A Study of the Effects of Prediction Activities on Instructional Outcomes in High School Genetics.

Anne Spratlan Sinclair
Louisiana State University and Agricultural & Mechanical College

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A study of the effects of prediction activities on instructional outcomes in high school genetics

Sinclair, Anne Spratlan, Ph.D.
The Louisiana State University and Agricultural and Mechanical Col., 1991
A STUDY OF THE EFFECTS OF PREDICTION ACTIVITIES ON INSTRUCTIONAL OUTCOMES IN HIGH SCHOOL GENETICS

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 Curriculum and Instruction

by

Anne Spratlan Sinclair
B.A., Judson College, 1964
M.S., University of Alabama, 1966
May, 1991
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ABSTRACT

The purpose of this study was to examine the instructional effects of incorporating prediction activities in a high school biology genetics curriculum. Criteria for instructional effectiveness included enhanced levels of classroom discussion and interaction, improved subject-related attitude, higher achievement motivation, and greater mastery of genetics concepts. Genetics was chosen as the domain of research because of the multiple variables operating which make it amenable to the making of predictions.

Four experienced high school biology teachers taught an experimental and a control class. Students in the experimental classes made written predictions using researcher-developed prediction activities as an introduction to 19 genetics topics. Experimental students were encouraged to discuss their predictions about the mechanisms of inheritance and to justify the rationale they used in making them. The experimental and control classes were taught similarly except for the introductory prediction activities.

The study employed both quantitative and qualitative analyses of the treatment and its effects on instructional outcomes. Quantitative measures included pre- and posttests for genetics achievement, attitude toward science, and
achievement motivation. Qualitative descriptions comparing and contrasting the experimental and control groups on levels of interest and participation were completed by the four teachers and by independent observers in the classrooms. Interviews were conducted with the teachers and randomly selected students at the completion of the study.

An analysis of the quantitative data revealed no statistically significant differences between the control and experimental classes on any of the quantitative measures. A significant positive correlation was shown between attitude toward science and achievement motivation for both groups. The triangulated quantitative and qualitative data indicated that significant teacher effects occurred. Two of the four teachers experienced positive changes in their teaching styles. They were described as asking more open-ended questions to elicit student predictions in the experimental classes.

Though the quantitative results revealed no significant differences between the experimental and control classes, the qualitative data strongly supported that making predictions promoted critical thinking and enhanced student interest and motivation evidenced by augmented classroom participation.
CHAPTER I

Introduction

The call to reform for science education appears to be "uncontested" (Hart & Robottom, 1990). Results of testing by the National Assessment of Educational Progress in Science showed a steady decline in seventeen-year-olds' science achievement scores in the United States since 1969 (Rakow, 1983). Rapid proliferation of scientific and technological information, paired with a decline in student achievement, dictate a change in how science is taught. The contention is that science education is mandated to produce students who can use their knowledge about science and technology autonomously (Science for All Americans, 1989). Linn (1984) believes this can be accomplished by providing students with opportunities to discover and assess new ideas for themselves, thus producing citizens who continue to learn on their own.

The National Science Board (NSB) Commission on Precollege Education in Mathematics, Science, and Technology (1983) called for the new basics in mathematics, science and technology which include "communication and higher problem solving skills and scientific and technological literacy--the thinking tools that allow us to understand the technological world around us" (NSB, 1983, p. v).
In 1989 two clarion calls were issued for reform in science education. The first, *Science for All Americans* (1989), was published by the American Association for the Advancement of Science (AAAS). Like *Project Synthesis* (Harms, 1979), this report called for scientific literacy. The recommendations put forth by the National Council on Science and Technology Education, a group of scientists and educators appointed by the AAAS to write the report, are that informational content be lessened and thinking skills be promoted. The council also recommended that more emphasis be placed on the nature of the scientific enterprise, as well as on important occurrences in the history of science and technology.

The second major call to reform in 1989 was made by Bill Aldridge, Executive Director of the National Science Teachers Association (NSTA). In his report, *Essential Changes in Secondary Science: Scope, Sequence, and Coordination*, he contended that the present science curriculum in the United States acts as a "terrible filter" by excluding many students who do not have the mathematics background necessary to handle the theoretical concepts that are emphasized. Aldridge feels the number of students who study science through grade 12 can be increased by emphasizing "how we know," and not by focusing on the mere acquisition of information. He believes that scientists and
science educators should select a small number of "main themes" and emphasize a mastery of these. A need for more practical hands-on experiences with science was also indicated. Aldridge maintained that learning should be pleasurable and motivating, leading to higher self-esteem. He proposed that these changes will foster the scientific potential in the United States because more young people will be involved in science, especially minority students and females who have been greatly underrepresented in recent years.

Science education is called to reform (Aldridge, 1989; Linn, 1984; Science for All Americans, 1989). The role of the science education researcher will be to assist in these efforts by conducting well-thought-out research studies that identify instructional practices that enhance learning and promote the development of autonomous individuals who are scientifically literate (Linn, 1984). This research project is directed toward such an end.

**Purpose of the Study**

The decline in motivation and attitude toward science during the middle and secondary grades, especially among females (Simpson & Olliver, 1990), and the call for emphasis both on process skills (Germann, 1989), and thinking skills (Smith, 1989) in the science classroom, gave impetus to this research effort. The purpose of this study was to examine
the instructional effects on learning, attitude, motivation, and classroom participation by incorporating prediction activities in a high school biology genetics unit. Criteria of effectiveness included: (a) enhanced levels of classroom discussion and interaction, (b) improved subject-related attitude, (c) higher achievement motivation, and (d) greater mastery of genetics concepts.

The researcher-developed prediction activities (see Appendix A) served as an introduction to selected topics in the genetics unit. Each of these activities was designed to elicit the students' prior knowledge about the mechanisms of inheritance, to stimulate classroom discussion and argumentation, and to promote critical thinking.

Statement of the Problem

The research problem can be stated as follows: Will prediction activities used in high school genetics enhance learning, attitude, motivation, and classroom participation? The problem can be broken down into five subproblems.

