria and Archaea maybe make like half of all species, then animals because there are a lot of insects and more are added there is also a lot plants, Not many protists and Fungi just have a few – not many of them mc -</td>
<td></td>
</tr>
<tr>
<td>Where you come from We are so like other animals, we have the same amino acids</td>
<td>We can know about genes other organisms have [We can learn about] organisms that produce things that are beneficial to us, like a medicine, and then they don’t tear down like the forest where you can find that organism mc+</td>
<td></td>
</tr>
</tbody>
</table>

Note. mc+, an incorrect proposition changed correctly; mc,; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition (Note continued)
that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- an correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD- Rom was too extensive to include possible answers under the instruction column.

Table L-3. Comparison of Pre-instruction and Post-instruction Propositions for Trevic

<table>
<thead>
<tr>
<th>Preinstruction – Interview #1</th>
<th>Instruction</th>
<th>Postinstruction – Interview #2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is a tree of specification, starting from being very broad to more narrow classification about where everything came form and how things changed</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history. TOL is (organization of) diversity of life. TOL - All organisms share/evolved from a common ancestor. Bacteria and Archaea are unicellular prokaryotes Eukarya have eukaryotic cells, multicellular except for protista</td>
<td>All life came from one thing, a common ancestor, and then it branched, becomes more specific, the different kinds. [TOL] Tells how many cells and the different kinds of cells, like the bacteria and Eukarya.</td>
<td>+</td>
</tr>
<tr>
<td>The environment, habitat, ecosystems, communities and things like that</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class, order, family, genus, species</td>
<td>Biodiversity is broken into parts, is classified into large groups and then narrows it down. Domain, kingdoms, phylum, family, genus, species</td>
<td>mc+</td>
</tr>
<tr>
<td>Monera, Protists, Animals, Plants</td>
<td>Domains are Bacteria, Archaea, and Eukarya Kingdoms are Protista, Plantae, Fungi, and Animalia</td>
<td>Bacteria, Archea, Eukarya, Protists, Animals, Plants, Fungi</td>
<td>mc+</td>
</tr>
<tr>
<td>Type of cell, prokaryotes</td>
<td>Basic characteristics (identify some for each): Bacteria and Archaea are unicellular prokaryotes (no</td>
<td>Have cells with no nucleus, prokaryotes Bacteria have flagella, and some help get rid of toxins.</td>
<td>+, T</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Means of getting substance</th>
<th>Plants are multicellular eukaryotes, have cell wall (cellulose), photosynthesize</th>
<th>eukaryotes have nucleus multicellular plants photosynthesize</th>
<th>+, T +, T 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means of getting substance, fungi absorb</td>
<td>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</td>
<td>eukaryotes have nucleus multicellular Fungi absorb, some are good for people w/ cancer, because of the vitamins. They are decomposers.</td>
<td>+, T +, T 0 +, G +, T</td>
</tr>
<tr>
<td>Means of getting substance, animals ingest</td>
<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
<td>eukaryotes have nucleus multicellular Animals eat their food, reproduce sexually.</td>
<td>+, T +, T 0 +, T</td>
</tr>
<tr>
<td>Difficult to explain How things are different</td>
<td>Biodiversity is total range of species diversity. Total number of species.</td>
<td>Many different species</td>
<td>mc+</td>
</tr>
<tr>
<td>Millions of them</td>
<td>Numbers of species: named (categorized) 1.4 mi [textbook] 1.6 mi [CD] 1.4 mi-1.6 mi [lecture]</td>
<td>There is more than 1.4 mi species</td>
<td>+, T</td>
</tr>
</tbody>
</table>
Numbers of species: scientists estimate exist 7mi to 10mi, up to 100 mi [textbook] More than 30 mi, up to 100 mi [CD]  
scientists think exists like 100 mi.  +, T  

New species added each year 7,000 to 10,000  

Animals probably makes the most  
Contribution to diversity by different groups:  
Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73%  
(Pr, A, B<<<<Pl & F<<A) [textbook]  
(A, B< F<= Pr< Pl<<A) [CD]  
(look for trend, not exact numbers)  
Most are bacteria and Archea.  
There is a lot of animals and plants, and just a few protists  
and few Fungi  
mc- - + mc  

For our knowledge sake  
If we don’t know about the bacteria and viruses that affect us, we can’t cure them  
Information and benefits from knowledge of systematics: Understanding origin of pathogens (i.e.  
HIV, hantavirus) and find better ways to control/cure these. Common understanding among  
scientific community  
Understanding natural history and ecology of organisms. Can help in genetic engineering of crop  
plants and finding active chemicals from medicinal plants  
Which organisms can cause disease and which can be used for medicine  
mc0  

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed (Note continued)
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Table L-4. Comparison of Pre-instruction and Post-instruction Propositions for Carla

<table>
<thead>
<tr>
<th>Preinstruction – Interview #1</th>
<th>Instruction</th>
<th>Postinstruction – Interview #2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different cells that exist</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history. TOL is (organization of) diversity of life. TOL - All organisms share/evolved from a common ancestor. Bacteria and Archaea are unicellular prokaryotes. Eukarya have eukaryotic cells, multicellular except for protista.</td>
<td>It’s all the living things. Organizes domains and kingdoms of life. How living things change.</td>
<td>mc+</td>
</tr>
<tr>
<td>Is about the different types of cells. Starts with the different kinds of cells and breaks down into bacteria and Archaea, which have prokaryotic cells.</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class, order, family, genus, species.</td>
<td>Reconstructs the order of life. Starts off with the largest groups, the domain and kingdom, and is broken down to phylum, class, order, and family and all the way to genus and species which makes the scientific name.</td>
<td>mc+</td>
</tr>
<tr>
<td>I know there are bacteria, plants, animals…don’t remember the other stuff</td>
<td>Domains are Bacteria, Archaea, and Eukarya. Kingdoms are Protista, Plantae, Fungi, and Animalia.</td>
<td>There are 3 domains, two of prokaryotes – Archaea and bacteria. Then eukaryotes have all the other kingdoms, fungi, plants and protists, and the animals.</td>
<td>+</td>
</tr>
<tr>
<td>Have Prokaryotic cells</td>
<td>Basic characteristics (identify some for each): Bacteria and Archaea are unicellular prokaryotes.</td>
<td>They have different kinds of cells. The Archaea live in extreme environments,</td>
<td>-</td>
</tr>
</tbody>
</table>

(Table continued)
### Table

<table>
<thead>
<tr>
<th>Eukaryotic cells. Protista is garbage dump. They get food from others that are smaller</th>
<th>Eukaryotic cells. Plants photosynthesize</th>
<th>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</th>
<th>Animals are multicellular eukaryotes, no cell wall, ingest</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no membrane-bound nucleus or organelles), live in diverse habitats, extreme in the case of Archaea, have diverse metabolisms.</td>
<td>the bacteria you can find anywhere there are good and bad ones</td>
<td>Protista get their food from other organisms that are smaller, like that picture you show us in class. Some are plankton in the ocean.</td>
<td>Some decomposers are fungi, keep the circle of life going</td>
</tr>
<tr>
<td>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</td>
<td></td>
<td>Fungi also give medicine, like penicillin</td>
<td>Fungi also give medicine, like penicillin</td>
</tr>
<tr>
<td>Eukaryotic cells. Protista is garbage dump. They get food from others that are smaller</td>
<td>Eukaryotic cells. Plants photosynthesize</td>
<td>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</td>
<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
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<tr>
<td></td>
<td>Plants photosynthesize</td>
<td>Plants photosynthesize</td>
<td>Animals ingest their food.</td>
</tr>
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<td>[Plants] have cell walls and vacuoles</td>
<td>[Plants] have cell walls and vacuoles</td>
<td>[Animals] are multicellular</td>
</tr>
<tr>
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<td>[Plants] give us oxygen, food</td>
<td></td>
<td>Some decomposers are animals.</td>
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<tr>
<td><strong>New species added each year 7,000 to 10,000</strong></td>
<td><strong>Contribution to diversity by different groups:</strong> Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73% (Pr, A, B&lt;&lt;Pl &amp; F&lt;&lt;A) [textbook] (A, B&lt;F≤Pr&lt;Pl&lt;&lt;A) [CD] (look for trend, not exact numbers)</td>
<td><strong>There are a lot of animals, most insects. I thought there were more birds than there are; insects totally freak me out, it’s gross there are so many! plants, then I would say bacteria and Archaea, protists, and last Fungi</strong></td>
<td><strong>mc+, CD mc+, CD mc0</strong></td>
</tr>
<tr>
<td><strong>I think about half are bacteria and then Animals, Plants, Fungi, Protista</strong></td>
<td><strong>Scientists studying animals and plants can help humans</strong></td>
<td><strong>Information and benefits from knowledge of systematics:</strong> Understanding origin of pathogens (i.e. HIV, hantavirus) and find better ways to control/cure these Common understanding among scientific community Understanding natural history and ecology of organisms Can help in genetic engineering of crop plants and finding active chemicals from medicinal plants</td>
<td><strong>It can help us learning about organisms which are helpful or not.</strong></td>
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</table>

*Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.*
<table>
<thead>
<tr>
<th>Preinstruction – Interview #1</th>
<th>Instruction</th>
<th>Postinstruction – Interview #2</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branches are different categories  How things evolved coming from one strain of bacteria and keep changing</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history. TOL is (organization of) diversity of life. TOL - All organisms share/evolved from a common ancestor. Bacteria and Archaea are unicellular prokaryotes Eukarya have eukaryotic cells, multicellular except for protista</td>
<td>The branches are different kinds of life forms that came from one ancestor. It shows how life changed into different kinds of organisms, how things got to be what they are</td>
<td>+</td>
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<tr>
<td>like the ecosystems and populations and species</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class, order, family, genus, species</td>
<td>Hierarchy of how domains and kingdoms are organized, system to put them together in groups Domains have the broader stuff, then kingdoms are split into phylum, families and class and order until you get to genus and species. The last two are the exact classification.</td>
<td>mc+</td>
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<tr>
<td>Archea, Bacteria, then Eukarya splits into protist and animals, plants, and fungi</td>
<td>Domains are Bacteria, Archaea, and Eukarya Kingdoms are Protista, Plantae, Fungi, and Animalia</td>
<td>Archea, Bacteria are smaller prokaryotic cells Animals, plants, fungi, and protists are eukaryotic</td>
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<tr>
<td>Structure different systems like the reproductive system having sexual and asexual reproduction what they eat</td>
<td>Basic characteristics (identify some for each): Bacteria and Archaea are unicellular prokaryotes (no membrane-bound nucleus</td>
<td>The bacteria are everywhere They move freely Some cause disease but also some are good.</td>
<td>+, CD +, CD +, CD</td>
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</tbody>
</table>

(Table continued)
or organelles), live in diverse habitats, extreme in the case of Archaea, have diverse metabolisms. Oxygen on Earth [produced by cyanobacteria [cyanobacteria] also fix nitrogen bacteria can help us with digestion. +, CD

<table>
<thead>
<tr>
<th>reproductive system having sexual and asexual reproduction what they eat</th>
<th>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</th>
<th>Protists can eat other stuff or photosynthesize - +, B</th>
</tr>
</thead>
<tbody>
<tr>
<td>reproductive system having sexual and asexual reproduction the need for carbon dioxide and nitrogen in plants</td>
<td>Plants are multicellular eukaryotes, have cell wall (cellulose), photosynthesize</td>
<td>Plants photosynthesize and give oxygen and recycle the carbon dioxide, they are multicellular - +, T mc+, B +, B</td>
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<td>reproductive system having sexual and asexual reproduction what they eat</td>
<td>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</td>
<td>Fungi reproduce by spores and are decomposers, some are fluorescent, can cause plant diseases. +, CD +, CD +, CD</td>
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<tr>
<td>reproductive system having sexual and asexual reproduction what they eat the need for oxygen in animals</td>
<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
<td>Animals are part of the food chain, they are herbivores and carnivores. - +, CD -</td>
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<tr>
<td>The teaching of things being different in life. How they are built and how they operate</td>
<td>Biodiversity is total range of species diversity. Total number of species.</td>
<td>The differences in life forms – on everything that concerns life including the ecosystems where things live Mc+</td>
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<tr>
<td>Many different species, millions of organisms</td>
<td>Numbers of species: named (categorized) 1.4 mi [textbook] 1.6 mi [CD] 1.4 mi-1.6 mi [lecture]</td>
<td>There is 1.6 mi species +, CD</td>
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</tbody>
</table>

(Table continued)
A lot

Numbers of species: scientists estimate exist 7mi to 10mi, up to 100 mi [textbook]
More than 30 mi, up to 100 mi [CD]

We have not discovered most of the species, a pretty high number.
For plants we know most of what is out there, but then for bacteria we don’t know a whole lot of what scientists think is out there.
We also know a lot about some animals.
There is a lot of insects and more being added.

New species added each year 7,000 to 10,000

Contribution to diversity by different groups:
Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73%
(Pr, A, B<<Pl & F<<A) [textbook]
(A, B<F<Pr<Pl<<A) [CD]
(look for trend, not exact numbers)

Animals have the most now, but bacteria may have the most if they are discovered.
Plants, protists, and fungi come next, and few bacteria

Understanding the different needs of living things and a lot of different things depend on each other

Information and benefits from knowledge of systematics: Understanding origin of pathogens (i.e. HIV, hantavirus) and find better ways to control/cure these. Common understanding among scientific community

It helps understand the ecosystems and knowing which organisms are where, then you can protect them.

(Table continued)
Understanding natural history and ecology of organisms. Can help in genetic engineering of crop plants and finding active chemicals from medicinal plants

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-ROM was too extensive to include possible answers under the instruction column.

Table L-6. Comparison of Pre-instruction and Post-instruction Propositions for Cyreneec

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<tr>
<th>Preinstruction – Interview #1</th>
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<th>Postinstruction –Interview #2</th>
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</thead>
<tbody>
<tr>
<td>Different organisms and how they are structured or categorized</td>
<td>Tree of life (TOL) represents the earliest branches in evolutionary history. TOL is (organization of) diversity of life. TOL - All organisms share/evolved from a common ancestor. Bacteria and Archaea are unicellular prokaryotes Eukarya have eukaryotic cells, multicellular except for protista</td>
<td>The organization of living things into categories or groups and how they are related</td>
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<td>Groups Looks and function</td>
<td>Hierarchy of classification – nested groups: domain, kingdom, phylum, class, order, family, genus, species</td>
<td>Breaks down how things are related and how they can be grouped into categories Starts with domain, kingdoms and broken down phylum, class, order, family, genus and the last one is species, the finer category</td>
<td>mc+</td>
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(Table continued)
<table>
<thead>
<tr>
<th>Kingdoms</th>
<th>Basic characteristics (identify some for each):</th>
<th>How they reproduce</th>
<th>How they survive</th>
<th>How they breathe (these were stated in common for all kinds of organisms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria, Archaea, Eukarya</td>
<td>Basic characteristics (identify some for each):</td>
<td>Bacteria can cause diseases</td>
<td>Protists have different ways of getting their energy – they photosynthesize, eat, absorb</td>
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<tr>
<td>Animals, Fungi, Plant</td>
<td>Bacteria and Archaea are unicellular prokaryotes (no membrane-bound nucleus or organelles), live in diverse habitats, extreme in the case of Archaea, have diverse metabolisms.</td>
<td>[Bacteria] can help cure (shots); Archaea live in extreme environments</td>
<td>Plants also provide food, oxygen, and medicines they are multicellular eukaryotes, plants photosynthesize</td>
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<td>Protists are single-celled eukaryotes; some have cell wall, diverse ways of acquiring energy (photosynthesis, absorption, ingestion).</td>
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<td>Fungi is also part of our food, some make lichens, some cause disease or make antibiotics</td>
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<td>Fungi are multicellular eukaryotes, have cell wall (chitin), absorb</td>
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<td>Animals give us food, or give food to other, like bugs can serve as food or they can help pollinate plants</td>
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<td>Animals are multicellular eukaryotes, no cell wall, ingest</td>
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<td>Is everything about the Earth Differences on environment, and habitats, populations, how Earth works Like the plate tectonics, how continents used to be joined together, and that is how we can explain presence of fossils in different places Changes of the organisms How organisms adapt</td>
<td>Biodiversity is total range of species diversity. Total number of species.</td>
<td>Is the variety of life The result of evolution and genetic diversity</td>
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<td>Many, millions</td>
<td>Numbers of species: named (categorized) 1.4 mi [textbook] 1.6 mi [CD] 1.4 mi-1.6 mi [lecture]</td>
<td>There are about 1.6 mi species described</td>
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<td>Numbers of species: scientists estimate exist 7mi to 10mi, up to 100 mi [textbook] More than 30 mi, up to 100 mi [CD]</td>
<td>A lot more need to be identified –</td>
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<td>New species added each year 7,000 to 10,000</td>
<td>More species are found each year – like 7 to 10 thousand</td>
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<td>Probably most are bacteria and Archaea and then animals, plants, and fungi and protists have the least</td>
<td>Contribution to diversity by different groups: Prokaryotes and Protists 5%; Plants and Fungi, 22%; Animals 73% (Pr, A, B&lt;&lt;&lt;Pl &amp; F&lt;&lt;A) [textbook] (A, B&lt;&lt;Pr&lt;Pl&lt;&lt;A) [CD] (look for trend, not exact numbers)</td>
<td>Most of what we know are animals. A lot will come from marine life For mammals we are pretty much close to know everything out there There are tons of insects. There are many plants, we pretty much know all Then protists, bacteria and Archea There are not many fungi</td>
<td>mc+, B</td>
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<td>+, CD</td>
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<td></td>
<td>mc+, CD mc0 mc0</td>
<td></td>
</tr>
</tbody>
</table>

(Table continued)
Important to know how bacteria function because when you get sick
To know about plants because we get oxygen
To know about animals because of our food.