1. Will high school students who participate in prediction activities during a genetics unit demonstrate a greater mastery of genetics concepts when compared to students who do not participate in these activities (i.e., on an achievement test)?
2. Will high school students who participate in prediction activities during a genetics unit demonstrate enhanced subject-related attitude when compared to students who do not participate in these activities (i.e., on an attitude toward science inventory)?

3. Will high school students who participate in prediction activities during a genetics unit demonstrate enhanced achievement motivation when compared to students who do not participate in these activities (i.e., on an achievement motivation inventory)?

4. Will high school students who participate in prediction activities during a genetics unit demonstrate a higher correlation among greater mastery of genetics concepts, enhanced subject-related attitude, and enhanced achievement motivation when compared to students who do not participate in these activities?

5. Will high school students who participate in prediction activities during a genetics unit demonstrate enhanced levels of classroom interaction when compared to students who do not participate in these activities (i.e., classroom discussion and content-related argumentation)?

Definition of Terms

Three terms require precise definitions because each has a variety of connotations: prediction, achievement motivation, and alternative conceptions. A more refined
explanation as to how these words will be used in the present study is necessary.

The definition of prediction that best describes the construct as it was used in this research project was presented by Thiel and George (1976). The researchers defined prediction as "the acquired ability to use one or more rules from the same or different rule classes to determine the outcome of an event or series of events without prior observation of the outcome of that event or series of events" (p. 155). The key factor, when applied to this study, is the making of predictions about the mechanisms of inheritance prior to formal instruction on each of the genetics concepts.

In a study to identify genetics misconceptions, Lawson and Thompson (1988) used the word prediction in the same way as it was used in the present research effort. Students in their study were asked to make predictions about genetics phenomena using an open-ended essay format. The following sample prediction assessed their understanding of acquired characteristics:

**Amputated Finger**

If this little girl had an accident and her finger was amputated and she married someone with a similar amputation, what would you predict their children's fingers would look
like at birth?

Please explain your prediction. (Lawson & Thompson, 1988, p. 738)

The term achievement motivation was defined by Oliver and Simpson (1988) in the form of a question: "To what extent does the student try to do as well as possible when engaging in science" (p. 144)? Using this definition as their focus, the researchers developed a quantitative instrument to measure achievement motivation (Simpson & Oliver, 1985). This inventory was administered to all students participating in the present study.

The third term that requires a more precise definition is alternative conception. In this study it will be used in the same sense as it was by Lawson, Abraham and Renner (1989). They prefer the term alternative conceptions to misconception for they feel the former carries a less negative connotation. These beliefs represent the student's personal effort to construct models from experience and are "conceptions which are inconsistent with, or even contradictory to, modern scientific views" (p. 77).

Rationale for the Study

Prediction

An extensive review of the literature (see Chapter II) revealed that research is needed to further describe how the making of student predictions affects interest, motivation,
and learning in science classes. Lavoie and Good (1988) noted the paucity of research on the "learning, teaching, or thinking processes associated with the science process skill of prediction" (p. 338). They called for research that assists in enhancing the teaching and assessing of this skill. Germann (1989) stated that in spite of recent emphasis on inquiry using process skills, studies have shown that they are not being taught in American science classes. Self, Self, and Self (1989) reached the same conclusion.

Holland, Holyoak, Nisbett, and Thagard (1986) stressed the role of rules in what they called the most important learning mechanism, prediction.

A rule that leads to a successful prediction should be strengthened some way, increasing the likelihood of its use in the future; one that leads to error should be modified or discarded. Predictions about the attainment of goals will normally be the most powerful source of feedback. (p. 16)

Prior knowledge and prediction. Head and Readence (1986) noted that a majority of studies support the contention that prior knowledge facilitates learning. Osborne and Wittrock (1983) believe that students' prior knowledge has been greatly underestimated in its importance to learning. They emphasized the need for students to
relate old and new information and called for research to explore how teachers can encourage the expression of pupils' ideas and levels of understanding.

Students' predictions about the mechanisms of inheritance were used by the teachers participating in this study to elicit prior knowledge about genetics concepts. The intention was then to implement instruction which addressed identified areas of difficulty, confusion, or misunderstanding.

**Perspective-taking.** As part of a qualitative evaluation in a study conducted in ninth grade physical science classes, Good, Strawitz, Franklin, Smith, Roberts, & Moncado (1988) asked the teachers involved to describe their feelings concerning the effectiveness of incorporating prediction into the lessons. The teachers noted an increase in class participation and student interaction resulting in energetic discussion when the students defended their predictions.

Fisher and Lipson (1986) suggested that a safe, nonthreatening environment promotes dialogue and encourages students to express their conceptions with no penalty for error. They argued that feedback between the teacher and the students should be open; students should be encouraged to recognize and explore their errors in order to learn from them. Fisher and Lipson maintained that the need for
dialogue is emerging as an important aspect of learning. They believe that deeper levels of understanding occur when errors are dealt with directly.

Johnson, Johnson, Pierson, and Lyons (1985) noted how little research has been done on how "perspective-taking ability" can be promoted in the classroom. They suggested that "structured academic controversy" is one of the ways that this could be accomplished. In a study which required students to predict volume, Linn (1984) found that students often learn by resolving differences between their conceptions through argumentation. Nussbaum and Novick (1982) found similar results while studying group interaction. When learners were confronted with the ideas of their peers, negotiations occurred which resulted in modifications of their alternative conceptions. Lawson, Abraham, and Renner (1989) feel that students should be encouraged to put their predictions to the test in the science laboratory and in dialogue with fellow students.

Stewart (1982) observed that successful solution of genetics problems requires "more than routinized use of problem-solving algorithms. A meaningful solution is one in which students can explain, in terms of genetics, why they have carried out each step" (p. 81). Stewart recommended that further research investigate whether meaningful
learning increases when students are asked to explain their answers to genetics problems.

Students in the experimental classes in the present study were encouraged to justify and defend their predictions with their teacher and the other students in a friendly, nonthreatening setting. One of the purposes of the dialogue about the predictions was to allow students to become aware of others' opinions, and to discuss any differences in an open and positive manner. The intent was to promote "friendly" controversy and argumentation for one's position during the times of discussion about the predictions.

Motivating effect. Kremer and Walberg (1981) feel that research in science education has neglected student motivation as an area of emphasis. They reviewed refereed science education journals from 1964 to 1979 and found only a few studies concerned with motivation and achievement at the secondary level.

Research has shown that instructional intervention can alter the motivational level of students, but these strategies have not as yet been clearly defined (Naccarato, 1988). Lavoie and Good (1988) contended that studies are needed to identify factors that affect the motivation of students while solving different kinds of problems. Smith (1983) identified motivation as a needed component in
problem solving. He observed that only recently have researchers included this factor in their theories of learning.

Mathison (1989) maintained that assisting students in developing a positive and anticipatory attitude toward an assignment holds great promise in enhancing student motivation. Good et al. (1988) found that the making of student predictions prior to laboratory activities provided a "motivating and focusing effect." Based on the results of their study, these researchers believe the reason prediction making increased motivation is because the students desired to verify whether or not they were correct during the laboratory investigation which followed.

Lavoie and Good (1988) observed that making predictions during the first phase of the learning cycle served as a motivating factor by arousing student interest and involvement. The researchers suggested that the making of predictions may serve as an advance organizer by focusing the students' attention on relevant information that is already known. Ausubel (1960, 1968, 1978) conceptualized advance organizers as a form of verbal mediation in which ideas are introduced prior to the main body of instruction. He provided evidence that meaningful learning occurs when it is preceded by meaningful contexts (advance organizers). The new material becomes incorporated into the present
cognitive structure when it can be subsumed under existing relevant concepts.

In the present study, both the experimental and control classes completed a pre- and posttest achievement motivation inventory (Simpson & Oliver, 1985) to determine whether the prediction activities affected this construct. Qualitative descriptions were also made by the teachers and independent observers in the classrooms on evidence of enhanced student motivation (i.e., greater involvement in discussion and increased argumentation and perspective taking).

**Attitude toward science.** Attitude toward what students are studying may account for as much as 25% of the variance in school achievement (Bloom, 1976). A long-term study by Simpson and Oliver (1990) revealed that from grades 6 through 10 attitude toward science consistently dropped. The decline was most marked among students with average ability. Students' attitudes were found to be highly correlated with those of their friends. One of the most interesting findings was that the science classroom had a strong influence on their attitude toward the subject. The researchers found that students with less favorable attitudes toward science selected fewer science courses during their high school years. Simpson and Oliver believe this affects students' future attitude and commitment toward science and their lifelong interest in learning science.
"By understanding how young people in our society learn to value science, and hence become competent in and committed to science, parents, educators and other leaders in our society can better plan for the future" (Simpson & Oliver, 1990, p. 17).

In the present study, Simpson & Oliver's (1985) attitude toward science inventory was administered to both experimental and control classes before and after the genetics unit to determine if the prediction activities influenced subject-related attitude.

Learning Theory

Osborne and Wittrock (1983) described learning using a generative model. Their theory posited that the brain is not a passive recipient of information. Rather, "It actively constructs its own interpretations of information, and draws inferences from them" (p. 492). The researchers believe that it is only through the desire of the learner to take the time and effort to generate meaning that learning is achieved. Constructivist philosophers such as Piaget (1969) would contend that knowledge is constructed by each individual as a result of a range of experiences. The learning theory that emerges from Piaget's work can be summarized by saying that learning occurs by constructing and expanding cognitive schemes by self regulation which involves two processes, assimilation and accommodation.
Assimilation results when the new information can be directly organized into existing mental schemes. When one is confronted with a situation for which a conflicting scheme is in place, disequilibrium occurs. This disequilibrium can only be reduced when self-regulation leads to the formation of mental structures which can account for this new perception. The construction of new schemes is termed accommodation. "Intellectual development proceeds as one moves from equilibrium to disequilibrium and then to new equilibrium with the concomitant development of new mental structures" (Walker, Hendrix, & Mertins, 1980, p. 105).

Good (1989) argued that prediction making should be incorporated into current learning and instruction theories in science. He feels that including prediction in a lesson holds promise for enhancing both motivation and critical thinking. If Plagetian learning theory (Plaget, 1969) were applied to the present study, one might reason that because many of the genetics concepts were new to the students, they likely experienced disequilibrium while making their predictions about the mechanisms of inheritance. Self-regulation begins at this point. When predictions were shown to be correct, then the new knowledge and understanding could be assimilated into existing mental structures. If predictions were incorrect, opportunities
were provided by the teachers which promoted accommodation of the new concepts.

Von Glasersfeld (1989) believes teachers need to understand that students often give solutions to problems that seem sensible to them, yet their ideas are often rejected. "Such bleak corrections are bound to diminish the student's motivation in future attempts" (p. 137). He contended that if the constructivist theory were applied to educational practices, profound changes would occur in student motivation. Von Glasersfeld feels that it is essential for teachers to understand how students assimilate new experiences. They need to explore how their students see problems and why their solution processes seem appropriate to them. In this way, the teacher can appreciate the students' conceptual framework, and instruction can be designed and implemented to promote accommodation of new ideas.

Figure 1 represents an effort by this researcher to describe, using a concept map, the hierarchical relationships of prediction to accommodation and assimilation, and to the affective and cognitive domains. Wandersee (1990) stated, "... concept maps are designed to parallel human cognitive structure ..." (p. 927). He maintained that they "reflect the psychological structure of knowledge" (p. 927) of the mapper. One is required to
Figure 1
identify relevant ideas subordinate to the superordinate concept and depict these in a "context-dependent hierarchical form" (p. 927). Novak (1989) contended that such a process promotes personal "meaning making."

**Genetics as the Domain of Study**

**Problem Solving and Cognition**

Smith and Good (1984) stated that "the most critical educational task of current society must be to develop within students the ability to think, to solve problems" (p. 895). Kuhn, Amsel, and O'Loughlin (1988) believe an important goal for science education is to assist students in gaining conscious control of the adjustment mechanisms of metacognition by encouraging students to think about their own thinking. Good (1989) suggested that making predictions may assist in promoting metacognition.