Information and benefits from knowledge of systematics:
Understanding origin of pathogens (i.e. HIV, hantavirus) and find better ways to control/cure these
Common understanding among scientific community
Understanding natural history and ecology of organisms
Can help in genetic engineering of crop plants and finding active chemicals from medicinal plants

We can learn about other species that can help us find a cure for cancer for example
The main thing is it can help us understand life better.

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Table L-7. Comparison of Pre-instruction and Post-instruction Propositions for Tanya

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Post instruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystems and populations, species</td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water, oxygen, and nutrient</td>
<td>Ecosystems is where species live</td>
<td>+</td>
</tr>
</tbody>
</table>

(Table continued)
cycling, purifying waste and producing soil; tropical rain forests are highly diverse; Rain forests and coral reefs are being destroyed

| Levels of biodiversity: species, i.e. (any of) High number of species have been described Rosy periwinkle in TF of Madagascar is source of two chemicals to treat two forms of cancer (leukemia and Hodgkin’s) Bark of Pacific yew tree form Pacific NW is source of anticancer drug Taxol. Corals from Indian Ocean are source of anticancer compound. | Species - pink flowers from the tropical rain forest that have a chemical to treat cancer | +, T |

| Levels of biodiversity: genetics, i.e. Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn. | Species are made of different genetics | 0 |

(Table continued)
<table>
<thead>
<tr>
<th>Reason for conserving biodiversity</th>
<th>Reasons for conserving biodiversity</th>
<th>Reasons for conserving biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>To protect the environment</td>
<td>To protect the environment</td>
<td>To protect the environment</td>
</tr>
<tr>
<td>Can help us find cures for diseases</td>
<td>Can help us find cures for diseases</td>
<td>Can help us find cures for diseases</td>
</tr>
<tr>
<td>Survival - Is not something we HAVE to learn in school, it is something that means the future to us and our families. For the future generations to be able to experience life as we have it now</td>
<td>Survival - Is not something we HAVE to learn in school, it is something that means the future to us and our families. For the future generations to be able to experience life as we have it now</td>
<td>Survival - Is not something we HAVE to learn in school, it is something that means the future to us and our families. For the future generations to be able to experience life as we have it now</td>
</tr>
<tr>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
</tr>
<tr>
<td>Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
<td>Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
<td>Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
</tr>
<tr>
<td>Pollution</td>
<td>Pollution</td>
<td>Pollution</td>
</tr>
<tr>
<td>habitats destroyed like cutting down trees</td>
<td>habitats destroyed like cutting down trees</td>
<td>habitats destroyed like cutting down trees</td>
</tr>
<tr>
<td>extinction of animals</td>
<td>extinction of animals</td>
<td>extinction of animals</td>
</tr>
<tr>
<td>wetlands in Louisiana being eroded away, like with the hurricanes-</td>
<td>wetlands in Louisiana being eroded away, like with the hurricanes-</td>
<td>wetlands in Louisiana being eroded away, like with the hurricanes-</td>
</tr>
<tr>
<td>It kills a lot of things, like our fish production and economy</td>
<td>It kills a lot of things, like our fish production and economy</td>
<td>It kills a lot of things, like our fish production and economy</td>
</tr>
<tr>
<td>you can get famine going on, diseases, all that stuff</td>
<td>you can get famine going on, diseases, all that stuff</td>
<td>you can get famine going on, diseases, all that stuff</td>
</tr>
<tr>
<td>We are killing a lot of things with pollution</td>
<td>We are killing a lot of things with pollution</td>
<td>We are killing a lot of things with pollution</td>
</tr>
<tr>
<td>Loss of biodiversity – causes and/or consequences examples: Increasing numbers of humans</td>
<td>Loss of biodiversity – causes and/or consequences examples: Increasing numbers of humans</td>
<td>Loss of biodiversity – causes and/or consequences examples: Increasing numbers of humans</td>
</tr>
<tr>
<td>Human activities driving species to extinction</td>
<td>Human activities driving species to extinction</td>
<td>Human activities driving species to extinction</td>
</tr>
<tr>
<td>Wasteful standards of living</td>
<td>Wasteful standards of living</td>
<td>Wasteful standards of living</td>
</tr>
<tr>
<td>Potential loss of medicine, food, and raw materials</td>
<td>Potential loss of medicine, food, and raw materials</td>
<td>Potential loss of medicine, food, and raw materials</td>
</tr>
<tr>
<td>Endangered species, extinction, loss of interactions, diseases</td>
<td>Endangered species, extinction, loss of interactions, diseases</td>
<td>Endangered species, extinction, loss of interactions, diseases</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution, reproduction, and extinction Or, should that be the domains and kingdoms, and family, species?</td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water, oxygen, and nutrient cycling, purifying waste and producing soil; tropical rain forests are highly diverse; Rain forests and coral reefs are being destroyed</td>
<td>Different plants make the ecosystem and provide food for the animals</td>
<td>mc+</td>
</tr>
</tbody>
</table>

(Table L-8. (Continued) Comparison of Pre-instruction and Post-instruction Propositions for Thiab)

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of biodiversity: species, i.e. (any of) High number of species have been described Rosy periwinkle in TF of Madagascar is source of two chemicals to treat two forms of cancer (leukemia and Hodgkin’s) Bark of Pacific yew tree form Pacific NW is source of anticancer drug Taxol. Corals from Indian Ocean are source of anticancer compound.</td>
<td>Like you can have many plants, those are species</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

(Table continued)
| Levels of biodiversity: genetics, i.e. | The genetics is what makes plants and the organisms different because they have different gene pools. It can make them resistant to disease like the corn relatives |  
| Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn. | mc+, T |

| To have a good environment | Reasons for conserving biodiversity  
- May vary -  
[Textbook]  
Rapid destruction of ecosystems (TRF, coral reefs)  
High rates of extinction  
Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions | It gives us food, medicine, even cures for diseases like cancer, raw materials for the industry  
Allows for new life forms to evolve and for the existence of those that are already present  
Is a way of keeping our lives as normal as possible –can’t have milk or meat if cows don’t have grass to eat. |
|  | -  
+ T |

| Pollution | Loss of biodiversity – causes and/or consequences examples:  
Increasing numbers of humans  
human activities driving species to extinction | Pollution can … make species go extinct, like when we were talking about evolution and you know the moths, the Industrial Revolution made the light moths disappear.  
Habitat destruction can result in extinction. If the forest is cut down and burned, plants like the wild corn may disappear and then can’t |
|  | mc |

(Table continued)
Wasteful standards of living potential loss of medicine, food, and raw materials
Endangered species, extinction, loss of interactions, diseases

make corn that is pest resistant

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ecosystems, communities, populations, species</strong></td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water, oxygen, and nutrient cycling, purifying waste and producing soil; tropical rain forests are highly diverse; Rain forests and coral reefs are being destroyed</td>
<td>Different ecosystems and the variety of things living there, some of them are affected</td>
<td>mc+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Levels of biodiversity: species, i.e. (any of) High number of species have been described</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Levels of biodiversity: genetics, i.e. Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is a big problem because of pollution Protecting our health and the environment</td>
</tr>
<tr>
<td>Reasons for conserving biodiversity</td>
</tr>
<tr>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
</tr>
<tr>
<td>High rates of extinction</td>
</tr>
<tr>
<td>Plays a major role in our life, source of food and medicines and other natural resources, like oxygen</td>
</tr>
</tbody>
</table>

(Table continued)
Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions.

Industries... the environment is paying for it, the ignorance we are destroying everything and it directly correlates to us, like diseases, etc.

Loss of biodiversity – causes and/or consequences examples:
- Increasing numbers of humans
- Human activities driving species to extinction
- Wasteful standards of living
- Potential loss of medicine, food, and raw materials
- Endangered species, extinction, loss of interactions, diseases

Cutting down trees and destroying the habitats - will kill the animals
Also pollution needs to be controlled

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<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tree of life, bacteria, archea, eukarya</td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water,</td>
<td>Ecosystems, like the forests- they have trees that help protect the ground from raindrops hitting the ground so hard  Bees and wasps that help our crops</td>
<td>mc+, CD</td>
</tr>
</tbody>
</table>

(Table continued)
| Levels of biodiversity: species, i.e. (any of) High number of species have been described | Different kinds of species, some are important for fiber…to make things – paper from wood-
| Rosy periwinkle in TF of Madagascar is source of two chemicals to treat two forms of cancer (leukemia and Hodgkin’s)  
| Bark of Pacific yew tree form Pacific NW is source of anticancer drug Taxol.  
| Corals from Indian Ocean are source of anticancer compound.  
| [CD] Natural fibers  
| Natural chemicals, medicinal plants  
| Crop species | And wetlands which are being destroyed, and all the trees and other species there will be affected | +, CD |
Levels of biodiversity: genetics, i.e. Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn.

[CD] Variation in wild species, disease resistance in crops, chemical variation in medicinal plants
Food varieties

Genetics which cause all the different changes in the species
The rice how scientist have been looking for some resistant kinds
The elm trees that had a disease killing them were kind of rescued by introducing a virus to the fungus

Is my everyday life and the world’s life
The air we breathe and the ground we walk on

Reasons for conserving biodiversity
Rapid destruction of ecosystems (TRF, coral reefs)
High rates of extinction
Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions

Gives us medicine
Could help us discover new viruses and fungi, and the more we know about the things that harm us, the better
It is going to help a lot in the future – For the generations to come and for our own survival (EOW intro)

Biodiversity is absolutely affected by all the land being engulfed
All the bacteria becoming resistant, which affect not only human life but also other plants and animals

Loss of biodiversity – causes and/or consequences examples:
Increasing numbers of humans

We can loose our sources of medicines and cures

<table>
<thead>
<tr>
<th></th>
<th>+, B</th>
<th>+, CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of biodiversity: genetics, i.e. Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn.</td>
<td>+, B</td>
<td>+, CD</td>
</tr>
<tr>
<td>[CD] Variation in wild species, disease resistance in crops, chemical variation in medicinal plants Food varieties</td>
<td>+, B</td>
<td>+, CD</td>
</tr>
<tr>
<td>Is my everyday life and the world’s life The air we breathe and the ground we walk on</td>
<td>+, B</td>
<td>+, CD</td>
</tr>
<tr>
<td>Reasons for conserving biodiversity Rapid destruction of ecosystems (TRF, coral reefs) High rates of extinction Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
<td>+, B</td>
<td>+, CD</td>
</tr>
<tr>
<td>Biodiversity is absolutely affected by all the land being engulfed All the bacteria becoming resistant, which affect not only human life but also other plants and animals</td>
<td>- +, T</td>
<td></td>
</tr>
</tbody>
</table>

(Table continued)
human activities
driving species to extinction
Wasteful standards of living
potential loss of medicine, food, and raw materials
Endangered species, extinction, loss of interactions, diseases

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The genetics because is different for all the species, so it is a kind of diversity</td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water, oxygen, and nutrient cycling, purifying waste and producing soil; tropical rain forests are highly diverse;</td>
<td>Different environments of the world or Ecosystems, In the forest the trees make up the forest Give us oxygen, but also depend on other things there for their survival the wetlands we have here, they protect from flooding and filter water</td>
<td>+, T, CD</td>
</tr>
</tbody>
</table>

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(Table continued)
Rain forests and coral reefs are being destroyed [CD]  
Forest services  
Pollination and pest control  
Wetlands and freshwater ecosystems

<table>
<thead>
<tr>
<th>Levels of biodiversity:</th>
<th>the species living there [in the ecosystems], is important because  some plants give pesticides  [some plants give] medicines, the rosy plant that gives two anticancer drugs and the Cinchona for malaria</th>
</tr>
</thead>
</table>
| species, i.e. (any of) | High number of species have been described  
Rosy periwinkle in TF of Madagascar is source of two chemicals to treat two forms of cancer (leukemia and Hodgkin’s)  
Bark of Pacific yew tree form Pacific NW is source of anticancer drug Taxol.  
Corals from Indian Ocean are source of anticancer compound.  
[CD] Natural fibers  
Natural chemicals, medicinal plants  
Crop species |

| Levels of biodiversity: | Genes that make them up [species living in an ecosystem]  
Different related plants may or may not have the same chemical, due to the different genetics – can’t remember the name but is one with a red flower and a white flower one is good as a medicinal plant the other is not |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>genetics, i.e.</td>
<td>Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to</td>
</tr>
</tbody>
</table>

(Table continued)
You need all organisms
Understanding other animals their needs and things that depend on them

<table>
<thead>
<tr>
<th>Reasons for conserving biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
</tr>
<tr>
<td>High rates of extinction</td>
</tr>
<tr>
<td>Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
</tr>
</tbody>
</table>

To be able to enjoy the outdoors as we do today
All things are interdependent. We depend on plants for oxygen, food, and medicine, they depend on animals for pollination
You need to know about the diversity, we might try some plants and others that are related, some may have something we can use and not others, so we shouldn’t destroy others that are out there and we still don’t know.

Different things cause loss…oil spills to pollution or cutting down trees
If an oil spill happens somewhere and you don’t know which organisms are there, then a lot of things can be affected, even bacteria that can be important…
If there was an endangered species there, then it can even go extinct

Loss of biodiversity – causes and/or consequences examples:
Increasing numbers of humans
human activities driving species to extinction
Wasteful standards of living

All organisms will be affected
Including us and the benefits we get clothes, food, medicine

| (Table continued) |
If [the species] was the food for another organism, then you have a whole food web that can be affected.

Potential loss of medicine, food, and raw materials
Endangered species, extinction, loss of interactions, diseases

Table L-12. Comparison of Pre-instruction and Post-instruction Propositions for Cyrene

<table>
<thead>
<tr>
<th>Preinstruction – Interview #2</th>
<th>Instruction</th>
<th>Postinstruction – Interview #3</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The different groups of organization, domains, kingdoms, phylum, class, order, family, genus, species</td>
<td>Levels of biodiversity: ecosystems, i.e. - [textbook] ecosystems have complex web of interactions among species; community interaction in the ecosystem affect water, oxygen, and nutrient cycling, purifying waste and producing soil; tropical rain forests are highly diverse; Rain forests and coral reefs are being destroyed [CD]</td>
<td>Ecosystems – wetlands and rain forest, and cultivated lands Different organisms help decompose dead stuff and recycle nutrients for plant growth Oceans help getting some of the CO$_2$ from atmosphere Crops depend on pollinators and many are being killed by pesticides.</td>
<td>mc+, B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+, B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+, CD!</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+, CD</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Levels of biodiversity: species, i.e. (any of) High number of species have been described Rosy periwinkle in TF of Madagascar is source of two chemicals to treat two forms of cancer (leukemia and Hodgkin’s) Bark of Pacific yew tree form Pacific NW is source of anticancer drug Taxol. Corals from Indian Ocean are source of anticancer compound. [CD] Natural fibers Natural chemicals, medicinal plants Crop species</th>
<th>Species - pink flower – source of anti-cancer drug About 25% of common medicines come from plants, like aspirin We only use a few plant species for our food source.</th>
<th>+, B +, CD +, CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of biodiversity: genetics, i.e. Genes of a wild relative of corn, only found in a small area of Mexico which was about to be cut and burned, may be important to enhance disease-resistance or create a perennial corn. [CD] Variation in wild species, disease resistance in crops, chemical variation in medicinal plants Food varieties</td>
<td>Genetics – making the American elms resistant to the fungus that wiped them out. <strong>Crops their genetics are very important too, like the corn, …</strong> And rice, only one kind is resistant to virus; it took a lot of testing to find that one. Genetic traits can help scientists make crops that last longer, give more food, are disease resistant</td>
<td>+, CD +, B +, CD +, B</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Because is important to know about all the different organisms</th>
<th>Reasons for conserving biodiversity</th>
<th>We might deprive future generations of essential things we have today. Life as we know it is not possible if we destroy the diversity, for us to survive, many different species and ecosystems are needed – all life - Need to conserve resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid destruction of ecosystems (TRF, coral reefs)</td>
<td>High rates of extinction Extinction may lead to unstable communities vulnerable to disease or adverse environmental conditions</td>
<td></td>
</tr>
<tr>
<td>More species to be discovered that we don’t know yet, and they can be gone</td>
<td>Loss of biodiversity – causes and/or consequences examples: Increasing numbers of humans human activities driving species to extinction Wasteful standards of living potential loss of medicine, food, and raw materials Endangered species, extinction, loss of interactions, diseases</td>
<td>As we cut forest down, we might loose plants that are important as medicines or could be important and we don’t know yet. If one species goes extinct too many things could be affected or not, but what if? Everything is related and interdependent – loose pollinators, loose genes, loose medicines</td>
</tr>
<tr>
<td>Man made pollution, We are destroying the planet, like cutting down trees to put new subdivisions Animals have no place to live, like the raccoons that went to my grandmother’s attic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>Postinstruction – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need sun, water, nutrients</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations (2n sporophyte and n gametophyte) Store food as starch or oil Photosynthetic, multicellular, cell wall of cellulose, eukaryotic</td>
<td>They photosynthesize Presence of starch cell walls</td>
<td>+  +  +  0</td>
</tr>
<tr>
<td>they don’t move</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everything came from a single common ancestor, like bacteria</td>
<td>Evolutionary origin of the plant kingdom is green algae</td>
<td>Green algae, protists -ancestor of plants</td>
<td>mc+</td>
</tr>
<tr>
<td>There are many kinds of plants Some are taller and some are very small, some have flowers (general statement made for all plant categories)</td>
<td>Characteristics of major phyla: Bryophytes – liverworts &amp; mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant.</td>
<td>Bryophytes are non-vascular [Bryophytes] lack true leaves, stems and roots</td>
<td>+  +</td>
</tr>
<tr>
<td></td>
<td>Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns &amp; horsetails requires moisture, wind and pollinators for reproduction; have spores no seeds</td>
<td>tracheophytes are vascular includes ferns have true leaves [Ferns] have spores, no seeds</td>
<td>+  +, T  +  +</td>
</tr>
</tbody>
</table>

(Table continued)
| Tracheophytes +  | Gymnosperms - pollen and seeds, wind pollinated no flowers | Gymnosperms are non-flowering  
[Gymnosperms] are vascular plants  
[Gymnosperms] have seeds  
Gymnosperms are wind pollinated | +  
+  
+  
+ |
| Tracheophytes +  | Angiosperms-pollen, seeds, flowers, pollinated by animals and wind | Angiosperms are flowering  
vascular plants  
with seeds  
Angiosperms are pollinated by animals and insects | +  
+  
+  
+ |
| Maybe flowers or trees, that’s what we see most | Most diverse group of plants is angiosperms | Angiosperms | + |
| Give off carbon dioxide when they are burned causing pollution | Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples)  
Water cycle  
Decomposition (nutrient cycling)  
Photosynthesis - Global warming  
Animal food, seed and pollen dispersal | Colorful flowers attract birds that become pollinators, like the hummingbirds  
Give us water and oxygen  
Provide animals with habitats to live and food like the panda bears and bamboo | -  
+  
mc  
+  
+, L |
| They are useful and we depend on them  
Things throughout life deal with plants diversity, like the Aloe Vera that has medicinal use, but others like marihuana, is not good | Benefits obtained from plants (multiple possible answers, check textbook vs. CD examples)  
Food, caffeine, nicotine, peppermint, mustard  
Clothes  
Medicines (Taxol, aspirin, memory) | We like pretty flowers and their smell may attract us  
Give us food, like carrots that are roots  
Give us medicine, like some that cure cancer (but don’t know name) | +  
+, G  
+, L  
+, T  
- |

*Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed (Note continued)*
correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.