Smith (1989) identified a need for joining subject matter instruction with thinking-skill instruction. "Good teaching in any subject has two central goals: to develop in-depth understanding of that subject and to enhance critical thinking skills. Problem solving requires both: understanding subject content and the ability to apply that understanding" (p. 67).

Genetics was chosen as the domain of research because of the nature of the problems presented. Smith (1988) stated that problem solving in genetics has been identified
by both teachers and students as the most difficult area of biology. He recommended that the central focus of instruction should be on the process of problem solving, not the product. Walker, Mertins, and Hendrix (1979) found that level of cognitive development was directly correlated with successful solution of genetics problems in college students. The results of a study by Mitchell and Lawson (1988) indicated that hypothetic-deductive reasoning ability was the major predictor variable that limited college students in genetics problem solving. Yet, formal operational thought was found to be neither necessary nor sufficient in the successful solution of Mendelian genetics problems in Smith's 1983 study comparing experts and novices. He argued that formal operational thought may be conducive, but not essential, to problem solving in genetics, and contended that the inclusion of such problems in the high school curriculum may "promote development to the formal level" (Smith, 1989, p. 74).

Prediction making is applicable when multiple factors can be manipulated for various effects (Lavoie & Good, 1988). If this is indeed the case, then the subject matter of genetics appears to be amenable to the making of predictions since appropriate manipulation of multiple variables is required for the comprehension of many of the complex mechanisms of inheritance.
Alternative Conceptions

Recent research on alternative conceptions clearly indicates that science instruction has only a "modest effect" in assisting most students to realize their theory is not consistent with scientifically accepted knowledge (Champagne, Klopfer, & Gunstone, 1982).

Making contact with these inferior strategies, and getting subjects to see their limitations, must be given as much, if not more, attention than developing the new strategies that will replace them. The challenge posed by instructional efforts should thus not be underestimated. (Kuhn et al., 1988, p. 233)

Good et al. (1988) found that those who made predictions and then tested them were better able to recognize their alternative conceptions. A study by Lavoie and Good (1988) showed that unsuccessful predictors had more misconceptions. Smith and Good (1984) suggested that student alternative conceptions should be addressed directly and early in the curriculum. They recommended some type of assessment procedure be used to identify misconceptions before formal instruction begins.

One area of current interest is investigating student alternative conceptions in genetics. Browning and Lehman (1988) feel that curriculum revision is necessary. They noted a need for the modification of teaching approaches in
order to address alternative conceptions. Stewart (1980) also argued that teachers and science education researchers should identify instructional strategies that target former misunderstandings.

In the present study the students' predictions were used by the teachers to identify alternative conceptions. Activities were then implemented to assist the students in accommodating the scientific concepts which were in conflict with their former conceptions.

**Combining Quantitative and Qualitative Research**

Traditionally, educational research has been conducted in the quantitative mode, utilizing objective and positivistic measures. Only recently have qualitative methods been employed to describe social interaction and other phenomena that are difficult to quantify. The design of quantitative research is largely experimental or correlational. Qualitative research, on the other hand, seeks to describe each setting, giving the reader enough detail to "make sense" of the situation (Firestone, 1987).

Howe (1988) argued that no incompatibility exists between the two approaches. Roberts (1982) stated that qualitative and quantitative research methods have complementarity. Even though the two approaches provide different types of information, Jick (1979) maintained that
If triangulation shows them to be mutually supportive, robustness is added to each of the findings.

Roberts (1982) feels that science education research should accommodate high-quality work from each of these research methods. Anderson (1990) noted that both researchers and evaluators have "expanded their repertoire of techniques, with qualitative approaches gradually acquiring a featured place . . ." (p. 553). More qualitative research in science education is called for by Easley (1982) to discover "the cognitive and social interaction mechanisms that underlie the learning process in classrooms" (p. 191).

Both quantitative and qualitative analyses of the treatment and its effects on instructional outcomes were employed in this study. Quantitative measurements included pre- and posttests on genetics achievement, attitude toward science, and achievement motivation. Qualitative descriptions comparing the experimental and control groups on evidence of student interest, discussion, and argumentation about the genetics topics were completed by the teachers involved in the study, as well as by independent observers in the classrooms.

Qualitative and quantitative dimensions were included in this research effort "because with both we can achieve
binocular vision. Looking through one eye never did provide much depth of field" (Eisner, 1981, p. 9).

**Importance of the Study**

This study contributes to educational knowledge by providing information on the effects of including prediction activities in a high school genetics curriculum. A research base has been established from which other studies concerning prediction can be conducted. Information gained generated recommendations for instructional strategies which hold promise for more effectively teaching genetics concepts and for enhancing classroom participation and critical thinking.

**Limitations**

Criticism has been raised against quantitative research methods. Rist (1982) described these procedures as having "sterile empiricism." He observed that the quantitative approach has lost favor because educators have recognized that it cannot answer all of the complex questions.

No longer is there overwhelming agreement that experimentation is *the only way* for settling disputes regarding educational practice. Two pithy phrases suggest the reorientation in much current educational research: 'generalizations decay,' and 'statistical realities do not necessarily coincide with cultural realities'. (Rist, 1982, p. 439)
Naccarato (1988) stated that many of the quantitative self-report measures of achievement motivation and attitude toward science are highly susceptible to being influenced by a need of the test taker to respond in a socially-desirable way. He also noted a lack of depth in the description of their validity and reliability, as well as a lack of nationally normed comparisons for most of these instruments. In addition, he believes that educators should not rely totally on pencil-and-paper assessments of motivation, but should include qualitative descriptions of classroom behaviors. Easley (1982) would agree. He described quantitative studies as focusing on linear relationships among variables that are predictive, whereas, qualitative research seeks to understand multiple interacting mechanisms.