Table L-14. Comparison of Pre-instruction and Post-instruction Propositions for Thiab

<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>Postinstruction – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>They don’t move</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations (2n sporophyte and n gametophyte) Store food as starch or oil Photosynthetic, multicellular, cell wall of cellulose, eukaryotic</td>
<td>Can’t move Photosynthesize, but some may be consumers-the Venus fly trap, they get insects,</td>
<td>mc0 0 +, G</td>
</tr>
<tr>
<td>They photosynthesize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Need water, sunlight, soils, air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maybe bacteria</td>
<td>Evolutionary origin of the plant kingdom is green algae</td>
<td>Green algae</td>
<td>mc+</td>
</tr>
<tr>
<td>There are differences in size, leaves, and petals (general proposition made for all kinds of plants)</td>
<td>Characteristics of major phyla: Bryophytes – liverworts &amp; mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant.</td>
<td>Bryophytes don’t produce seeds they like very moist places</td>
<td>+ +</td>
</tr>
<tr>
<td></td>
<td>Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns &amp; horsetails requires moisture, wind</td>
<td>Ferns have sporophyte their spores are airborne</td>
<td>+, T +</td>
</tr>
</tbody>
</table>

(Table continued)
and pollinators for reproduction; have spores no seeds

<table>
<thead>
<tr>
<th>Tracheophytes + Gymnosperms- pollen and seeds, wind pollinated no flowers</th>
<th>Gymnosperms has all the conifers which are seed plants, but with naked seeds their pollen is airborne</th>
<th>+, T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracheophytes + Angiosperms-pollen, seeds, flowers, pollinated by animals and wind</td>
<td>Angiosperms produce seeds Flowers Fruits</td>
<td>+ + +</td>
</tr>
<tr>
<td>I remember you said something in the other chapter, there are a lot of plants</td>
<td>Most diverse group of plants is angiosperms</td>
<td>+</td>
</tr>
<tr>
<td>Make oxygen for us to breathe</td>
<td>Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples) Water cycle Decomposition (nutrient cycling) Photosynthesis - Global warming Animal food, seed and pollen dispersal</td>
<td>Food for insects insects pollinate flowering plants - blue lupines and bees and the hummingbirds and red flowers Some are good for nitrogen fixation with bacteria</td>
</tr>
<tr>
<td>Medicines</td>
<td>Benefits obtained from plants (multiple possible answers, check textbook vs. CD examples) Food, caffeine, nicotine, peppermint, mustard Clothes</td>
<td>Medicines, like taxol in yew trees They give us oxygen and food Tobacco (some think is a blessing) that is a plant, but the nicotine also causes cancer, so then you need other plants to cure the cancer! Stuff to make our clothes, like cotton</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>Postinstruction – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>they can’t move, Need oxygen, sunlight, water, nutrients, carbon dioxide, nitrogen</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations (2n sporophyte and n gametophyte) Store food as starch or oil Photosynthetic, multicellular, cell wall of cellulose, eukaryotic</td>
<td>Absorb carbon dioxide and give oxygen [through] photosynthesis The way they reproduce, gametophyte and sporophyte</td>
<td>0 + +</td>
</tr>
<tr>
<td>All things have a common ancestor</td>
<td>Evolutionary origin of the plant kingdom is green algae</td>
<td>Green algae</td>
<td>+</td>
</tr>
<tr>
<td>They have different characteristics Some look like algae, the shape of the leaves, some have flowers (general statement for all plants)</td>
<td>Characteristics of major phyla: Bryophytes – liverworts &amp; mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant.</td>
<td>Liverworts and mosses are bryophytes they don’t have vessels Bryophytes are gametophyte dominant</td>
<td>+, T + +</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns &amp; horsetails requires moisture, wind and pollinators for reproduction; have spores no seeds</th>
<th>Ferns are tracheophytes they are vascular plants They are sporophyte dominant</th>
<th>+, T + +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracheophytes + Gymnosperms- pollen and seeds, wind pollinated no flowers</td>
<td>Gymnosperms are plants with seeds Don’t have flowers are tracheophytes – which means they are vascular They are also sporophyte dominant</td>
<td>+ + +</td>
</tr>
<tr>
<td>Tracheophytes + Angiosperms- pollen, seeds, flowers, pollinated by animals and wind</td>
<td>Angiosperms have flowers seeds [Angiosperms have] bigger leaves angiosperms are tracheophytes or vascular They are also sporophyte dominant</td>
<td>+ + + +</td>
</tr>
<tr>
<td>I know there is a lot of plants</td>
<td>Most diverse group of plants is angiosperms flowering plants</td>
<td>+</td>
</tr>
<tr>
<td>Important to the animals, they get shelter and food</td>
<td>Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples) Water cycle Decomposition (nutrient cycling) Photosynthesis - Global warming Animal food, seed and pollen dispersal</td>
<td>Food and shelter to animals 0</td>
</tr>
</tbody>
</table>

(Table continued)
Landscaping
Giving us oxygen, make the air better
People in other countries use trees to build their houses and plants to weave baskets, some make their garments out of leaves

Benefits obtained from plants
Food, caffeine, nicotine, peppermint, mustard
Clothes
Medicines (Taxol, aspirin, memory)

Oxygen
Different things come from different kinds of plants
We eat different kinds of plants.
We get a lot of medications from plants, like aspirin.

Table L-16. Comparison of Pre-instruction and Post-instruction Propositions for Carla

<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>Postinstructor – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce their own oxygen and give us oxygen</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations (2n sporophyte and n gametophyte) Store food as starch or oil Photosynthetic, multicellular, cell wall of cellulose, eukaryotic</td>
<td>Making their own food – photosynthesis Some reproduce from seeds</td>
<td>- + +</td>
</tr>
<tr>
<td>Prokaryotic</td>
<td>Evolutionary origin of the plant kingdom is green algae</td>
<td>Scientists believe that land plants came from green algae</td>
<td>mc+, T</td>
</tr>
</tbody>
</table>

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-ROM was too extensive to include possible answers under the instruction column.
there are different kinds, like grass and flowers, and trees

<table>
<thead>
<tr>
<th>Characteristics of major phyla:</th>
<th>seedless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryophytes – liverworts &amp; mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant.</td>
<td></td>
</tr>
<tr>
<td>Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns &amp; horsetails requires moisture, wind and pollinators for reproduction; have spores no seeds</td>
<td>ferns seedless plants are vascular plants</td>
</tr>
<tr>
<td>Tracheophytes + Gymnosperms- pollen and seeds, wind pollinated no flowers</td>
<td>Gymnosperms include the pines are vascular have seeds no flowers some have cones like the pines some look very weird like that African plant \textit{Welswitchia}</td>
</tr>
<tr>
<td>Tracheophytes + Angiosperms-pollen, seeds, flowers, pollinated by animals and wind</td>
<td>Angiosperms have seeds Have flowers Have conductive vessels</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flowering plants</th>
<th>Most diverse group of plants is angiosperms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering plants have the most species</td>
<td></td>
</tr>
</tbody>
</table>

Food, shelter | Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples) Water cycle | Give food to insects and birds and they are pollinated |

(Table continued)
<table>
<thead>
<tr>
<th>Decomposition (nutrient cycling)</th>
<th>Photosynthesis - Global warming</th>
<th>Animal food, seed and pollen dispersal</th>
<th>To make house pretty</th>
<th>Medicines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits obtained from plants (multiple possible answers, check textbook vs. CD examples)</td>
<td></td>
<td></td>
<td>Provide beauty, like roses and orchids</td>
<td>Medicines for cancer or snake bites</td>
</tr>
<tr>
<td>Food, caffeine, nicotine, peppermint, mustard Clothes Medicines (Taxol, aspirin, memory)</td>
<td></td>
<td></td>
<td>A lot of our food comes from grasses, like rice</td>
<td>Rubber from some trees</td>
</tr>
<tr>
<td>Paper from wood pulp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table L-17. Comparison of Pre-instruction and Post-instruction Propositions for Caleb**

<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>Postinstruction – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosynthesis</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations (2n sporophyte and n gametophyte) Store food as starch or oil Photosynthetic, multicellular, cell wall of cellulose, eukaryotic</td>
<td>They produce oxygen, need carbon dioxide, sunlight and water for photosynthesis. They are the ones that turn sunlight to energy for other organisms [plants] Need nutrients Have roots and rhizoids important to anchor and to get nutrients</td>
<td>+</td>
</tr>
<tr>
<td>Protists</td>
<td>Evolutionary origin of the plant kingdom is green algae</td>
<td>Terrestrial plants came from a green algae, spirogyra which grows in the pond here</td>
<td>+, A</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>The way they look</td>
<td>Characteristics of major phyla: Bryophytes – liverworts &amp; mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant.</td>
<td>Bryophytes include the moss but not like Spanish moss they have rhizoids instead of roots.</td>
<td>+, A</td>
</tr>
<tr>
<td>Starts with the algae [pointing to bryophytes]</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Reproductive structures like spores in ferns</td>
<td>Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns &amp; horsetails requires moisture, wind and pollinators for reproduction; have spores no seeds</td>
<td>Ferns are like a middle class plant, they are vascular but seedless Are sporophyte dominant</td>
<td>+, B, M*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Reproductive structures like flowers with pollen</td>
<td>Tracheophytes + Gymnosperms- pollen and seeds, wind pollinated no flowers</td>
<td>Gymnosperms include the conifers and cycads – have cones for reproduction These were the most common before the flowering plants</td>
<td>+, B</td>
</tr>
<tr>
<td>Some may have adaptations, like they live in water or have tendrils</td>
<td>The angiosperms are flowering plants, have seeds interact with animals – like some have very bight colors to attract pollinators</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>We pretty much know all that is out there for plants,</td>
<td>Most diverse group of plants is angiosperms</td>
<td>Angiosperms</td>
<td>+</td>
</tr>
</tbody>
</table>

(Table continued)
Food chains
Some serve to control erosion

| Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples) |
| Water cycle |
| Decomposition (nutrient cycling) |
| Photosynthesis - Global warming |
| Animal food, seed and pollen dispersal |

animals and other organisms use plants for food provide shelter to animals Help in filtering, like in swamps And somewhat help in decomposing, like the more fertile soil, plants grow better Give oxygen and take carbon dioxide

Medicines
Food

Benefits obtained from plants (multiple possible answers, check textbook vs. CD examples)

Food, caffeine, nicotine, peppermint, mustard
Clothes
Medicines (Taxol, aspirin, memory)

Medicinal plants. There are main groups of plants that we use a lot, like wheat, rice, corn. They are large crops, and there are others we don’t use that much. Some plants can be used a pesticides.

Fiber – clothing, paper We also send flowers, some are really pretty like orchids and roses

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.

Table L-18. Comparison of Pre-instruction and Post-instruction Propositions for Cyrenec.

<table>
<thead>
<tr>
<th>Preinstruction – Interview #3</th>
<th>Instruction</th>
<th>PostinSTRUCTION – Interview #4</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need sun, water, insects, animals, wind, air</td>
<td>Unique characteristics of plants: Reproduction – sexual or asexual with alternation of generations</td>
<td>Give us oxygen in photosynthesis Need photosynthesis for survival, turn sun energy into food and fuel They function like a bridge with the sun for all organisms</td>
<td>+ + M*</td>
</tr>
</tbody>
</table>

(Table continued)
| Protistas are the closest group | Evolutionary origin of the plant kingdom is green algae | From organisms that live in water, algae in the protista | 0 |
| Having flowers or not or cones, size is different, how leaves look (general statement for all groups) | Characteristics of major phyla: Bryophytes – liverworts & mosses, non-vascular, no true roots/stems/leaves; requires moisture for reproduction; gametophyte dominant. Limited size (most < 1in) | Bryophytes, like the mosses are the smaller plants | +, B |
| | Tracheophytes- vascular with lignin on vessels; true roots/stems/leaves; sporophyte dominant + ferns & horsetails requires moisture, wind and pollinators for reproduction; have spores no seeds | Ferns don’t have seeds but spores instead [ferns] are vascular | +, B |
| | Tracheophytes + Gymnosperms- pollen and seeds, wind pollinated no flowers | Gymnosperms have pollen Seeds no flowers but some have cones can grow in poor soils vascular All pines and the giant sequoias are here | + |

(Table continued)
| Tracheophytes +  
| Angiosperms-pollen, seeds, flowers, pollinated by animals and wind | Flowering plants produce with pollen in flowers, have seeds, vascular | +  
| +  
| +  
| There are a lot of plant species | Most diverse group of plants is angiosperms | Flowering plants | +  
| Food, insects eat plants | Role of plants in ecosystem (multiple possible answers, check textbook vs. CD examples)  
| Water cycle  
| Decomposition (nutrient cycling)  
| Photosynthesis - Global warming  
| Animal food, seed and pollen dispersal | Some animals pollinate plants Interdependent with other organisms  
| Fungi can kill plants, like the elm trees  
| Herbivores eat plants, like pandas and koalas.  
| Some plants have chemicals to avoid that – caffeine, skin toxins like the poison ivy & cashews | +  
| +, CD  
| +, L  
| +, B  
| Our food  
| Medicinal plants | Benefits obtained from plants (multiple possible answers, check textbook vs. CD examples)  
| Food, caffeine, nicotine, peppermint, mustard  
| Clothes  
| Medicines (Taxol, aspirin, memory) | Nourishment different foods like fruits and crops, many from grass family  
| Medicine – cure for some diseases  
| Building material, like wood  
| Paper  
| Oils, like from coconut and olives, sunflowers  
| Flowers bring color, make us happy, now I notice plants and flowers everywhere | +, CD  
| 0  
| +, CD  
| +, CD  
| +, CD  
| +  

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.
Table L-19. Comparison of Pre-instruction and Post-instruction Propositions for Tanya

<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystems are made of many different plants. Must be different in different parts of the world because a lot of it has to deal with the type of environment</td>
<td>Global patterns in Biodiversity at the ecosystem level Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, desert, grasslands</td>
<td>There are ecosystems with many species and others were the species are more spread</td>
<td>-</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest</td>
<td>Wetlands, have different plants</td>
<td>0</td>
</tr>
<tr>
<td>I think is tropical forest</td>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity</td>
<td>Tropical rain forests, along the Equator</td>
<td>+</td>
</tr>
<tr>
<td>A place or area of real importance or characteristics</td>
<td>Hot spots are ecosystems of high species diversity that are endangered These are located in</td>
<td>Places that have abundance of plant diversity. Tropical areas</td>
<td>mc0</td>
</tr>
<tr>
<td>You can have cross breeding which contributes to plant diversity</td>
<td>Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn, strawberries, blueberries;</td>
<td>Scientists get genes of wild species of corn to cross with other corn to modify it usually they can get the genes from the other plants – like wild corn. There are some medicinal plants that scientist found can be used for medicines to treat AIDS</td>
<td>+, T</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Threats to diversity: Habitat destruction like: <strong>Deforestation</strong> in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture)</th>
<th>In tropical forests people are cutting down trees, also deforestation is affecting the wetlands in Louisiana – more houses and roads everywhere</th>
<th>+, T, L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Invasive species</strong> – New to the ecosystem. Have no predators.</td>
<td>Like some plants the tree, in class, Chinese tallow that’s growing all over the place</td>
<td>+, L</td>
</tr>
</tbody>
</table>

(Table continued)
May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow; lecture and text – climbing ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD –loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm]

<table>
<thead>
<tr>
<th>Pollution</th>
<th>Population growth</th>
<th>Overharvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution – wetland water [CD]</td>
<td>causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.</td>
<td>(text) caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.</td>
</tr>
</tbody>
</table>

(Table continued)

470
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Corrected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ are consequences of the loss of species diversity due to threats</td>
<td>With deforestation many species can be lost, some of the species lost could have use as medicines and we don’t know -they are looking for that</td>
<td>+</td>
</tr>
<tr>
<td>How animals and plants are interdependent, and not all eat the same things</td>
<td>_____ are examples of complex interactions in diverse ecosystems. (pollination, seed dispersal-all, examples may vary according to source) Complex interactions are disrupted in threatened ecosystems.</td>
<td>+, T</td>
</tr>
<tr>
<td>I think is all, like the different characteristics and number of species. But it doesn’t make much sense to me.</td>
<td>Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity – including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience.</td>
<td>mc0</td>
</tr>
</tbody>
</table>

**Note.** mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.
### Table L-20. Comparison of Pre-instruction and Post-instruction Propositions for Thiab

<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem diversity is the biotic and abiotic factors, and all plants and animals Plants support the animals</td>
<td>Global patterns in Biodiversity at the ecosystem level Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, dessert, grasslands</td>
<td>Ecosystem diversity and the distribution of species is not equal because different areas have different things, like desserts have less and different animals and plants than what we see here for example There is tropical rain forest, dessert, temperate evergreen – a lot of different ecosystems</td>
<td>mc+, T</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest</td>
<td>tropical… or temperate deciduous forest, wetlands, and pine savannas</td>
<td>+, T, L</td>
</tr>
<tr>
<td>Tropical rain forest has more [species] than anywhere else</td>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity</td>
<td>Tropical rain forest – in Central America and northern South America</td>
<td>+, T</td>
</tr>
<tr>
<td>Oaks mostly in Louisiana</td>
<td>represents some plant diversity in the ecosystem(s) identified above.</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Places with a lot of sunlight – the tropical areas</td>
<td>Hot spots are ecosystems of high species diversity that are endangered These are located in Tropical rain forests</td>
<td>Areas that are very diverse but are most threatened by human impact Tropical rain forests</td>
<td>mc+, L</td>
</tr>
<tr>
<td>The genes is what makes up the plants- why they are different Need to maintain gene diversity for the sake of animal diversity</td>
<td>Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn,</td>
<td>Is important, because some [plants] may have the chemicals that cure something but not others, [like] Yew tree, some kinds don’t have the chemical that can be used to treat cancer patients</td>
<td>mc+, T</td>
</tr>
</tbody>
</table>

(Table continued)
strawberries, blueberries; CD: corn, rice, wheat, 100 food species). Genetic diversity is also important for medicinal species (Text: yew- cancer and Calophyllum- AIDS).