Criticism has been raised against qualitative research as well. The first and most often stated criticism is the lack of generalizability. To counter this, Guba (1978) maintained, based on the work of Cronbach (1975), that instead of making generalizations the primary consideration in research, a more important emphasis would be "careful description." Reliability of qualitative studies has also been called into question (Easley, 1977). Opper (1977) asserted that this lack of standardization is really not a criticism. He contended that qualitative methods require an
absence of such standards. Bogdln and Biklin (1982) described qualitative research as having "meaning" as the essential concern. The goal is to understand "participant perspectives from their own point of view" (pp. 29-30).

To offset the criticisms of qualitative and quantitative research methods, the present study has included each of these approaches. Lawrenz and McCreath (1988) believe that both research techniques are needed to provide comprehensive descriptions. The assets and deficits of each appear to be mutually compatible. The quantitative procedures are less susceptible to bias, whereas, the qualitative components provide rich descriptions of the particular situation (Rist, 1982).

Concerning Naccarato's (1988) criticism that self-report measures of achievement motivation generally have low reliability and validity, the 7-item attitude toward science scale and the 4-item achievement motivation inventory used in the present study have a reported reliability of .94 and .88, respectively (Simpson & Oliver, 1985). In order to give a multidimensional evaluation of student motivation, independent observers visited both the experimental and control classes and qualitatively described evidence of student motivation. These descriptions were triangulated with the qualitative descriptions made by the
teachers, and the quantitative measures to more comprehensively compare and contrast the two groups.

Summary

Presently, there is emphasis in science education research on improving instructional practices in order to enhance student learning and to assist in the development of individuals who are scientifically literate (Aldridge, 1989; Linn, 1984; Science for All Americans, 1989.) The intent of the present study was to assist in this effort by describing and field-testing a teaching and learning technique designed to promote enhanced class participation and critical thinking. The stated purpose of this study was to examine the effectiveness of including prediction activities in a 10th grade genetics unit in biology. Aspects of effectiveness that were of greatest interest were enhanced levels of classroom discussion and interaction, improved subject-related attitude, higher achievement motivation, and greater mastery of genetics concepts. Students were asked to make predictions about the patterns and mechanisms of inheritance, as well as to explain, justify, and discuss their predictions.

The rationale for this study focuses on the need for further research in science education describing how the making of student predictions affects interest, motivation, and learning. Good et al. (1988) found that the making of
student predictions augmented classroom discussion and argumentation. The researchers called for additional research on prediction making and its potential as a motivating teaching strategy.

Plagetian learning theory (Plaget, 1969) may be applied in this study. The making of student predictions about the mechanisms of inheritance initiates self-regulation. If predictions are shown to be correct, the new information can be assimilated directly into existing cognitive structure (schemes). Disequilibrium likely results if predictions are shown to be incorrect. Accommodation of the new ideas can occur if appropriate learning opportunities address the areas of difficulty.

Genetics was chosen as the domain of research because of the nature of the problems presented. Manipulation of multiple variables and formal level thinking are often required to understand many of the mechanisms of inheritance, hence this area of biology has been identified as the most difficult by both students and teachers (Smith, 1988). Lavoie and Good (1988) believe that predictions can be made when multiple variables are operating. Genetics appears to be amenable to prediction making because of the interaction of these multiple factors.

Both qualitative descriptions and quantitative measures were employed in this study. Each of these research
approaches has been called into question because of the "sterile empiricism" of quantitative methods (Rist, 1982), and the lack of validity, reliability, generalizability, and consistency of qualitative studies (Easley, 1977). Quantitative research is described as having much precision, but little scope. Just the opposite is true for qualitative methods (Roberts, 1982). An argument can be made against these criticisms since this study utilized both quantitative and qualitative evaluations and descriptions. As Lawrenz and McCreath (1988) suggested, the former "provide the 'hard' data necessary to document the degree of the effects," while the latter "provide richness to the data" and constitute an intuitive and "valuable source for identifying potentially relevant variables" (p. 406).
CHAPTER II

Review of Related Literature

Introduction

The intent of this literature review is to describe research relevant to the present study which has as its purpose to examine the instructional effects of including prediction activities in a high school biology genetics curriculum. Pertinent topics are (a) the process skill of prediction, (b) prior knowledge and alternative conceptions (c) achievement motivation, (d) attitude toward science, (e) problem solving studies in genetics, and (f) combining qualitative and quantitative research approaches.

These topics will primarily be reviewed independently and their relevance to the present research effort will be described.

The Process Skill of Prediction

Prediction has been identified as an important process of inquiry and has long been incorporated into scientific thought process (Good et al., 1988). In recent years there has been renewed interest in teaching science as a process (Self et al., 1989). The basic process skills include observing, inferring, measuring, communicating, classifying, and predicting. Integrated process skills, which encompass and expand the basic skills, include identifying and describing relationships, operationally defining variables,
constructing hypotheses, designing investigations and experimenting, acquiring and processing data, and constructing tables and graphs to display data (Funk, Fiel, Okey, Jaus, & Sprague, 1979).

The National Commission for Excellence in Education (1983) stated that prediction is an essential part of scientific inquiry and problem solving, yet, most science teachers do not adequately include the process skills in their instruction (Germann, 1989). Costenson and Lawson (1986) reported that often science teachers do not like inquiry approaches because they feel students are not capable of the rigors that this type of curriculum requires.

Herber (1978) defined prediction as "an intellectual or emotional extension of one's knowledge or experience into the unknown, under the constraint of specific conditions or actions" (p. 181). Funk et al. (1979) offered the following definition: "Prediction is a forecast of what a future observation might be" (p. 57). Thiel and George (1976) defined prediction as "the acquired ability to use one or more rules from the same or different rule classes to determine the outcome on an event or series of events without prior observation of the outcome of the event or series of events" (p. 155). They identified four factors that affect prediction: (a) experience, (b) the rules used to predict or infer, (c) the types of rules, and (d) the
nature of the task requiring prediction. Tannenbaum (1971) stated that competence in using the process skill of predicting requires that a student "recognize and use pertinent arguments, reasons, or principles to justify a prediction" (p. 135).

Holland et al. (1986) emphasized the role of rules in prediction making. These researchers feel that when a rule leads to a successful prediction it must be strengthened so that it can be used again. On the other hand, when predictions are in error, the student should be assisted in discarding or modifying these ideas. Good (1989) maintained that a learning environment which includes opportunities for making and verifying predictions assists students in recognizing inadequacies in their rule systems and provides the motivation to develop more acceptable rules where there is a better fit between prediction and outcome. He believes prediction-based learning encourages students to be more conscious of their own conceptions and theories and feels these beliefs should be put to the test in the laboratory. Good stated, "I am convinced, for theoretical as well as empirical reasons, that a formal prediction phase is necessary in any science learning theory that focuses on students' prior conceptions" (p. 18).

Concerning theories, Kuhn et al. (1988) argued that students should be encouraged to think "about" their
theories, not just "with" them. Without this awareness of the theory, the relevance of the evidence cannot be assessed. The researchers found that the less strongly a student's belief was held the more effective scientific evidence was in changing the belief system. They maintained that assisting students in gaining control of the adjustment mechanisms needed to refine their theories is one of the essential goals for science education.

Self et al., (1989) noted that since the early 1960s interest has been shown for teaching biology as a process as well as a "body of information," yet there is little evidence of this being implemented in the biology classroom. Dillashaw and Okey (1980) identified Biological Sciences Curriculum Study as the only curriculum project which was specifically designed to utilize and measure competence in the science process skills. There appears to be a need for additional emphasis in biology education on the development and utilization of content specific process skills including prediction.

Prior Knowledge and Prediction

Ausubel (1968) stated that the most important influence on learning is "what the learner already knows" (p. vi). Ausubel, Novak, and Hanesian (1978) suggested that effective teaching should begin with identifying the existing concepts that students bring with them to class, and then building
upon these during instruction. Posner, Strike, Hewson, and Gertzog (1982) would agree, for they viewed learning as more than the addition of new "bits" of information; it requires interaction and reconciliation between old and new knowledge.

The generative learning model (Osborne & Wittrock, 1983) also placed emphasis on knowledge and experiences that students bring with them to the classroom. Like Posner et al. (1982), Osborne and Wittrock believe there is a need for students to be actively involved in learning, constructing understanding by relating the past with the present. Their contention is that learning can only be understood in terms of knowing what "generations" of new understandings have been constructed. Stevens and Collins (1980) asserted that teachers must probe to discover student constructions. A prerequisite is an understanding of students' prior knowledge—those understandings which are brought with the learner. They argued that teaching strategies should build on these. Osborne, Bell, and Gilbert (1982) would agree, for they too believe that teaching should begin with the ideas students presently hold.

According to Osborne and Wittrock (1983), teacher-education programs should include experiences such as interviewing children to identify possible reasons why they hold specific views about topics. A need was
Identified for teachers to be sensitive to, and encourage the expression of pupils' ideas. They believe that in the past students' prior knowledge has been greatly underestimated in its importance to learning. Osborne and Wittrock called for research to find methods which assist teachers in determining what views students hold prior to instruction, and what classroom practices facilitate the generation of new cognitive constructions. They also identified a need to further explore knowledge structure, retrieval cues from long-term memory, and the ways individuals construct memory from new ideas and link these understandings to what is already known.

Head and Readence (1986) observed that research has generally supported the belief that prior knowledge facilitates learning. Pearson, Hansen, and Gordan (1979) found that prior knowledge had a positive effect on both recall and recognition. However, it was shown that if students held "inaccurate schema," prior knowledge could interfere with reading comprehension (Lipson, 1984).

Hewson and Hewson (1983) based their study on the assumption that the source of learning difficulties experienced by science students lies in the knowledge they bring with them to the classroom. The researchers maintained that prior knowledge includes both scientifically correct conceptions as well as alternative conceptions. In
order for new understandings to be integrated with prior knowledge, Hewson and Hewson identified three things which must occur. First, the new information must be *intelligible*, that is, it must be understandable by the students. Second, the new concept must be *plausible*: it must be seen to "be true." Finally, the new knowledge must appear *fruitful* so that it is seen resolving problems and leading to new approaches. "In other words it provides explanatory and predictive power" (p. 722).

Hewson and Hewson (1983) concluded:

We would like to argue that because students have experiences and thoughts about the world, they do come to class with ideas, often ill-formed, hazy, and inappropriate, but ideas nevertheless. These are what students use to understand their world, that is, to make it plausible. When the accepted scientific view is presented it is to these same ideas that it must be reconciled if it is to be accepted. If no reconciliation is effected, either by appropriate teaching or by the student's individual effort, then it is small wonder that science is progressively viewed as abstruse, difficult, incomprehensible, and finally and most dangerously, irrational. (p. 742)

Prior knowledge can play one of two roles. If it is directly addressed then it may be seen as the key to
successful instruction. But if not addressed, then learning can be seriously impeded (Hewson & Hewson, 1983). Lavoie and Good (1988) raised some important questions in their study as to the importance of prior knowledge and cognitive development on prediction success. They identified misconceptions as a "major barrier" to making accurate predictions.

The experimental treatment prediction activities used in the present study were designed by this researcher to elicit prior knowledge about the mechanisms of inheritance. The intention was that by identifying present knowledge, the teachers could more effectively build on appropriate constructions or address misunderstandings and deficiencies.

Prediction in Reading

Readence (1981) identified prediction making as a type of prereading strategy. Head and Readence (1986) suggested that prediction activates prior knowledge by encouraging the use of what is already known. Making predictions also appears to provide guidance in purpose setting, thereby enhancing comprehension. By seeking verification of their predictions, students are encouraged to think about their beliefs in relation to the new information.

Anticipation Guides were developed by Readence, Bean and Baldwin (1985) which utilized prediction as a preinstructional strategy to activate prior knowledge before
reading. A series of carefully worded statements was presented to the learners to challenge previous beliefs. The controversial aspect of the statements was intended to arouse curiosity, hence, motivating them to read in order to resolve the conflict. The researchers contended that this strategy can be adapted for any grade level and for varied media, such as films, or even field trips. Nichols (1983) believes formal prediction guides assist students in focusing on important details as they read, thereby increasing comprehension. Readence et al. (1985) maintained that anticipation guides proved valuable for diagnosing student misconceptions. They recommended that instructional decisions be made based on the identification of these misunderstandings.