Different plants have different gene pool and that causes evolution and more diversity

| Different plants have different gene pool and that causes evolution and more diversity | Genetic engineering – a positive aspect: depends on wild species present in diverse ecosystems – i.e. corn, American chestnut tree and blight fungus resistance Genetic engineering – a negative aspect: It can affect natural ecosystems if pest or herbicide resistant crops, like Bt corn and cotton, invade these and if they influence insect evolution or evolution of other resistant weeds. | It is used to make other varieties of plants and animals by picking the good characteristics and making better fruits, and vegetables more resistant to disease or insects - and that make more or grow bigger like the strawberries, corn, or some fish Is important because we are running short of food because there is more and more people, and we are using the land to build houses and malls | mc+, T |

| habitat destruction, like deforestation | Threats to diversity: Habitat destruction like: **Deforestation** in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture) | Deforestation, very bad in the tropics, a lot being destroyed | + |

(Table continued)
Invasive species – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow; lecture and text – climbing ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm]

Exotic species are invading and overtaking our native species Chinese tallow and the water hyacinths in the wetlands

Pollution – wetland water [CD] +, L, T

Population growth causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.

Population overgrowth is the worst maybe, because it brings more deforestation, more houses, and more deforestation +, G

Overharvesting (text) - caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers' plants are endangered.

(Table continued)
| Extinction | _______ are consequences of the loss of species diversity due to threats | Exotic species- invading, expensive to our economy, and can make our species go extinct. In some TRF monkey’s can’t survive because they are cutting down trees. Can loose plant species that can help cure diseases like cancer and aids. | +, T |
| All organisms are interdependent | _______ are examples of complex interactions in diverse ecosystems. (pollination, seed dispersal-all, examples may vary according to source) Complex interactions are disrupted in threatened ecosystems. | Some plants have symbiosis with nitrogen fixers or with insects or birds. Some plants can give food and energy to other animals and at the same time get some benefit, they get pollinated. Blue flowers – they have a special way of giving the pollen to the bees. Red flowers in rain forest that give nectar to hummingbirds. They are adapted to each other. If the forest is gone, then there are no more red flowers for the birds. Insects lay their eggs in the flowers or plants – like the butterflies. | +, T |
| I’ve seen the word, I can’t explain it. | Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity – including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience. | Is all together, if you lose diversity, then some peoples jobs will be affected, like biologists. If loose some plants, say …wheat, then a whole industry goes down the drain. Medicine is also affected by biodiversity, say a plant is discovered that cures AIDS, then many things will depend on it. …and the plant can be in danger because is in a tropical forest…and the animals that pollinate it…so it’s all together. | + |

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct; mc- a correct proposition changed to incorrect; mc a incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.
Table L-21. Comparison of Pre-instruction and Post-instruction Propositions for Trevic

<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>You can find different ecosystems everywhere, because there are different environments all over the world, because of the different climates</td>
<td>Global patterns in Biodiversity at the ecosystem level Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, desserts, grasslands</td>
<td>There are different kinds of ecosystems, and they have different kinds of species Like there is temperate forest with evergreen and there are desserts</td>
<td>+, T</td>
</tr>
<tr>
<td>Swamps and wetlands, woods</td>
<td>Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest</td>
<td>Wetlands, woods</td>
<td>0</td>
</tr>
<tr>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity</td>
<td></td>
<td>Tropical rain forests has the most species</td>
<td>+</td>
</tr>
<tr>
<td>There’s different species because of natural selection and movement of species, so you don’t have the same species everywhere.</td>
<td>_______ represents some plant diversity in the ecosystem(s) identified above.</td>
<td>Wetlands in LA…You can find sugar cane, mosses, oak trees cypress are common here</td>
<td>-</td>
</tr>
<tr>
<td>Beach</td>
<td>Hot spots are ecosystems of high species diversity that are endangered These are located in</td>
<td>Ecosystems like the tropical rain forest, dying off at a very fast rate</td>
<td>mc0</td>
</tr>
<tr>
<td>Plants are genetically different when you look at their composition, that is important for the survival of the fittest</td>
<td>Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn, strawberries, blueberries; CD: corn, rice, wheat, 100 food species).</td>
<td>They [wild species] help keep the ecosystem alive Crops, like the corn breeding with wild ones made it they way we know it</td>
<td>-</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th><strong>Changing the genetics of plants – increases the diversity</strong></th>
<th>Genetic engineering – a positive aspect: depends on wild species present in diverse ecosystems – i.e. corn, American chestnut tree and blight fungus resistance. Genetic engineering – a negative aspect: It can affect natural ecosystems if pest or herbicide resistant crops, like Bt corn and cotton, invade these and if they influence insect evolution or evolution of other resistant weeds.</th>
<th>Can make plants resistant to diseases</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deforestation.</strong></td>
<td>Threats to diversity: Habitat destruction like: Deforestation in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture)</td>
<td>Deforestation – in tropical rain forests. Natural disasters - like Katrina</td>
<td>+, T +, G</td>
</tr>
<tr>
<td><strong>Invasive species</strong> – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow;</td>
<td>Exotic invaders - Chinese tallow</td>
<td>+, L</td>
<td></td>
</tr>
</tbody>
</table>
Pollution, the chemical plants here, they have spills. Pollution – wetland water [CD]

Population growth causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.

Overharvesting (text) - caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.

Deforestation - killing off animals because their habitats are destroyed. [Deforestation in TRF] - hummingbird in the book, if all the forest is gone; there is no shelter, no plants to pollinate, no food. [Exotic invaders] - push native species to extinction and a lot of research and money goes for those

---

<table>
<thead>
<tr>
<th>Lecture and text – climbing ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm]</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Pollution</th>
<th>Population growth causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Overharvesting (text) - caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.</th>
</tr>
</thead>
</table>

| Deforestation - killing off animals because their habitats are destroyed. [Deforestation in TRF] - hummingbird in the book, if all the forest is gone; there is no shelter, no plants to pollinate, no food. [Exotic invaders] - push native species to extinction and a lot of research and money goes for those |
| --- | --- | +, T |

(Table continued)
<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>We all need each other for survival - here in the United States we are affected by what happens in the tropical rain forest</td>
<td>_______ are examples of complex interactions in diverse ecosystems. (pollination, seed dispersal-all, examples may vary according to source) Complex interactions are disrupted in threatened ecosystems.</td>
<td>All things are interdependent, some plants can be home for bacteria or fungus Plants use some from the environment and also put something back to it Animals use plants for shelter and food, like squirrels and birds</td>
</tr>
<tr>
<td>I am not so sure about this. Has to do with evolution and diversity.</td>
<td>Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity – including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience.</td>
<td>Has to do with the number of species, the amount of diversity and evolution and how genetics makes things diverse. Also the complex may be, you know, do you get what you need or do we keep the living organisms?</td>
</tr>
</tbody>
</table>

Note. mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD- Rom was too extensive to include possible answers under the instruction column.
### Table L-22. Comparison of Pre-instruction and Post-instruction Propositions for Carla

<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think the diversity is distributed in the same way.</td>
<td>Global patterns in biodiversity at the ecosystem level. Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, deserts, grasslands.</td>
<td>Different climates all over the world determine what grows there, so the kinds of species are different and there are different ecosystems.</td>
<td>mc+</td>
</tr>
<tr>
<td>In different biomes there are different food webs</td>
<td>Wetlands Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest.</td>
<td>A lot of wetlands! Are important for transportation, recreation, and food. The pine savannas.</td>
<td>+, L</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity.</td>
<td>More species toward the equator – in tropical rain forest.</td>
<td>+, B</td>
</tr>
<tr>
<td></td>
<td>_______ represents some plant diversity in the ecosystem(s) identified above.</td>
<td>[Wetland] You can find the cypress, the state tree, iris.</td>
<td>+, L</td>
</tr>
<tr>
<td>No clue, maybe tropical areas, they are warmer</td>
<td>Hot spots are ecosystems of high species diversity that are endangered. These are located in _______</td>
<td>Areas that need to be left alone, don’t mess with them because of the diversity they have like 50% of the world’s Tropical forests- like in Brazil.</td>
<td>mc+, CD</td>
</tr>
<tr>
<td>This is what makes organisms different</td>
<td>Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn, strawberries, blueberries; CD: corn, rice, wheat, 100 food species).</td>
<td>It is important to conserve the genetic diversity. Is important to know where organisms come from, like with the corn or the food we eat, most is not from here – like the rice, coffee, corn, soybeans. They come originally form far away places – Africa, Asia, South.</td>
<td>+, CD</td>
</tr>
</tbody>
</table>

(Table continued)
<table>
<thead>
<tr>
<th>Genetic diversity is also important for medicinal species (Text: yew- cancer and Calophyllum- AIDS)</th>
<th>America…but we grow them here, so is important to know where they come from. It can help preserve a species if something happens.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Messing up with the DNA of the plants, this changes them</td>
<td>Genetic engineering – a positive aspect: depends on wild species present in diverse ecosystems –i.e. corn, American chestnut tree and blight fungus resistance Genetic engineering – a negative aspect: It can affect natural ecosystems if pest or herbicide resistant crops, like Bt corn and cotton, invade these and if they influence insect evolution or evolution of other resistant weeds.</td>
<td>Can help making pest resistant species or cold resistant species, like some strawberries +, CD</td>
</tr>
<tr>
<td>There are threats, areas are disappearing by deforestation or just because of change, like the wetlands are being engulfed</td>
<td>Threats to diversity: Habitat destruction like: <strong>Deforestation</strong> in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture)</td>
<td>Human destruction is the most important, deforestation – a lot of forest lost in LA and in the TRF- there is agriculture and logging Housing in LA and in the whole US +, CD, G</td>
</tr>
</tbody>
</table>
**Invasive species** – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow; lecture and text – climbing ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm]

Exotic invaders - like the one with heart shaped leaves [Chinese tallow] and the climbing ferns which are kind of everywhere, and the purple flowers that grow in wetlands of the east

<table>
<thead>
<tr>
<th><strong>Pollution</strong> – wetland water [CD]</th>
<th>Wetlands can be affected by this</th>
<th>+, CD</th>
</tr>
</thead>
</table>

| **Population growth** causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees. | In Louisiana we see a lot of trees being cut because we are building more and more subdivisions | +, G |

**Overharvesting** (text)
- caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.
| ____ are consequences of the loss of species diversity due to threats | [Exotic invaders] - come and kill other things that can’t survive with them [Habitat destruction] - a lot of forest lost in LA and in the TRF Loose more species | + |
| Virus can attack bacteria, bacteria and fungi can be decomposers...part of food webs | ____ are examples of complex interactions in diverse ecosystems. (pollination, seed dispersal-all, examples may vary according to source) Complex interactions are disrupted in threatened ecosystems. | +, T |
| I know is related to biodiversity. Is like all together, all that affects diversity, but I don’t really know how to explain each part | Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity – including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience. | +, B |
| It is difficult to explain. All together, part of biodiversity, living things, like the huge industry of strawberries in Louisiana that affects millions of dollars. | 0 |

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<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>The diversity of species is spread out evenly, but in different proportions. Antarctica doesn’t have many animals, there may be more bacteria there [Antarctica] or more single celled organisms</td>
<td>Global patterns in Biodiversity at the ecosystem level Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, desserts, grasslands</td>
<td>There are different kinds of ecosystems, tropical forests, savannas, desserts, temperate conifer forests. There are more species towards the equator in the tropical areas.</td>
<td>mc+, B</td>
</tr>
<tr>
<td>Swamps</td>
<td>Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest</td>
<td>Wetlands broad leaf forest temperate savannas mixed forest</td>
<td>+, L, CD</td>
</tr>
<tr>
<td>Tropics</td>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity</td>
<td>The tropical rain forest – in some Pacific islands, they had a lot of different plants</td>
<td>+, CD</td>
</tr>
<tr>
<td>Cypress</td>
<td>______ represents some plant diversity in the ecosystem(s) identified above</td>
<td>[wetlands] that have cypress, which is the state tree, iris, duckweeds – smallest flowering, water lilies, Spanish moss. They are home for many species</td>
<td>+, L, CD</td>
</tr>
<tr>
<td>Maybe is a result of evolution, places were evolution is faster, like the Galapagos</td>
<td>Hot spots are ecosystems of high species diversity that are endangered These are located in ___</td>
<td>Places were biodiversity is seriously threatened, so they need to implement conservation in stronger way – like in some tropical rain forests and in the US there is one in California</td>
<td>mc+, CD</td>
</tr>
<tr>
<td>The genetic differences determine the plant diversity</td>
<td>Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn, strawberries, blueberries; CD: corn, rice, wheat, 100</td>
<td>Most plants we eat come from far away places. There are places were species originate, were the species are genetically diverse. So it is important to understand how the wild ones are growing, so this can help grow them in other places, like here, or help (Table continued)</td>
<td>+, CD</td>
</tr>
</tbody>
</table>

Table L-23. Comparison of Pre-instruction and Post-instruction Propositions for Caleb
| Food species | Genetic diversity is also important for medicinal species (Text: yew- cancer and Calophyllum- AIDS) | It can help protect the crops that we depend the most, which is only – about 4 – the rice, wheat, potatoes and corn | +, CD |
| Changing the genetics of the species | Genetic engineering – a positive aspect: depends on wild species present in diverse ecosystems – i.e. corn, American chestnut tree and blight fungus resistance Genetic engineering – a negative aspect: It can affect natural ecosystems if pest or herbicide resistant crops, like Bt corn and cotton, invade these and if they influence insect evolution or evolution of other resistant weeds. | This is kind of like playing with the species, you can do tests. | 0 |
| Humans, pollution, deforestation | Threats to diversity: Habitat destruction like: Deforestation in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture) | Wetlands – too much population growth Deforestation – for farming, lumber, or just development – big problem here Natural disasters also destroy the habitat, like Katrina | +, L, G |
| | Invasive species – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow; Exotic species- loosestrife is one with purple flowers that grows in wetlands, but not in LA, other wetlands. That plant is killing a lot of other plant life in other wetlands Also the water lilies [hyacinths]- the purple flower | | +, CD |
| (Table continued) | | | |

485
<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
<th>Example</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>lecture and text – climbing</td>
<td>ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm</td>
<td>In Louisiana the fire ants are a problem everywhere, but they can affect soybeans, and corn, and okra- maybe this is the worst of all invasive</td>
<td>+, CD</td>
</tr>
<tr>
<td>Pollution</td>
<td>wetland water [CD, lecture]</td>
<td>Pollution from insecticides is a big problem for wetlands too From oil in LA</td>
<td>+, CD</td>
</tr>
<tr>
<td>Population growth</td>
<td>causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.</td>
<td>Population growth - because we are growing too much and need more space to live It goes together with deforestation, when you see [compare] the maps, there is more people-less forest everywhere</td>
<td>+, CD</td>
</tr>
<tr>
<td>Overharvesting</td>
<td>(text) - caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>____________ are consequences of the loss of species diversity due to threats habitation destruction – no habitat for wild life species</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

(Table continued)
The interaction among species can affect how they change over time. Like the finches in the Galapagos, the plant diversity there affects the diversity of birds. **_____ are examples of complex interactions in diverse ecosystems.**

- Complex interactions are disrupted in threatened ecosystems.

| Pollinators and the plants they visit are co-adapted. The pollinators get food while the plant reproduces. The interactions can affect the evolution. It could be shelter too. Like the pine trees and woodpeckers. Seed dispersers, like birds, monkeys, lemurs — if their habitat is gone in the TRF, then they have no food, no shelter. In some places trees can’t reproduce because the dispersers are not there.
| -
| +
| +, L
| +, T

| Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity — including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience.
| I think is the way everything is put together. How species themselves are complex and they have complex interactions and many interactions with everything, like other species, or the environment, and other things too...changes...deforestation, and building houses
| mc+

**Note.** mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-Rom was too extensive to include possible answers under the instruction column.
Table L-24. Comparison of Pre-instruction and Post-instruction Propositions for Cyrenecc

<table>
<thead>
<tr>
<th>Preinstruction – Interview #4</th>
<th>Instruction</th>
<th>Postinstruction – Interview #5</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>They [plants] only grow in certain places, so there is differences between continents, but there is diversity everywhere but the kinds of things are different</td>
<td>Global patterns in Biodiversity at the ecosystem level. Different kinds of ecosystems distributed according to temperature and rainfall patterns. Temperate deciduous, tropical, desserts, grasslands</td>
<td>There is like 15 of them [ecosystems], some are temperate, with conifers, tropical, desserts, savannas</td>
<td>+, B</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Louisiana’s (local) diversity at the ecosystem level: wetlands, long-leaf pine savannas, temperate deciduous forest</td>
<td>Swamps Tropical moist broadleaf forest Temperate shrub land savannas</td>
<td>+, L, CD</td>
</tr>
<tr>
<td>Tropical forests</td>
<td>Ecosystem diversity: Tropical rain forest is the ecosystem with highest species diversity</td>
<td>Tropical rain forests are the most diverse, - find them in Central and South America and the islands</td>
<td>+, B</td>
</tr>
<tr>
<td>Diverse areas, like in the tropics</td>
<td>[swamps] - bald cypress which is the state tree and are kind of endangered because they are being cut for mulch, Spanish moss, and duckweed, the smallest flowering plant The [Pine] savannas – have diverse understory</td>
<td>Places where there is more man-made decline and the diversity there is higher. These need to be conserved, they are in trouble. Mainly tropical areas and subtropical have hot spots, like in South America</td>
<td>+, CD</td>
</tr>
</tbody>
</table>

(Table continued)
<p>| Ecosystem diversity: is source of genetic diversity, wild species, of important plants for food (Text: corn, strawberries, blueberries; CD: corn, rice, wheat, 100 food species). Genetic diversity is also important for medicinal species (Text: yew- cancer and Calophyllum- AIDS) | The crops are changing and their pests are also changing, so they try to make them more resistant, but this could change the taste, looks. Breeding plants in the wild we got the corn we eat. Trying to make crops that produce more. We need species in the wild to reproduce and supply the other species if everything was wiped out. Medicinal plants - some flowers...you can get medicine, like for cancer, but need to know about the genetics of them, some are good, but not all have the chemicals | +, B |
| Genetic engineering – a positive aspect: depends on wild species present in diverse ecosystems –i.e. corn, American chestnut tree and blight fungus resistance Genetic engineering – a negative aspect: It can affect natural ecosystems if pest or herbicide resistant crops, like Bt corn and cotton, invade these and if they influence insect evolution or evolution of other resistant weeds. | Strawberries made more resistant. Down side is farmers could use more pesticides because say, g.e. corn is not affected but other weeds are more resistant, so is a problem then, not good | +, T |
| Cutting down trees to put in more subdivisions | Threats to diversity: Habitat destruction like: Deforestation – Destroying the wetlands Is worst in tropical rain forests, like 1% is lost every year In the US is mostly for wood – lumber. You | +, CD |
| (Table continued) |  |  |</p>
<table>
<thead>
<tr>
<th>Deforestation in TRF (text, CD), temperate deciduous forest (text) wetlands, LLP (lecture)</th>
<th>You could see the maps in the activity, but we also saw this in real life when we were going to visit the farm, these huge trucks full of tree trunks and the huge place were they were kept – it was unbelievable!</th>
</tr>
</thead>
</table>
| Invasive species – New to the ecosystem. Have no predators. May damage ecosystem, displace, out compete, or prey on native species [lecture- Chinese privet, Chinese tallow; lecture and text – climbing ferns, water hyacinths, kudzu; text only- algae, long-horned beetle; CD – loosestrife; text and CD- fire ants, gypsy moths, exotic chestnut blight fungus caused near extinction of American elm] | Exotic species can wipe out everything – like the [Chinese] tallow that is spreading in Louisiana is an exotic plant and there is also a purple one that spreads in other wetlands, not here  
Fire ants and the zebra mussels are in Louisiana  
The mosquito fish- is good and bad, controls mosquitoes but kills some minnows |
| Pollution | Man-made problems - the worst of all is pollution – air  
Pollution in the wetlands – with pesticides, sediments, sewage – is a problem in California |
| Humans- adding more | Population growth causes habitat destruction and displaces lemurs in Madagascar. Consequently, there are 20 endangered species of trees.  
When we did the maps we looked at population density and deforestation  
Population – as we need more and more space for more and more people, we are cutting down forests, so there is less forest and plant diversity declines |
<table>
<thead>
<tr>
<th><strong>Overharvesting</strong> (text)</th>
<th>The dodos – are extinct, so there are some plants that now don’t have the seed dispersed</th>
</tr>
</thead>
<tbody>
<tr>
<td>- caused extinction of dodo bird and giant tortoises in the island of Mauritius. Tambalacoque tree has no seed dispersers now. Monkeys, deer, tapir in Mexico, with less seed dispersers’ plants are endangered.</td>
<td>+, T</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>___________ are consequences of the loss of species diversity due to threats</th>
<th>Exotic species can wipe out everything – like the [Chinese] tallow that is spreading in Louisiana, the fire ants can affect crops species like corn, and soybeans [deforestation] destroy important species that can be cure for AIDS or cancer, like the yew tree, or even important species for Louisiana Many species will loose their shelter or habitat if wetlands are gone –many plants affected by the purple invasive one [loosestrife-by description]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+, L, CD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How species are interdependent</th>
<th>How flowering plants have different interactions with animals, like insects or birds. They can carry pollen or seeds. The survival of species depends on the interactions for all forms of life. When birds disappear, the seeds are not eaten, the trees can go extinct too</th>
</tr>
</thead>
<tbody>
<tr>
<td>___________ are examples of complex interactions in diverse ecosystems. (pollination, seed dispersal-all, examples may vary according to source) Complex interactions are disrupted in threatened ecosystems.</td>
<td>+</td>
</tr>
</tbody>
</table>

(Table continued)
| Don’t understand this very well. | Biocomplexity (for the purpose of this course) is the integration of all different areas/aspects that affect the study and understanding of biodiversity – including social, economical, geographical, chemical, genetics, ecological aspects explored throughout this learning experience. | How complex biodiversity is. Like there is the tree of life on one side, all the taxonomical categories. But you also have all the human needs, and the problems or threats of diversity. All in life is affected by multiple interactions | + |

*Note.* mc+, an incorrect proposition changed correctly; +, from none, vague, or no examples to correct and/or more specific; mc0, an incorrect proposition that remained incorrect; 0, proposition remained correct, or an incorrect was lost; mc- a correct proposition changed to incorrect; mc an incorrect proposition changed correctly but vague or incomplete or changed from none or vague to incorrect; -, an correct proposition changed to none, vague, or correct proposition but not adequate to the instruction. For basic characteristics if not noted in the instruction column, it was verified if coming from the CD-ROM, and noted as such when indeed it was. In this case, the information in the CD-ROM was too extensive to include possible answers under the instruction column.
APPENDIX M

LESSON PLAN AND OBJECTIVES FOR LESSON ONE

Lesson 1: Lesson Plan & Lecture Notes

Time:
Pre-treatment activities should take one class period.
Lecture chapter 18 should take approximately one to one and a half class periods, depending on discussion and questions.
Activities #1 and #2 should take one and a half to two class periods. These might be started when lecture is over, time permitting and as long as both sections are started on the same day.

Research Plan:
- Assign each section to an instructional approach: treatment (textbook + CEB CD-ROM) and comparison (Textbook only).
- Administer pre-treatment concept map and survey. All students have been previously introduced to the basics of concept mapping in this course. They have created group concept maps and have completed “fill-in-the-box” concept maps.
- Do purposeful selection of participants. Inform classes that the activities they will be conducting in class as well as all assessment activities will be part of a research in science education. If students in the course do not want their work to be part of the research data, they need to write a “NO” by their names in the activities. Their course grade will not be affected by that, it will if they do not complete the activities at all as they are part of the points for the course.
- Invite selected participants to be part of the “case studies”. They have the option to discontinue their participation at any time.
- Remind selected participants to schedule appointment with me to conduct interview #1.

Lecture textbook chapter 18 – Seeking order amidst diversity

> Objectives:
* Recognize how taxonomy and systematics are interdependent
* Recognize classification of organisms can provide information about benefits provided by organisms that are taxonomically related
* Recognize hierarchy of classification
* Name the different domains and kingdoms of life and the basic characteristics of organisms in these categories
* Interpret the meaning of the tree of life image in terms of evolution and diversity of life
* Identify “numbers of species” as a definition for biodiversity
> **Concepts:**
(Students are expected to gain familiarity or proficiency with these concepts after completing Lesson 1, including chapter 18 and the lectures).

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiosperms</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>Bryophytes</td>
<td>Endangered species</td>
</tr>
<tr>
<td>Gymnosperms</td>
<td>habitat destruction</td>
</tr>
<tr>
<td>Rain forest</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution</td>
<td>Family</td>
</tr>
<tr>
<td>Genus</td>
<td>Kingdom</td>
</tr>
<tr>
<td>Order</td>
<td>Phylum</td>
</tr>
<tr>
<td>species (number of)</td>
<td>Systematics</td>
</tr>
</tbody>
</table>

> **Lecture Notes:**
- Remind students at the start of the class that they will be quizzed on this material (refer to course schedule).

- Both groups will be exposed to power point lecture on chapter 18. Partially completed lecture notes are provided to the students for them to fill out during lecture.

- Additional information (not in the textbook) has been added in lecture as examples. (see instructor version of notes).

- Lecture notes also include some information (as review) from chapters already covered in class.

- Students will fill out kingdoms’ table in notes interactively during class discussion.

- **CD treatment section:** Announce in class- Next class will be held in computer lab

> **Activities:**
- Textbook group will complete worksheets in class. CD-ROM section will work on computer lab.

- Depending on progress of lecture, may start activities after lecture is over. Start activities on both sections on the same day.

> **Quiz:**
- Assessment day will follow completion of activities.

- Remind selected participants to schedule appointment with me to conduct interview #2 post quiz.

> **Interviews:**
- Selected participants will participate in the first interview prior to lectures/activities. A second interview will be conducted post-treatment (lecture and textbook-based vs. CD-ROM-based worksheets). Selected participants will take part in concept map co-construction.
Activity 1 - Textbook only

Activity 1 - textbook

Tree of Life

1. Ch 18 – Who was Carl Linnaeus?
   Swedish scientist/naturalist who laid the groundwork for the modern classification system.

2. How many species have been discovered?
   1.1 million species named.
   Total number of species up to 100 million.

3. Construct the tree of life. From the figures in pg.7 and the information in ch 18, give two characteristics of each group.
4. Life detectives: Predict which of 4 these groups you think have the most species.

<table>
<thead>
<tr>
<th>Groups with the most species</th>
<th>Portion contributed ( # \text{spp} )</th>
<th>Was the result expected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>100,000</td>
<td>N</td>
</tr>
<tr>
<td>Protista</td>
<td>50,000</td>
<td>N</td>
</tr>
<tr>
<td>Fungi</td>
<td>2,300,000+</td>
<td>N</td>
</tr>
<tr>
<td>Animalia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To complete the table above, then visit chapters 19-22 and for any particular phyla or as a kingdom find out how many species your selected group actually has.

5. How important are the vertebrates in the functioning of ecosystems? (from the ones you selected)

Very important because some vertebrates are food to some organisms.

6. How important are flowering plants?

Very important because they are food and shelter for some organisms.

7. How important are other groups of organisms?

Each organism has an integral part in the ecosystem we all depend on each other.
Activity 1 – CD-ROM + textbook

In the next few weeks you will complete several activities from additional material on different topics of this course.

You will earn points from these activities, therefore your attendance to class is important (remember there are no make ups for in-class activities). In addition, the information obtained from these activities will be part of your material for the quiz.

Activity 1: Conserving Earth’s Biodiversity

Access CEB program
On Main Menu, select Diversity of Life
Listen (read) to Introduction
Select Numbers of Species
Described species

1. What was the contribution of C. Linnaeus?
   Modern System of Taxonomic classification in the 18th century (1.4 million species)

2. How many species have been discovered?
   1.4 million

3. What do we know about majority of species?
   They received only the most rudimentary study – only description of species and given a scientific name

4. Described species activity:

4A. Explorations:

4A.1. Select 4 groups you think have the most species.

4A.2. Then check what portion of the world’s described species do they have?

<table>
<thead>
<tr>
<th>Groups with the most species</th>
<th>Portion contributed</th>
<th>Was the result expected?</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>9,800</td>
<td>.61%</td>
<td>Np - I thought more</td>
</tr>
<tr>
<td>Insects</td>
<td>740,000</td>
<td>94%</td>
<td>Yes</td>
</tr>
<tr>
<td>Roundworms</td>
<td>12,000</td>
<td>1.4%</td>
<td>No</td>
</tr>
<tr>
<td>Fishes</td>
<td>22,000</td>
<td>1.4%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
If plants was not one of your groups in #4A1, 4A2, check for plants

<table>
<thead>
<tr>
<th>Groups with the most species</th>
<th>Portion contributed</th>
<th># spp</th>
<th>%</th>
<th>Was the result expected? Y/ N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering plants</td>
<td>150,000</td>
<td>15%</td>
<td>N</td>
<td>no</td>
</tr>
<tr>
<td>Other plants</td>
<td>215,000</td>
<td>1.7%</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

5. Further thought: Click on the colored box for each of the groups you selected and

5A. How important are the vertebrates in the functioning of ecosystems? (from the ones you selected)

5B. How important are flowering plants?

They are everyday feeding utensils for thousands of species.

5C. How important are other groups of organisms? (If you did not selected any originally, pick one).

Fungi - there are 70,000 species and 4.50% of all described species.
Activity 2: Diversity of Life: Kinds of Organisms

Use information from Ch 18 & 19 to answer the following questions:

1. What kind of cells do organisms in the Archaea bacteria & Eubacteria have?
   Prokaryotic, single cell microbes, that lack organelles such as the nucleus, chloroplasts, and mitochondria.

2. Which are the oldest organisms on Earth?
   Archaea

3. Where can you find Archaea bacteria and Eubacteria?
   Anywhere & Everywhere.

4. Complete the table below:

<table>
<thead>
<tr>
<th>POSITIVE Aspects</th>
<th>Archaea</th>
<th>Eubacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>More closely related to eukaryotes</td>
<td>Rigid cell wall that contains peptidoglycan.</td>
</tr>
<tr>
<td></td>
<td>Coccoliths</td>
<td>Classify groups into 3 kingdoms</td>
</tr>
<tr>
<td>NEGATIVE Aspects</td>
<td>Lack rigid cell wall that contains peptidoglycan.</td>
<td>Lack organelles such as nucleus, chloroplasts, and mitochondria.</td>
</tr>
<tr>
<td></td>
<td>Lack organelles such as nucleus, chloroplasts, and mitochondria.</td>
<td>Prokaryotic taxonomy is also complicated by the difficulty of defining species boundaries in Archaea.</td>
</tr>
</tbody>
</table>

5. What kind of cells organisms in K. Protista have?
   Both eukaryotic & prokaryotic.

6. How do these organisms obtain their nourishment (food, energy)?
   Autotrophs capture solar energy through photosynthesis, protists ingest their food, and parasitic forms can absorb nutrients from their surroundings.

7. Which protist forms part of plankton? Some of the single-celled algae species are collectively known as plankton. Some protozoa form plankton.
8. What is plankton?

According to the species, it can be either unicellular or multinuclear. Single-celled organisms can be divided into many small cells containing 1 to many nuclei.

9. What kind of cells organisms in Kingdom Fungi have?

Microscopic organisms that live in marine or freshwater environments, including zooplankton and plankton.

10. List 3 things about fungi that interested you from the reading:

- Fungi forms no embryos, instead they use spores to propagate. So they can reproduce sexually and asexually.
- Some fungi are saprobic, which digest the bodies of dead organisms. Others are parasitic feeding on living organisms, causing disease. Ugh!
- Nearly 100,000 species of modern fungi have been described. Biologists have only begun to comprehend the diversity of these organisms. At least 1000 additional species are described each year.

Use Ch 20 to answer the questions below.

11. What kind of cells organisms in Kingdom Plantae have?

Diploid cells.

12. List 3 things about plants that interested you from the reading. (Do not go into different categories, we will do that next time)

- The earliest plants are believed to have been similar to today's nonvascular plants, such as mosses.
- Medicines such as taxol, aspirin, stimulants such as nicotine and caffeine, and spicy flavors such as mustard and peppermint are all derived from angiosperm plants.
- Conifers spread widely as Earth became drier during the Permian Period (286 to 245 million years ago), which followed the Carboniferous period.

Use Ch 22 to answer questions below.

13. What kind of cells organisms in Kingdom Animalia have?

Most multicellular, but some cells lack a cell wall.
Activity 2: Conserving Earth's Biodiversity

Access CEB program
On Main Menu, select Diversity of Life
Select Tree of Life
Read Introduction

Select Archaebacteria & Eubacteria

1. What kind of cells do organisms in this group have?
   Prokaryotic & Eukaryotic

2. Which are the oldest organisms on Earth?
   Archaea

3. Where can you find Archaebacteria and Eubacteria?
   Ex: hot spring, volcanoes, on Earth (ex: humans)

4. Complete the table below:

<table>
<thead>
<tr>
<th></th>
<th>Archaebacteria</th>
<th>Eubacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POSITIVE</strong></td>
<td>They can tell or show the effects of extreme environments</td>
<td>Bacteria helps make medicines to fight infectious diseases</td>
</tr>
<tr>
<td></td>
<td>Cannot get used to</td>
<td>Can fix gases into usable forms by plants</td>
</tr>
<tr>
<td><strong>NEGATIVE</strong></td>
<td>They function in extreme conditions &amp; most harmful</td>
<td>Causes diseases such as pneumonia &amp; bubonic plague</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also create toxins such as botulism</td>
</tr>
</tbody>
</table>

Select K. Protista

5. What kind of cells does this organism have?
   Eukaryotic cells
APPENDIX O

DESCRIBED SPECIES ACTIVITY

(From Conserving Earth’s Biodiversity CD-ROM, Perlman & Wilson, 2002)
I. Multiple Choice: Please select the best answer for the questions below. Use the scantron to enter your answer. Questions with the ☺ will be answered using the projected image.