A study was conducted by Olshavsky and Kletzing (1979) to determine whether poor readers could predict as well as good readers while reading concrete style stories. They found that good readers made significantly more accurate predictions than poor readers. The researchers suggested that good readers are more capable of formulating hypotheses, while poor readers tend to read at the literal level. Olshavsky and Kletzing (1979) observed that most textbooks are written by presenting information directly; they recommended that prediction be taught initially by using concrete materials.
Smith (1979) asserted that prediction is essential for understanding text because it assists in information processing by narrowing focus through the "prior elimination of unlikely alternatives" (p. 85). Nichols (1983) believes that immediate results can occur using this approach with only minimal effort by the teacher. "Properly used, prediction is a simple but highly effective method of encouraging our students to learn content material" (p. 228).

Prediction in the Social Sciences and Social Studies

People do not usually make predictions "by following the calculus of chance or the statistical theory of prediction" (Kahneman & Tversky, 1973, p. 237). Instead, they utilize a limited number of heuristics which may or may not lead to reasonable judgments. Kahneman and Tversky's thesis is that people make their predictions by "the degree to which the outcomes represent the essential features of the evidence" (p. 238). In doing this the rules of statistics are often violated because factors such as prior probabilities of outcomes and reliability of the evidence are ignored. "A fundamental rule of statistical prediction is that expected accuracy controls the relative weights assigned to specific evidence and to prior information" (p. 239).
McAulay and Camello (1976) maintained that the key to successful predictions in social studies activities is the use of a questioning strategy that requires resource reliability, justification of causality, determination of inferred trends, and the influence of personal values on projected events. By making predictions, the students not only acquire an understanding of how events can be linked to causes, values, and goals, they also gain practice in distinguishing between relevant and insignificant factors. Students come to learn that their personal values and judgments affect predictions, therefore, "the child comes to realize that he can shape his own future and that some external factors can be controlled in shaping that future" (p. 348).

Prediction in Science Education

A well-designed and relevant study was conducted by Lavoie and Good (1988). They examined the inclusion of the science process skill of prediction during the first phase of the three-phase learning cycle. The purpose of their research was to describe the mechanisms of thought associated with making predictions. They were interested in how prior knowledge, cognitive level, and the making of successful predictions affected the prediction process. The study utilized a computer simulation on water pollution with tenth grade biology students. Lavoie and Good included two
qualitative research techniques. Piagetian clinical interviews were used to identify subjects for the study. Ericsson and Simon's (1984) "think aloud" interview technique served as the second qualitative technique. The intent was to elicit verbalization of the subject's reasoning and thought.

The researchers found that successful predictors tended to have high or moderate initial knowledge, formal-level thinking ability, and high academic achievement. Greater improvement in prediction was found from stage one to stage three of the learning cycle in subjects who had high initial knowledge. Lavoie and Good (1988) suggested that higher prior knowledge may have assisted the students in focusing on relevant information about the relationships between the variables.

Unsuccessful predictors were found to have low initial knowledge, were concrete in their thinking, and displayed low academic achievement. They also displayed more misconceptions and confusion, seemed to give little thought to their responses, and did not seem to wonder about effects or relationships. Successful subjects showed more persistence and higher motivation during exploration and prediction than did the unsuccessful subjects. Those who experienced success averaged 50% more simulation runs, took more notes, and generally seemed more interested.
Successful predictors systematically manipulated the independent variables, whereas, the less successful made unsystematic manipulations changing several independent variables at a time.

Another relevant study conducted by Good et al. (1988) also included prediction in the initial phase of the learning cycle. The researchers prepared physical science and physics prediction activities based on studies reported in various journals and monographs. These activities were used to assess students' ideas about the science concepts under consideration. Those in the experimental group recorded their predictions prior to content presentation. This constituted the initial phase of the learning cycle. The next phase involved laboratory experiences that allowed students to seek confirmation of their predictions, as well as to explore related ideas.

As part of a qualitative evaluation, the teachers involved in the study were asked to describe their feelings about the effectiveness of student predictions in promoting motivation, class discussion, and friendly argumentation. The teachers noted an increase in class participation and student interaction, resulting in more energetic discussions. They also indicated that students who made predictions and then tested them were better able to realize their alternative conceptions, and replace them with more
scientifically accurate descriptions. The studies by Lavoie and Good (1988) and Good et al. (1988) both concluded that prediction making served as a motivating factor and called for additional research. The present study evaluated student motivation and involvement in the lesson when prediction making was included as an introductory activity to the lesson.

Thiel and George (1976) also investigated prediction making. They tested whether giving verbal and visual rules would enhance the ability of students to make predictions. The researchers noted several studies which indicated that rule-giving was important in increasing skill performance. Scandura (1968) hypothesized that most learning is rule-governed. Carlson (1967), Lowery and Allen (1969), Kuhn and Novack (1970), and Ring and Novack (1971) all reported that rule giving enhanced learning. Thiel and George (1976) suggested that the questions to ask are what kinds of rules are used in making predictions, and what effects do rules have in the development of the skill of prediction?

Thiel and George (1976) found that the group performances of students given the algorithms, and those that were not, showed no significant differences. This suggested that concrete-operational children may not use rules unless they can correlate them with what is already
present in their cognitive structure. The researchers maintained that the curriculum designer, as well as the classroom teacher, need to become more aware of the role that rules play in prediction skill development.

An important implication of Thiel and George's study (1976) was that the types of rules used in successful prediction making have not been thoroughly described. Because of their emphasis on the importance of rules, the experimental treatment students participating in the present study were required to explain their predictions and justify the rationale (rules) they used in making them.