Use the bank of words below to answer questions 1 and 2
a. phylogeny b. systematics c. taxonomy d. histology

1. The science that studies diversity by reconstructing the evolutionary history or relatedness of organisms

2. Science that deals with naming of organisms and placing them in hierarchical categories

3. The evidence that the HIV virus originated from non-human primates is based on the most powerful way of inferring evolutionary relationships. Select the type of evidence:
   a. historical studies of primitive African societies
   b. comparing DNA base sequences among different viruses
   c. medical histories of humans
   d. medical histories of primates in captivity

4. This biologist is acknowledged as the father of taxonomy. He contributed the binomial system of classification still in use today
   a. Charles Darwin
   b. Robert H. Whittaker
   c. Aristotle
   d. Carl Linnaeus

5. How did Darwin's evolutionary theory change the significance of the taxonomic categories of organisms?
   a. Darwin's theory of natural selection has had no affect on taxonomy.
   b. Darwin described the Kingdoms that we use today which include all organisms.
   c. The relationships between organisms became completely known and many species were renamed.
   d. Taxonomic categories are now considered to reflect the evolutionary relationships of organisms
   e. Taxonomists no longer consider anatomical similarity in classifying organisms.
6. According to the taxonomic principles, the diversity of life is organized into hierarchical categories of organisms. Which of the following sequences represents the taxonomic categories listed from the **most specific** to the **most general/most inclusive**: 

a. domain - kingdom – phylum – family – good – students - class – order  
b. species – genus – family – order- class- phylum- kingdom- domain  
c. genus – domain – family – species – order – kingdom – phylum – class  

© Use the figures projected on the screen to help you answer questions 7-11

7. A modern system of classification gives the category name "Domain" to which of these?  

a. Protista  
b. Eukarya  
c. Plants  
d. Fungi  
e. all of the above

8. Which of these groups includes all organisms with eukaryotic cells, which can be unicellular or multicellular and get their nutrients through absorption  

a. Plants  
b. Fungi  
c. Bacteria

9. Which of these groups includes organisms that have prokaryotic cells and are single cells  

a. Plants  
b. Fungi  
c. Animals  
d. Archaea  
e. More than one is correct

10. Which Kingdom contains only multicellular, eukaryotic organisms that are photosynthetic?  

a. Protista  
b. Bacteria  
c. Plants  
d. Fungi

11. Of the pairs listed below, choose the one where the organisms will have the **closest phylogeny** or evolutionary history.  

a. mushroom - lizard  
b. Oak tree – *E. coli*  
c. cow – oak tree  
d. oak tree – mushroom

12. Two examples of phyla/divisions included in the plant kingdom are  

a. Bryophyta and Basidiomycota  
b. Chordata and Anthophyta  
c. Bryophyta and Gymnosperms  
d. Basidiomycota and Chordata
13. Scientific names are
   a. given to some organisms, only the important ones
   b. all written in French or English
   c. unique to the organism

14. Which of the following options is a correct way to write the scientific name the live oaks?
   a. Quercus virginiana
   b. Quercus virginiana
   c. Quercus virginiana

15. The scientific name for the eastern, western, and mountain bluebirds can be written as
   *S. sialis*, *S. mexicana*, and *S. currocoides*. Which of the following statements is true about these birds?
   a. They all are the same species
   b. They all belong to the same genus
   c. They are the same organism but look different
   b. All of the above

16. Systematics is considered a very active field in Biology. This can be partially explained by the “unsettled taxonomy”. Some points of discussion include:
   a. Kingdom monera was split into two domains based on profound differences in ribosomal RNA of bacteria
   b. Several Kingdoms can be identified in the domains Archaea and Bacteria
   c. Several kingdoms can be identified separating the former kingdom protista
   d. All of the above

17. The "phylogenetic species concept" that defines a species as "the smallest diagnosable group that contains all the descendants of a single common ancestor" is valid for
   a. sexual reproducing species
   b. asexual reproducing species
   c. species that do not reproduce
   d. both a and b are correct
   e. all are correct

18. Biodiversity is
   a. The living and non-living world
   b. The amount of organisms
   c. The endangered organisms
   d. The total range of species diversity, the ‘tapestry of life’

19. More than 2/3 of the world's species of eukaryotes are believed to inhabit
______________, which is an ecosystem that covers about 6% of the Earth.

a. ocean  
b. fresh water  
c. temperate deciduous forest  
d. temperate rain forest  
e. tropical rain forest

20. How many different species have been described?

a. 14,000  
b. 30 million  
c. about 1.4 to 1.6 million

21. The estimated (possible) number of species is ________________ than the described (known) species in this planet

a. about the same for some organism, but much larger for others  
b. much larger  
c. smaller  
d. the same

22. Which group of organism accounts for the most species described (known to exist) to present?

a. Protist  
b. Plants  
c. Fungi  
d. Animals  
e. Prokaryotes

23. Which of these factors accounts for loss of species diversity in different ecosystems around the world, i.e. tropical rain forest

a. rainfall  
b. earthquakes  
c. deforestation  
d. fires

24. Which of these habitats promises to be a source of many new species not discovered yet?

a. desserts  
b. deep-sea floor  
c. artic zone  
d. temperate forest

25. When a forest is cut down plant species, as well as animals like the black-faced lion tamarin, may become threatened and eventually may be lost forever. When a species is lost forever it is said it became

a. extinct  
b. persistent  
c. exotic  
d. endangered  
e. extant
Concept Map # 1 – Caleb
Lower portion of Caleb’s concept map #2
APPENDIX R
LESSON PLAN AND OBJECTIVES FOR LESSON TWO

Lesson 2: Lesson Plan and Lecture Notes

Time:
Reading essay and discussion should take half class period.
CD-ROM activity #3, worksheets, and essay should take one to one and a half class periods.

Research plan:
- Read and discuss essay to make students aware of different levels of biodiversity and the importance of biodiversity.
- Expose students to worksheet and CD-ROM activity #3 (according to section)
- Introduce students to the “Golden List of Species”
- Have students write essay
- Conduct third interview with participants

Lecture:
> Objectives:
* Recognize the three different levels of biodiversity: species, genetics, ecosystem
* Be able to give examples of each level of biodiversity
* Discuss reasons to conserve biodiversity
* Identify causes and consequences of loss of biodiversity

> Concepts:

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiosperms (flowering)</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>(bio) complexity</td>
<td>Ecosystems</td>
</tr>
<tr>
<td>threats</td>
<td>Evolution</td>
</tr>
<tr>
<td>food</td>
<td>Endangered species</td>
</tr>
<tr>
<td>pollination</td>
<td>genetics</td>
</tr>
<tr>
<td>Wetlands</td>
<td>medicines</td>
</tr>
<tr>
<td>habitat destruction</td>
<td>species (number of)</td>
</tr>
<tr>
<td>Rain forest</td>
<td>Systematics</td>
</tr>
</tbody>
</table>

> Lecture Notes:
- Both groups will read essay in class
- A discussion will follow
  * What is biodiversity?
    ⇒ “complexity” is introduced (only time) as part of the definition in this essay.
    Ask students to pay attention to this word as it will become important as they are exposed to the different lessons and build their understanding

* Which “factors” contribute to diversity of life?
* Where is biodiversity highest? Can you identify a problem going on here?

* What is the meaning of “one rivet too many”? What happens when ecosystems, like rainforests, are affected? Endangered species → extinction

* What are examples of benefits we get from some species found in TRF?

* Can you give examples of other ecosystems close to “home”? (wetlands, pine forests)

* Can you give examples of benefits we get from ecosystems close to home?

- Distribute “Golden List of Species” sheet. Instruct students to use this to keep a record of the plant species they encounter that capture their attention for a reason.

- Depending on time left, start activity. Both sections need to start on same day. After students finish worksheet activities, bring them outside. Students will be encouraged to think about the benefits they receive from biodiversity using as background their local diversity and common ecosystems in Louisiana. They will write an essay on their reasons for conservation.

- It may take longer for CD-ROM group to complete the worksheets. If after second class period students need additional time to complete essay, then do as homework.

> Activities:

- CD section: Will follow essay discussion by completing worksheets for activity #3 using the CEB program (“What is Biodiversity” and “Reasons for Conservation”).

- Textbook section: Students will complete textbook-based worksheet.

- Use answer sheets

- Have both groups complete essay: What are my reasons for conserving biodiversity?

- Essay will be revisited at the end of the study lesson (do not let students know).

> Interviews:

- Schedule interview #3 with research participants.
APPENDIX S
ACTIVITIES FOR LESSON TWO

Lesson 2: Textbook Group Activity Three

Activity #3

I. **Important**: Please keep a list of all plant species that capture your interest as you complete the lessons on plant biodiversity. (Golden List of Species, yellow sheet).

II. Essay: Read Earth Watch Essay: Why Preserve Biodiversity? pg. 15

III. Go outside to start completing the next activity: Write essay

**Essay: What are my reasons for conserving biodiversity?**
Lesson 2: CD-ROM Group Activity Three

Activity #3

Access the CEB program
Access Introduction

I. Important: Please keep a list of all plant species that you are introduced to throughout the program as we complete the different activities (Yellow pages).

II. Complete the following:

I.3 What is biodiversity?
   a. Listen/read introduction by E.O. Wilson
   b. Answer the following question

In your own words explain what biodiversity means? What are the levels of biodiversity?
(Use the answer sheets. Clearly identify the question)

I.4. Reasons for Conservation
A. Ecosystems: Click on the following sections:
   a. Forest services
   b. pollination and pest control
   c. wetlands and freshwater ecosystems

   If you have additional time later (after finishing all the work) you can go back to the other two sections

   * For each section write 2 things that you learned or impacted you the most after reading the section

   Use the answer sheets. (Clearly identify the question)

B. Species as resources Click on the following sections:
   a. Natural fibers
   b. Natural chemicals
   c. Medicinal plants
   d. Crop species

   If you have additional time later (after finishing all the work) you can go back to the other two sections

   For each section write 2 things that you learned or impacted you the most after reading the section

   Use the answer sheets. (Clearly identify the question)

C. Genes as resources Click on the following sections:
   a. Variation in wild species
b. Disease resistance in crops  
c. Chemical variation in medicinal plants  
d. Food varieties

If you have additional time later (after finishing all the work) you can go back to the other two sections

For each section write 2 things that you learned or impacted you the most after reading the section

Use the answer sheets. (Clearly identify the question)

III. Essay

Essay: What are my reasons for conserving biodiversity?
Lesson 3: Lesson Plan & Lecture Notes

Time:
Lecture chapter 21 should take approximately two class periods, due to demos and interaction with students. Activities #4 should take one and a half to two class periods. These might be started as soon lecture is over, as long as both sections are started on the same day. One class period will be used for quiz on chapter 21.

Research Plan:
- Lecture on chapter 21
- Students in both sections (CD-ROM and Textbook) will complete a worksheet based on textbook
- Students in textbook course will complete an additional textbook-based worksheet, while students in the CD-ROM section will complete a CD-ROM-based worksheet.
- A quiz based on chapter 21 will follow the lesson.
- Student participants will be interview later, with concept map co-construction. Concept map list of words includes words that students were exposed in lesson #2 as well.

Lecture textbook chapter 21 – The Plant Kingdom

> Objectives:
* Identify the basic and unique characteristics of the plant kingdom
* Recognize the evolutionary origin of plants
* Explain how the challenges met by plants as they invaded the terrestrial environment resulted in increasing complexity of the organisms
* List the 4 major phyla of the plant kingdom and their characteristics
* Identify flowering plants as the most diverse group
* Recognize the diversity of reproductive structures
* Describe the multiple roles plants play in ecosystems (nutrient cycling, energy producers, shelter, food)
* Identify the benefits we obtain form plants (food, medicines, shelter, fiber, aesthetics, etc.)

> Concepts:

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deforestation</td>
<td>Angiosperms</td>
</tr>
<tr>
<td>Genetics threats</td>
<td>deforestation</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Endangered species</td>
</tr>
<tr>
<td>Food (from plants)</td>
<td>Family</td>
</tr>
<tr>
<td>monocots</td>
<td>Genus</td>
</tr>
<tr>
<td></td>
<td>habitat destruction</td>
</tr>
<tr>
<td></td>
<td>medicines</td>
</tr>
<tr>
<td></td>
<td>Plant biodiversity</td>
</tr>
<tr>
<td></td>
<td>Bryophytes</td>
</tr>
<tr>
<td></td>
<td>Ecosystems</td>
</tr>
<tr>
<td></td>
<td>Evolution</td>
</tr>
<tr>
<td></td>
<td>Genetics</td>
</tr>
<tr>
<td></td>
<td>Gymnosperms</td>
</tr>
<tr>
<td></td>
<td>Kingdom</td>
</tr>
<tr>
<td></td>
<td>Mosses</td>
</tr>
<tr>
<td></td>
<td>Pollination</td>
</tr>
<tr>
<td></td>
<td>Rainforest</td>
</tr>
<tr>
<td></td>
<td>seeds</td>
</tr>
<tr>
<td></td>
<td>species</td>
</tr>
<tr>
<td></td>
<td>systematics</td>
</tr>
</tbody>
</table>
> Lecture Notes:
- Both groups will be exposed to power point lecture on chapter 21. Partially completed lecture notes are provided to the students for them to fill out during lecture.

  * Notes include some figures that are not in the textbook. Most of these refer to concepts/ examples mentioned in the textbook. Others are part of the discussion and information added to make content locally relevant to the students (LA examples).

- Start class with reading/discussing case study (p.409) – ‘Hunting for Medical Treasures”. Point out to the students that even though the concept of “bioprospecting” is new, they were already exposed to the idea of “plants as source of medicines” in the essay in lesson 2.

- Then present another point of view (larger scale) with the essay (p.486)- “Plants help regulate the distribution of water”

- Use both essays to connect to previous information in this course: evolution & systematics/taxonomy – role of genetic variation in medicines (US vs. European variety of Taxol). Also discuss consequences of deforestation in temperate forest & tropical rain forest – different scales, but equally important

  - Plants as resources at different levels
  - Importance of genetics
  - Consequences of the loss of species in tropical and temperate forests

Remind them these are services or goods we obtain from the diversity of the plant kingdom. Stress this point at the end of lecture again with the secondary chemicals.

- Throughout discussion of the different phyla and examples I will provide real or preserved specimens, and try to establish connections to the activities and experiences of daily life.

- Once lecture is over, announce to CD-ROM group next class will be held in computer lab

- Remind selected participants to schedule appointment with me to conduct interview #4 post quiz

> Activities:
- Both groups will complete worksheets in class. One textbook-based worksheet is the same for both groups.

- Both groups will complete a second worksheet either textbook-based or CD-ROM-based.
- Depending on progress of lecture, may start activities after lecture is over. Start
activities on both sections on the same day.

> **Quiz:**
- Assessment day will follow completion of activities.

> **Interviews:**
- This interview will include concept map co-construction, using concepts that were presented in this lesson as well as some concepts from previous lessons.
APPENDIX U
ACTIVITIES FOR LESSON THREE

Textbook Group Activity # 4 – Plant Kingdom

Answer the following questions using your textbook. You will use your textbook to find more information about plant diversity. You can also use any of the additional references available in the classroom.

1. In your own words, list some of the unique characteristics of the plant kingdom.

2. Check out pg. 490, fig. 23.26. What kind of plant is the one shown in the picture? (to which major group it belongs)

3. Do you think this plant is a parasite for the tree? Explain your answer.

4. Which LA plant discussed in lecture has the same mode of growth of the plant in the figure?

5. How are Vascular Plants (Tracheophytes) unique?

6. One important characteristic of all vascular plants is:

7. How are vascular plants, Gymnosperms, and Angiosperms related?

8. How are Gymnosperms unique?

9. One important characteristic of all Gymnosperms plants is:

10. Mention one unique characteristic of conifers. What are some important characteristics of the life cycle of pines?

11. What are some important characteristics of the flowering plants (Angiosperms)?

12. Are all flowering plants alike? Using your textbook and additional references explore characteristics and what grabs your attention to different plants. Provide some examples to support your answer.
1. In your own words, list some of the unique characteristics of the plant kingdom listed in this section.

2. What kind of plant is the epiphytic bromeliad growing on a tropical tree?

3. Do you think this plant is a parasite for the tree? Explain your answer.

4. To which LA plant is the bromeliad related? (you were expose to this info in class).

II. Select and read, Vascular Plants
   1. How is this group unique?

   2. One important characteristic of all plants in this group is:

   3. How is this group related to Gymnosperms and Angiosperms?

III. Select Gymnosperms
   1. How is this group unique?

   2. One important characteristic of all plants in this group is:

IV. Select Pinacea

   1. How is this group unique?

   2. One important characteristic of all plants in this group is:

V. Select Dicotyledons.

Choose 3 Families from here, and write the most important characteristics and why it grabbed your interest.

VI. Select Monocotyledons.

Choose 1 family from here, and write the most important characteristics and why it grabbed your interest
APPENDIX V

CEB’S PLANT KINGDOM

(From Conserving Earth’s Biodiversity CD-ROM, Perlman & Wilson, 2002)

**Plantae**

- Plants are multicellular eukaryotic organisms that develop from embryos and derive their energy from photosynthesis.

- The plants have adapted to terrestrial life, although some have returned to aquatic environments.

- Plants are largely responsible for the transformation of the sun's energy into food and fuels, and for the production of most of the oxygen in our atmosphere.

- This kingdom is divided into non-vascular plants and vascular plants.

- Non-vascular plants, or bryophytes, do not have rigid conductive tissues and require moist environments for reproduction; they comprise three phyla, the mosses (Bryophyta), liverworts (Hepatophyta), and hornworts (Anthocerotophyta).
APPENDIX W

QUIZ CHAPTER 21

Multiple Choice: Select the best answer. Use the scantron to answer your test. You will use projected images to help you answer questions with a ☺ symbol. If you need one of these question repeated, please raise your hand and let the instructor know.

1. Members of the plant kingdom are:
   a. Photosynthetic
   b. Eukaryotic & Multicellular
   c. store food as starch or oil
   d. All of the above
   e. All except c

2. Terrestrial plants are believed to have evolved from:
   a. Bryophytes
   b. Green algae
   c. Brown algae
   d. Blue-green bacteria

3. With respect to plant reproduction, there has been an evolutionary trend toward...
   a. gametophyte dominance
   b. increased need of water
   c. sporophyte dominance
   d. greater spore production

4. In the typical reproductive cycle of plants with alternation of generations, the gametophyte produces
   a. haploid spores
   b. diploid gametes
   c. diploid embryo
   d. haploid eggs and sperms

5. Which of these represents the correct match between a challenge (need) plants met in their transition to the terrestrial environment and the evolutionary adaptation that solved that need?
   a. More CO₂ availability: waxy cuticle
   b. humid environment: pollen
   c. anchor: rhizoids and roots
   d. support: flowers and fruits
6. Indicate the time (step) that marks the “presence of seeds” in the evolution of the plant kingdom

A.    B.    C.

7. Bryophytes are very small plants that depend on simple structures called __________, to anchor the plant and absorb water.

a. Roots
b. Mycorrhizae
c. Rhizomes
d. Tracheophytes
e. Rhizoids

Diversity in the plant kingdom: Use the figures to match questions 8-11

8. A seedless vascular plant, restricted to humid environments. In colonial times it was used to scour pots & pans

9. An unusual gymnosperm, wind pollinated, has naked seeds, and claimed to improve memory

10. Represents most evolved (pinnacle) group of plants with about 230,000 species.

11. Non vascular plant, no seeds

12. Which of the following weather conditions would you expect to have the greatest NEGATIVE IMPACT on sexual reproduction of ferns and mosses?

   a. excessively wet and raining conditions
   b. above average temperatures for several days
   c. excessively dry period for several days
   d. the shade of a forest

13. Pollen evolved in response to...

   a. an increase in pollinators
   b. lack of spores
   c. dry land environments
   d. moist environments rhizoids
14. What is/are advantages to producing broad leaves compared to narrow needle-like leaves?
   a. increased water loss
   b. increases gas exchange
   c. increases surface area for light capture

15. The bald cypress found in LA’s wetlands is an unusual conifer because
   a. are not evergreen
   b. have flowers
   c. do not produce seeds
   d. have broad leaves

16. Over evolutionary time vascular plants outgrew the non-vascular ones, thanks to the presence of water and nutrient conducting vessels. These vessels also provide rigid support because they have __________ in their cell walls.
   a. chitin  b. lignin  c. starch

17. Which of the plants has vascular tissue, dominant sporophyte, but does not produce seeds. Plants in this same group are the source of the coal we burn today.

18. How may a pine seed or a bean seed improve the chances of survival of a young plant?
   a. Seeds retain food reserve for embryo
   b. Seeds become dry very easily
   c. all are easily dispersed by wind

19. Many different conifers can survive in cold, dry habitats because they
   a. have leaves with no cuticle
   b. loose leaves in the late Fall
   c. have “anti-freeze” in their resin and photosynthesize year round

20. According to one of the essays read in class, loss of vascular plants in tropical rain forests due to deforestation could affect transpiration and therefore
   a. affect rainfall patterns and distribution of water
   b. change the kinds of plants establishing in the forest
   c. have an impact in global warming
   d. all of the above

21. Pines have male and female ________ and are primarily ________ pollinated.
22. The conifer forests of the Pacific Northwest is a threatened ecosystem, however in this ecosystem you can find the Pacific yew, which is an important source of

a. oil
b. cancer treatment drug Taxol
c. wood
d. pollen

23. Flowers play an important role contributing to the outstanding diversity of the angiosperms. Which of the following is true about flowers?

a. produce gametes
b. contains ovaries that produce fruits
c. attract pollinators
d. all are true

24. The broad leaves in angiosperms

a. help in seed dispersal
b. provide protection for the embryo
c. have “antifreeze”
d. are source of important chemicals for food or medicine

25. Which of the alternatives below best describes the diversity represented by real mosses, ferns, pine trees, sequoias, bamboos, and duckweeds?

a. reproductive diversity: capsules, sporangia, cones, and fruits
b. diversity in the flowers they produce
c. diversity in size
d. diversity in presence of cell wall (present/absent)
e. a and c are correct
Most figures are from chapter 21, Audesirk, Audesirk & Byers (2002) and were used only for instructional and assessment purposes for students using this textbook.
Lesson 5: Lesson Plan and Lecture Notes

Time:
This lesson will use two class periods. About half of the first class period will be used for lecturing on selected sections of chapter 41 and additional local examples (wetlands and long leaf pine savannas). Will follow lecture with discussion of essay. The second class period will be used for worksheet activities (activity #5).

Research plan:
- Lecture based on ecosystem diversity at the global and local scales
- Read and discuss essay to make students aware of how genetics and ecosystems play a role in plant biodiversity
- Expose students to worksheet and CD-ROM activity #5 (according to section)

Lecture chapter 41 - Earth’s Diverse Ecosystems

> Objectives:
* Recognizes biodiversity at the ecosystem level
* Recognize global and local ecosystem diversity
* Recognize ecosystems with higher species diversity, and be able to identify where they are located.
* Recognize deforestation as a threat to biodiversity
* Identify exotic species as a local threat to some Louisiana ecosystems
* Identify the relation between endangered ecosystems and hot spots, and geographical location of these
* Identify role of diverse ecosystems as home for wild species populations
* Identify wild species populations as a source of genetic variation for crop and medicinal plants species
* Review role of plants as source of food & medicine
* Review causes and consequences of loss of habitat.

> Concepts:
Familiarity Proficiency
Exotic species Biodiversity deforestation Ecosystems
Hot spots Endangered species flowering plants food (crops, plants)
genetics habitat destruction medicines
Plant biodiversity plants Rain forest
species (number of) threats Wetlands

> Lecture Notes:
- Remind students at the start of the class that they will be quizzed on this material and the concepts presented throughout the different activities so far. After this lesson we will have one more activity.
- Both groups will be exposed to power point lecture on sections of chapter 41 to establish relationship between biomes and ecosystems and give a global perspective of biome diversity. Notes will be provided.

- Additional information (not in the textbook) has been added in lecture as examples of local ecosystem diversity.

- Both groups will read essay *Crops, Livestock, and wild genes* in class. A discussion will follow:
  
  - What does this essay adds to our current knowledge of biodiversity?
  - We studied earlier genetic variation in relation to evolution. How is this concept important in the area of plant biodiversity?
  - Explain the role of plant biodiversity as “important in crop development in the past and hold a promise for the future”
  - What problem are we facing with the reserves of wild genes? What is the root of that problem?
  - Which ecosystems seem to be the ones most affected at a global scale?
  - Do or could we experience the same situation at the local scale?

- Announce they will complete worksheet activities in the next class (orange copies).

> Activities:

- CD section: complete worksheets for activity #5 using the CEB program (Global patterns).

- Textbook section: Students will complete textbook-based worksheet.

> Interviews:

- No interviews will be conducted after activity 5.
APPENDIX Z

ACTIVITIES FOR LESSON FIVE

Textbook group: Activity # 5 – Global Biodiversity

1. List one or two things that you may know about the following

   a. hot spots

   b. exotic invaders

2. How do you think a & b above affect plant diversity?

Instructions
Use your chapter 41 from your textbook to answer the questions below.

Questions
1. Read the definition of biodiversity in pg. 864. Explain what you consider are important aspect of this definition.

2. Explain how ecosystems and biomes are related. How many different biomes are in the world?

3. Using the map in pg. 863, please identify the type of biome found in Louisiana. Select another place of your interest and identify the type of biome(s) for it.

<table>
<thead>
<tr>
<th>Place</th>
<th>Type of biome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisiana</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>

4. Work this section with a partner:

   a. Read the information provided for the different types of biomes (pgs. 864-875). Complete the table below with information about numbers of species (were provided – low (L), medium (M), or high (H)). Provide an example of services or benefits obtained from that type of biome. Provide how the biome is affected. Summarize in your own words.
<table>
<thead>
<tr>
<th>Biome</th>
<th>Diversity (L, M, H)</th>
<th>Services</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical rain forest (TRF)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savanna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate deciduous forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dessert</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiga</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tundra</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Using the map in pg. 863, indicate which region of the world would you expect to find the highest species diversity. Explain why you think different regions have differences in species diversity.

c. Select an area (a biome, region of the world) of high species diversity and an area of low species diversity. Can you give an example of a kind of plant that may be there?

d. Looking at other regions of the world, do you think biome a good predictor for plant species diversity?

e. Why do you think biomes are named after plant types and not on other organisms?

5. If deforestation is a problem in the TRF, then what do you think will happen to species diversity in this type of biome? Is deforestation a problem in any other ecosystems in the world?
6. As a class you shared the definition of “hot spots” and a consensus definition was discussed with the instructor. Based on the information you found in question 4 and your answer for question 5, where would you expect to find “hot spots”.

7. For the following plants, give how scientists have modified them:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Genetic modification/purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td></td>
</tr>
<tr>
<td>Strawberries</td>
<td></td>
</tr>
<tr>
<td>Blueberries</td>
<td></td>
</tr>
<tr>
<td>Meadowfoam</td>
<td></td>
</tr>
</tbody>
</table>

a. Where do the genes to modify these plants come from?

b. What do you think could happen if the wild species related to these plants went extinct?

c. How do you think genetically modified plants may affect the future of food plants?
I. 1. List one or two things that you may know about the following
   a. hot spots
   c. exotic invaders

1. How do you think a & b above affect plant diversity?

Instructions
- Access CEB program and select Global Biodiversity from the main menu
- Listen to Introduction
- Complete activities and answer questions as indicated below.

Questions
1. Select Global Patterns, listen to Introduction. Explain what you consider are important aspect of biodiversity.

2. Select Global Patterns – Biomes - Overview.
   a. Explain how are ecosystems and biomes related? How many different biomes are in the world?

   b. Interpret the map for North America (click on zoom in/out, then on NA). When you zoom in, you can select to see country names & borders. Identify, which is (are) Louisiana’s type of biome(s). Select another place of your interest and identify the type of biome(s) for it. Zoom out when done.

<table>
<thead>
<tr>
<th>Place</th>
<th>Type of biome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisiana</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>
3. Work this section with a partner:
Click on All Other Maps and select Plant Species Diversity. Read Overview. Interpret the
global map:

a. Select 4 areas from the ones listed in the table below, indicate with an X the range of vascular
species diversity. (Check regions projected). Use the last column to indicate if the region has
areas of low species diversity near areas of high species diversity (Y/N).

<table>
<thead>
<tr>
<th>Region</th>
<th>Low &lt;500</th>
<th>Med-L 500-1500</th>
<th>Med-H 1500-3000</th>
<th>High &gt;3000</th>
<th>Y or N</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central America</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South America</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Europe</td>
<td></td>
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<tr>
<td>Asia</td>
<td></td>
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<tr>
<td>SE Asia</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia and Islands</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

b. Discuss with your partner: Are there any areas of the map that surprise you (had more or less
than expected plant species) – was the area the same or different for each of you? Explain why
do you think different regions have differences in species diversity.

c. Select an area of high species diversity. Click on Compare Maps and select the region of
interest. Select “Plant Species Diversity” map and “Biomes” map. What kind of biome(s) is
present in the area of high species diversity you selected? Can you give an example of a types of
plants (i.e. broad leaf, grass…) that may be there?

d. Locate the same biome somewhere else in the world or select another type of biome. Predict
and record if that region of the world will have low, medium, or high species
diversity.______________________.

e. Check the Plant Species Diversity map to see if your prediction was correct. (circle one). __Y
N close_

f. Do you think biome is a good predictor for plant species diversity?__________

Why do you think biomes are named after plant types and not on other organisms?
5. Work this section with a partner:
From “map comparisons” go back twice. Click on All Other Maps and select Centers of Food Plant Diversity.

a. Read Overview. Of the estimated 273,000 plant species, how many provide 90% of the human food intake? ___________

b. Which 4 plants contribute the highest caloric intake for the world.

. 

c. How many families are represented in the top 4 plants? ___________

d. Of these, the “one” you like or consume the most is _________________ which has its center of origin in ________________.

e. Something I learned about this plant is:

f. Based on the essay read in class, what do you think is the importance of the “centers of food plants and genetic diversity” for the past, present, and future of food plants in general – or the one you chose in specific? Briefly explain.

g. So, if all the wild relatives of this plant went extinct what do you think will happen?

h. Go back to Explorations. Find the name and place of origin of the 1 plants in the picture. Select another ONE of the 11 centers of food plant diversity where foods that you like originated. Fill the information in the table.

<table>
<thead>
<tr>
<th>This plant… (give common name)</th>
<th>In this family…</th>
<th>Originally comes from….</th>
<th>I also learned …</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Click on All Other Maps and select Conservation Hot Spots. Read Overview. Interpret the global map:
a. In your own words define

- **Hotspots** –

- **Endemic species** -

b. How many of the world’s plant species are found in HS? __________

c. Compare HS and Biomes maps. Which biomes contain the most hotspots? What can you say about the population density in that area?

d. Out of the 24 hot spots regions in the word select one HS of your interest by clicking on the blue number. Provide information on the importance of the region and the threats of the area.

<table>
<thead>
<tr>
<th>#</th>
<th>Name of region</th>
<th>Important because ...</th>
<th>Threatened by...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Click on **All Other Maps** and select **World Deforestation Patterns**. Read **Overview**.

a. Distinguish between **disturbed and original forests**

b. Which area of the world seems to be more affected by **Deforestation**?

c. Select any region of your interest and compare with other maps. Go to “**Compare maps**” and select “Deforestation Patterns” on the bottom left. Select over different maps on the bottom right to contrast deforestation along other maps. Write down any comment as you compare these maps to the **Population Density, Global Land Cover, and Deforestation Pattern maps** to ...

- **Biome(s) in the area:**

- **Plant species diversity:**

- **Food plant diversity:**

- **Hot spots:**
APPENDIX AA

EXAMPLE MAP ACTIVITY FROM CEB
(From Conserving Earth’s Biodiversity CD-ROM, Perlman & Wilson, 2002)
Lesson 6: Lesson Plan and Lecture Notes

Time:
Two class periods will be used for this phase. Reading and discussing three essays should take about one class period. Then, students will use one a second class period to complete worksheet activities (activity #6).

Research plan:
- Read and discuss essay to make students aware of some of the threats to biodiversity
- Expose students to worksheet and CD-ROM activity #5 (according to section)

Lecture
> Objectives:
* Recognize ecosystems depend on a complexity of interactions among diverse species, biocomplexity
* Review evolutionary success of flowering plants as a consequence of pollination and seed dispersal interactions with animals
* Recognize the role of exotic species as negative species interactions that can lead to loss of plant biodiversity and plant species extinction
* Give examples of exotic species
* Be able to identify deforestation, exotic species, overharvesting, and human population as threats to plant biodiversity
* Identify positive and negative aspects of genetically engineered species and its effects on plant biodiversity
* Give examples of genetically modified species

> Concepts:

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocomplexity</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>Endangered species</td>
<td>exotic species</td>
</tr>
<tr>
<td>flowering plants</td>
<td>food (crops, plants)</td>
</tr>
<tr>
<td>habitat destruction</td>
<td>medicines</td>
</tr>
<tr>
<td>plants</td>
<td>species</td>
</tr>
</tbody>
</table>

> Lecture Notes:
- Remind students again at the start of the class that there is a quiz coming up based on the material and the concepts presented throughout the different activities.

- Both groups will read first essay *On dodos, bats, and disrupted ecosystems*. A discussion will follow:
  * What has caused flowering plants to be such a successful plant group?
  * Can you provide one example of the complex interactions between plants and other organisms?
* How these interactions may be affected when the animals disappear? (either are no longer at a certain place or go extinct)
* What are some causes that lead to this scenario?

- Both groups will read essay *Exotic invaders*. Discussion will follow:
  * This is not a completely new concept, as it was introduced with the biomes theme. Do you recall what an exotic species is?
  * Why are they successful?
  * What are some examples of exotic plants?
  * DO you recall local examples of plants that are exotic species in LA?
  * Do you consider plants that are exotic species affect the plant biodiversity of a region? Why?

- The last essay both classes will read is *Do recombinants hold promise or peril?* Lead discussion to critically evaluate the role of genetic engineering as it affects plant biodiversity. Students have been exposed before to the theme of genetic engineering in altering crops and the need to conserve the sources of wild species as sources of genes. But consider the consequences of creating “artificial” plant diversity?
  Discussion will follow:
  * Which organism caused the near extinction of the American chestnuts tree?
  * What would be the benefit of altering the genetics of the chestnut blight fungus? * How can genetic engineering affect plant biodiversity (and biodiversity in general)? Give positive and negative points regarding this issue.

- Announce they will complete worksheet activities in the next class (yellow copies).

- Remind students project presentations are coming up.

> Activities:
- CD section: complete worksheets for activity #6 using the CEB program (Threats!).

- Textbook section: Students will complete textbook-based worksheet.

> Interviews:
- Let participants know interviews will be conducted after project presentations.
Textbook group       Activity # 6 – Threats!

Instructions

The questions listed below are based on the material you have been exposed through textbook essays and discussion. You can use the textbook to help you answer the questions. You can also refer to textbook chapter 41 for additional information about the threats to different ecosystems.

Questions

1. In which world biome or ecosystem is biodiversity most endangered?
   ___________________________________________

2. How much of this ecosystem is being lost? __________________________________

3. Look at the figure in pg. 233. Based on what you observe in this figure and what you read in the essay On Dodos..., explain why do you think it may be important saving the tropical rain forest?

4. List what you consider are the main threats to plant biodiversity

5. Recall from the previous lesson (#5) the type of predominant ecosystem(s) in Louisiana. Read over the different ecosystems (biomes)
   a) List what you think are the two main reasons for deforestation in the United States
      1. 
      2.
   b) Do you consider deforestation a threat (danger) in Louisiana? Why? What may be some of the reasons for deforestation?
   c) Can deforestation affect plant biodiversity? If so, how? Explain your answer and use examples.
6. Make a list of what you consider are threats that affect the Louisiana wetlands. How these may affect wetland plant diversity?

7. What is the value of Louisiana’s wetlands?

8. According to the essay Exotic Invaders, p. 830, What is an exotic species?

9. List all the exotic species you have become familiar with through your essay reading or class discussion. Classify them as plants (Pl), fungi (F), animals (A), protists (Pr). Provide an example of which organisms may be affected by these exotic species?

10. How do exotic species affect the United States economy?

11. How do exotic species may impact plant species diversity? Give specific examples (from class discussion and essays).

<table>
<thead>
<tr>
<th>Exotic species</th>
<th>Present in Louisiana?</th>
<th>Which plants may be (or not be - indicate) affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire ants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zebra mussel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsy moth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Any other examples?

12. Go back to question #1 – Revisit your answer and state here: What do you consider is the most important threat to the ecosystems and plant biodiversity in Louisiana?

13. Please state the 3 most important things you learned by doing this activity.
Instructions

- Access CEB program and select Threats to Biodiversity from the main menu
- Listen to Introduction.
- Complete activities and answer questions as indicated below.

Questions

1. In which world biome or ecosystem is biodiversity most endangered? ______________

2. How much of it is being lost? __________________________________________________

3. Why do you think may be important to save the tropical rain forest?

4. List what you consider are the main threats to plant biodiversity.

5. Go back and select Habitat Loss. Select Forest Loss in the US
   a. List what you consider are the 2 main reasons for deforestation in the US
      1) 
      2) 
      b. Play the animation. What percent of LOUISIANA’s forested region do you estimate has been lost in 300 yrs.? Is deforestation a threat in Louisiana?
      c. How could this loss affect the plant biodiversity? Explain your answer, use examples.

5. Go back and select Wetland destruction.
   a. List all the threats that affect the wetlands ecosystems. Circle the ones you consider directly impact the LOUISIANA’s wetlands.
      1) 
      2) 
      3) 
      4) 
      5) 
   b. Link to Wetland loss in the US (blue words)
      Interpret the map: Between 1780 and 1980 LOUISIANA has lost ____________% of its wetlands.
      c. Go Back to Wetland destruction. Explain how water pollution can affect the local plant diversity.
**d.** Identify one valuable service provided by wetlands in general and those from Louisiana.

6. Go back to **Threats to Biodiversity.** Select **Exotic Species.** Listen to the **Introduction.**

   a. What is an exotic species? How do you think they impact the economy?

   b. Go back and select the case of **Purple Loosestrife (PL)** from the **Exotic Species** menu.

   - What percentage of the United States does PL covers? _________
   - List the characteristics which have made PL a successful exotic?

   - Describe how PL affects wetland diversity.

   - Give examples of other plant species that are out-competed (affected) by PL.

7. Go back to **Exotic species.** Explore other cases of exotics and their impact in Louisiana’s plant species or ecosystem diversity.

<table>
<thead>
<tr>
<th>Exotic species</th>
<th>Present in La?</th>
<th>Which plants may be (or not be - indicate) affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire ants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zebra mussel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsy moth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. *(Optional)* You can explore any other threats of your interest. If you do, please indicate your most important findings. You can use additional paper if needed.

9. Based on the information to which you have been exposed in this activity, judge which is the most important threat(s) to the ecosystem and plant species diversity in Louisiana

10. Please state the 3 most important things you learned by doing this activity.
Trevic’s First Essay

Essay: What are my reasons for conserving biodiversity?

My reasons for biodiversity spread across a wide area. I feel that biodiversity plays a major role in life and is as important to humans as breathing. Many humans think that the world, in its entirety, belongs to us and that we could use the natural resources as we see fit. If we were to continue to live like this, many essential minerals and nutrients would be depleted. This would mean we would not be able to have any of medicine and herbal remedies because they would be gone.

By cutting forestation in order for our needs, we not only destroy a habitat for other organisms, we also destroy some of Earth’s natural beauty. Also by killing plants, we are in a sense losing some of the oxygen in our atmosphere. Humans need to remember that we rely on plant life for most of our oxygen. Humans must always keep in mind that changes in biodiversity may not have an immediate effect but in time the effects will show.
Trevic’s Essay Re-visit

I still feel the same about my essay but also I feel that if we destroy biodiversity we are destroying ourselves because we rely on every piece of the puzzle for the big picture.
We need to protect biodiversity. I want my child and his children and so on to enjoy the different planet in the way I have. As we systematically deplete our earth’s natural resources, we are depriving our grandchildren of the essential products of our world. We need many different species and ecosystems to maintain life as we know it. Just because man thinks he has rights over everything in the world doesn’t make it right or true. We should learn to conserve all life and resources on earth. It’s good and necessary for us (humans) to survive as well. One day we will not have all of the resources that we need for survival.
There are many reasons for conserving biodiversity. I want my kids, grandkids, and great-grandkids to be able to enjoy the earth's beauty, resources as much as we, now, do. I think we need to conserve the species of our planet because I believe that every creature has a purpose, and every plant will be, and is, needed. If we cut down all of our trees, we won't have the resources we need to build, make paper goods, etc., and most importantly, animals won't have any homes and the air quality (air that we need to survive) will be so bad that we may not survive it if we get too lose too many trees. If we deplete our crops and do not have the means to replant we'll go hungry and eventually this will lead to our demise (not only ours but many other species as well, if not all). Every form of life has its place in this world and all species are needed for some process in life. I believe that we have to preserve biodiversity for the world's survival.
**APPENDIX EE**

**EXAMPLES OF THE GOLDEN LIST OF SPECIES**

Textbook group

---

**MY PLANT SPECIES LIST**

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Interest</th>
<th>Plant name</th>
<th>Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black gum</td>
<td>rolled</td>
<td>Monkey gum</td>
<td>rolled</td>
</tr>
<tr>
<td></td>
<td>leaf</td>
<td></td>
<td>leaf</td>
</tr>
<tr>
<td>Plant name</td>
<td>Interest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neem tree (or)</td>
<td>Extracts used in tooth paste, insecticides, and anti-septics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosy periwinkle (or)</td>
<td>Contains anti-cancer drugs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catharanthus roseus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yew tree (or)</td>
<td>Contains taxol, a chemical used against breast cancer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulmus americanus or</td>
<td>Many killed off by the Dutch elm disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carya nivana</td>
<td>&quot;Grassenstunt&quot; virus resistant rice crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinchona officinalis</td>
<td>Source of malaria fighting drug quinine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinchonatree</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cactus</td>
<td>Preserves lots of water, has lignin, has holes in it</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fern</td>
<td>Grow vegetatively by rhizomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>Tri-plotid - the coconut is a seed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pine</td>
<td>Male cones - open to receive pollen. Male cones - do not open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinus labra - pine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orchid</td>
<td>Designed to track bees into carrying the pollen to reproduce in the next</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bryophyta - mosses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatophyta - liverworts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthocerophyta - hornworts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epiphytic bromeliad-tropical, non-vascular</td>
<td></td>
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</tbody>
</table>
APPENDIX FF

STUDENTS’ EXAMPLES OF CONCEPT MAP FOUR

Examples of Concept Map # 4 – Thiab
APPENDIX GG

POST-UNIT QUIZ

Plant Biodiversity Final activity Quiz

Multiple choice: Select the alternative that is the best answer for each question. Questions with the ☺ symbol will be answered with the help of a projected image. Please use the scantron to answer the quiz.

☺1. This visual representation suggests biodiversity

a. is a result of evolution of life
b. is the variety of life on Earth
c. is more important in some groups than others, that’s why animals are at the top
d. More than one answer is correct ________________

☺2. Which of these images shows the ancestor from which the plant kingdom most likely evolved?

a. cyanobacteria
b. green algae
c. fungi

3. A researcher needs to report the plant biodiversity of an area. What would you suggest s/he can do after selecting a sample area?

a. count how many total plants are there
b. count how many individuals of each different kind of plant are in the area
c. determine the size of the plants in an area

4. When considering the number of species, you say that Earth’s biodiversity

a. consists of about 1.5 million described species
b. includes an estimated number of species somewhere between 5-30 million
c. is concentrated in the temperate zone
d. A and B are correct
e. B and C are correct

5. All species in the plant kingdom play a unique and important role in the ecosystem because they

a. transform sunlight into chemical energy through photosynthesis
b. Fix Nitrogen
c. Produce carbon dioxide
d. Can reproduce
6. Which of the following helps describe the diversity of the Plant Kingdom?

a. plants may reproduce with flowers, cones, spores, or swimming gametes
b. plants have a wide range of sizes, from about 1 in. to several meters tall
c. some plants are adapted to live in deserts, rain forest, or cold temperate forests
d. some plants live in water, on other plants, or grow in the ground
e. all of the above

7. This image represents the group of plants that became most successful, the one with the highest number of species, due to plant-animal interactions (especially insects).

8. This LA plant is representative of the diversity of the gymnosperms. It has both stem and root adaptations, and is an unusual conifer that sheds its leaves in cold weather.

9. This LA plant is an epiphytic flowering plant, but its common name and growth habit leads us to think is a parasitic bryophyte. It was used for brick building and stuffing mattresses.

10. When identifying the diversity in the plant kingdom, taxonomists use different characteristics. If you were a taxonomist, what evidence do you see in this image that can help you determine the class to which this LA plant belongs? (hint: dicots)

a. The netted leave venation pattern
b. the branching pattern of the stem
c. it produces fruits and seeds
d. the presence of flowers

11. This image represents an important service provided by plants to the ecosystems. What is the concept a biologist will use to explain this image?

a. Herbivory - insect is eating the plant
b. Pollination - butterfly is transfer pollen while getting its own food
c. Commensalism – butterfly gets shelter and food, no effect on plant
d. Competition – butterfly needs the same resources as the plant

12. All over the planet there are different ecosystems characterized by differences in water availability, temperature, and vegetation. Which of these images represents the ecosystem with the highest plant biodiversity?

13. In which region of the world can you find the ecosystem you selected in Q #12?

14. If a hot spot is defined as an area with high species diversity and high ecosystem threat, then in which region of the world do you expect to find most hot spots?

15. Using genes as resources, genetic engineers could benefit plant biodiversity by

a. cloning endangered species
b. weakening pathogens like the chestnut blight
c. transferring genes of pathogen-resistant plant species to weaker plant varieties
d. all of the above

16. What is a connection between the Pacific yew, the rosy periwinkle, and *Calophyllum* tree?
a. these plant species are source of medicines to treat cancer and AIDS and are found in different ecosystems endangered by deforestation
b. they are seedless plants that live in tropical rain forests, are an important source of folk medicine
c. their leaves are an important source of food and medicine but they are over harvested

17. Diverse fruits, like strawberries and tomatoes, have in common that they
a. develop from flower parts
b. come from seedless plants
c. have stems adapted for storage
d. have roots adapted for storage

18. Which of the following is NOT a threat to plant biodiversity in LA ecosystems?
a. prescribed fire regimes
b. human population growth
c. spread of exotic species
d. deforestation rates and pollution

19. Knowing the place of origin and distribution of wild relatives (or varieties) of crop and medicinal can help scientist to
a. promote conservation of ecosystems in the places of origin of wild varieties
b. use those as resources of genetic diversity to improve yield
c. help plants, like blueberries, become heat tolerant
d. all the above

20. Which of the following could be a consequence of an exotic/invasive species like Chinese tallow, water hyacinths, and fire ants presence in LA’s ecosystems?
a. Plant species diversity will increase and more animals will come
b. Some animals may loose food or shelter if LA’s native plant species can’t grow well
c. The complexity of the ecosystems will not be altered, i.e. interactions remain the same
d. More animals can be supported, i.e. is favorable to the black bear

21. These plant species have in common they…
a. have no predators and spread (reproduce) easily
b. are very beneficial to the ecosystem improving biodiversity
c. flower at the same time
d. do not produce seeds

22. Predict what will happen if diverse mammals like bats, lemurs, tapirs, and monkeys keep disappearing in many tropical forests.

a. Seed dispersal will be reduced and plant species can go extinct
b. Increase space and food for the growing human population growth
c. Reduce pollution levels
d. Plant diversity increases in absence of these predators

23. Plant biodiversity can be protected through conservation of the environment by

a. joining a political party
b. recycling, planting native plants, and reducing energy consumption
c. planting more plants, regardless of their place of origin
d. draining the wetlands to promote development of agriculture
e. recycling and adding fertilizer to the lawn

24. Finish the sentence: Extinction is

a. probable b. inevitable c. forever

25. Which of these statements best explains the complex interactions of life (Biocomplexity)

a. All life forms evolved from single cell common ancestors and taxonomy is used to classify the organism
b. Socio-economic factors as well as biological, chemical, and geological factors interacting and affecting biodiversity
c. Oxygen, water, and energy are needed to support the web of life
d. Numbers of species and their distribution is a good measure of complexity
Figures projected with this quiz:

Question 1

Question 2

Question 7
Question 8

A

B

C

D

E

Question 9

A

B

C

D
Figures are from chapters 18, 21, 41, Audesirk, Audesirk & Byers (2002); S. Guzman, V. Thaxton, and from the CEB (Wilson and Perlman, 2002). All figures were used only for instructional and assessment purposes for students using the CEB and textbook as instructional resources.
APPENDIX HH

LESSON PLAN AND OBJECTIVES FOR LESSON FOUR

Lesson 4: Lesson Plan & Lecture Notes

Time:
Project description and model lecture (chapters 23 & 24) should take approximately three class periods. Additional class time in the third period will be used to let groups meet and start looking for their plant sample. An additional class period will be used to let students work on project.

Research Plan:
- Project guidelines
- Model lecture.
- Provide support for research in a one-on-one basis

Lecture:
> Objectives:
* Label the basic body parts of vascular plants and their main function
* Distinguish between the two classes of flowering plants
* Recognize evolutionary adaptations of plants result in a diversity in root systems, leaves, growth habits
* Demonstrate understanding of plant classification
* Identify stages in life cycle of plants according to the alternation of generations
* Identifies role of flowers as reproductive structures
* Recognizes role of plant biodiversity in pollination and seed dispersal interactions in the ecosystem
* Recognizes fruits come from flower structures

Through the project:
* Can illustrate LA plant diversity
* Demonstrates value of plant diversity as resource
* Employs independent research skills
* Employ group work skills

> Concepts:
Proficiency
| Angiosperms | Bryophytes | Ecosystems | Evolution |
| Family | Food (from plants) | Kingdom | Genetics |
| Genus | Gymnosperms | Plant biodiversity | medicines |
| monocots | Mosses | Pollination |
| seeds | species | Systematics |

> Lecture Notes:
- Distribute and explain project guidelines
- Both groups will be exposed to power point lecture. This should serve as a model for their presentation. Full notes will be provided to allow time for discussion of questions they may have.
- Explain that I am using a *model* plant that is *not from LA* (they must do a LA plant). BUT – in LA there are muscadines (wild grapes, included in talk), and vineyards & a small wine industry.

- Concepts from chapters 18 and 21 should be review.

- A limited number of concepts are from chapters 23 and 24. Point out to the students a lot of the physiology and microscopic characteristics have been left out, in order to focus on those characteristics that can help them familiarize more easily with plant biodiversity. They can read about these from the textbook.

> **Activities:**
  - Once model lecture is over, both sections will have class time to start up project
    - select partner
    - brainstorm about plant & have time to use resources to look for plant (computer lab, LA native trees, and posters will be available to both sections)

> **Interviews:**
  - Participant students will be interviewed after project presentations
APPENDIX II
MARY WORTH’S INQUIRY DIAGRAM

INQUIRY

Notice, Wonder, Explore

Take action, extend questions

Focus observations and raise questions

Focused explorations

explore, observations take action

Test out with new investigations

collect data

Organize data, formulate patterns and relationships

Bring together data/ideas and formulate patterns and relationships

Exploratorium
Institute for Inquiry

Diagram:
Hubert Dyasi, CCNY
Karen Worth, EDC
VITA

Sandra was born in San Juan, Puerto Rico, to Carmen M. Grajales and Francisco A. Guzman. In 1987, she obtained a Bachelor of Science from the University of Puerto Rico at Mayagüez, graduating Magna Cum Laude. Sandra continued graduate studies at the University of Puerto Rico at Rio Piedras. There she developed her research on tropical rain forest recovery following Hurricane Hugo. Sandra received her Master of Science in biology in 1992. She worked as a field research assistant for the Terrestrial Ecology Division, Center for Energy and Environment Research, University of Puerto Rico.

Sandra and her husband Fermín moved to Louisiana to fulfill the goal of pursuing a doctoral degree. After the shock of the first winter, Sandra and Fermín learned to appreciate the majesty and beauty of Louisiana’s plants, and its contrast to the tropical rain forest. During her years as a doctoral student, Sandra participated in research in the tropical forests in Costa Rica and Panama. Her academic life includes experience presenting in various conferences regionally and nationally, contributing as author to eight articles including topics in field ecology and science education, translating to Spanish a children’s botanical story, and serving twice as a grant reviewer for the CCLI program of the National Science Foundation. As a member of the 15 Degree Visual Cognition Laboratory at LSU, Sandra has served as a children’s book reviewer for the Giverny Award and has help represent the campaign for Preventing Plant Blindness.

Sandra’s passion for teaching biology led her to join the River Parishes Community College in Sorrento, Louisiana, as a biology Instructor. While at RPCC she has participated in numerous committees and has received funding for two grants. After completing her doctoral degree, Sandra plans to continue developing research in plant
biology education, continue teaching and preventing plant blindness. She will use the free
time to have fun enjoying and promoting nature conservation with her husband Fermín
and their two seedlings, Erika and Alex.