In a qualitative study conducted by Sinclair and Fowler (in press) ninth grade environmental science students made predictions about what their world would be like in 25 years using a prediction strategy adapted from McAulay and Camello (1976). This strategy required resource reliability and a consideration of the influence of personal values. The researchers stated that the students participating in the study increased their understanding of how events are linked to causes, values and goals, and they also enhanced their skill of distinguishing between relevant and insignificant factors. Sinclair and Fowler concluded that by using the prediction strategy, the students came to learn that their personal values and judgments affect their predictions, which lead to the realization that their decisions assist in
determining what the future will be like. In the present research effort several of the experimental treatment activities required the students to make predictions based on personal beliefs. In each case they were asked to reflect on how their personal values influenced their responses.

Summary

The use of prediction as an instructional strategy in the classroom has received research emphasis in reading education (Head & Readence, 1986; Nichols, 1983; Olshavsky & Kletzing, 1979; Readence, 1981; Readence, Bean & Baldwin, 1985), the social sciences and social studies (Kahneman & Tversky, 1973; McAulay & Camello, 1976), and science education (Good et al., 1988; Lavole & Good, 1988; Thiel & George, 1976). From these studies there is a general indication that the making of predictions enhances learning by focusing the students' attention on the concepts under consideration (Lavole & Good, 1988; Nichols, 1983), and by motivating the students to seek verification of their predictions (Head & Readence, 1986; Good et al, 1988; Lavole & Good, 1988; Nichols, 1983).

Only a few studies in science education were identified by this researcher which investigated prediction making as an instructional approach. There appears to be a need for the development of teaching and learning strategies that
include prediction, as well as studies that further describe and evaluate the inclusion of prediction making in the curriculum. The present study was involved in such an effort.

**Genetics as the Domain of Study**

**Problem Solving in Genetics**

Smith (1989) identified the need for science teachers to more effectively integrate subject matter content with problem solving. He stated, "Good teaching in any subject has two central goals: to develop in-depth understanding of that subject and to enhance critical thinking skills. Problem solving requires both: understanding subject content and the ability to apply that understanding" (p. 67). Smith and Good (1984) stated that "the most critical educational task of current society must be to develop within students the ability to think, to solve problems" (p. 895).

Most of the research on problem solving in biology has involved studies in classical genetics dealing with issues such as alternative conceptions, cognitive demands of genetics problems, and expert-novice problem solving strategies. Stewart (1982) found that the difficulty high school biology students experience in solving genetics problems was not their lack of combinatorial reasoning, but a lack of adequate understanding of meiosis and reduction
division. They were able to generate the gamete genotypes using an algorithm, but were not able to explain how this related to the mechanisms of segregation in meiosis. With only a very few exceptions, students were able to define related terms and concepts, but were not able to describe how they correlated with each other, or to the overall problem they were attempting to solve.

The method used for the selection of the 14 students participating in Stewart's study (1982) was not described. Also, most of the students were identified as successful problem solvers. A lack of a representative sampling indicates a need for further research with students of varying abilities.

A number of studies (Cho, Kahle, & Nordland, 1985; Smith, 1983; Thompson & Stewart, 1985; Tolman, 1982) have shown that unsuccessful problem solvers are most frequently reported to display a weak understanding of the relationships between the information given in the problem, the meiotic events involved, and the application of the appropriate algorithm (Smith, 1989).

An area of problem solving that has recently been investigated by researchers is the comparison of expert and novice subjects. At the post secondary level, Smith and Good (1984) analyzed the problem solving abilities of undergraduates (novices) and graduate students and
Instructors in biology (experts) while they solved moderately complex genetics problems. Because some of the successful problem solvers were novices, the researchers recognized that the dichotimization of expert and novice was not applicable. The latter used strategies not unlike the experts, differing primarily in lack of less content-specific protocols.

Smith and Good (1984) found that successful subjects performed a task analysis, broke the problem into parts, and solved it in a step-by-step manner using a "knowledge development" (working-forward) approach. They were also better able to recognize patterns. "Pattern recognition is often the key to planning the solution path and is sometimes the problem's solution itself" (Smith, 1989, p. 70). Unsuccessful problem solvers were often observed using "means-ends" (working-backward) analysis, frequently resorting to one-step solutions or random trial and error. They also applied incorrect information (misconceptions) to the problem solution and were less accurate in their bookkeeping. Those that experienced less success paid little attention to detail and, almost without fail, began to work before there was a clear understanding of the goal of the problem. Unsuccessful problem solvers typically used faulty or inappropriate logic, and often did not "recognize logical necessity." Smith (1983) found that less successful
students were not as able to differentiate between "essential and nonessential information" in the problem.

An important implication of Smith and Good's study (1984) was that common alternative conceptions should be addressed directly, and early in the genetics curriculum. They recommended that a pretest be used to identify inappropriate or prescientific interpretations of the mechanisms of inheritance. In the present study, the students' prior knowledge of genetics was assessed by both the genetics achievement pretest and the predictions which the students made about the mechanisms of inheritance.

Another study at the college level comparing novice and expert solutions of genetics problems was conducted by Hackling and Lawrence (1988). Their investigation focused on the ability of problem solvers to use cues in a systematic testing of alternative hypotheses to explain inheritance patterns in pedigrees. They maintained that pedigree problems are in a separate category since a diagram is presented to the students and the testing of hypotheses is required. The researchers stated that genetics pedigree problems require the student to use "task-appropriate schemas" in order to recognize critical cues in much the same way as diagnosis is made from the recognition of disease symptoms in medicine. Chase and Simon (1973) found that the ability to encode critical cues within data was a
characteristic of expert problem solvers when encoding chess positions. Genetic pedigree diagrams have been likened to chess board positions because both involve a visual display of cues.

The results of Hackling and Lawrence's study (1988) showed that the experts were more rigorous in the falsification of alternative hypotheses, and varied their problem-solving strategies relative to the specific pedigree diagram. The novices were unable to make these strategy modifications. Because hypotheses cannot be conclusively verified by confirming evidence, the researchers concluded that teachers should emphasize the value of falsifying alternative hypotheses.

In a similar study Smith (1988) analyzed the problem solving protocols of undergraduate (novice) and graduate genetics students and biology faculty members (experts) as they solved classical genetics pedigree problems. The researcher found that successful problem solvers used an organized approach, whereas, the unsuccessful subjects seemed to be generally disorganized, "jumping to conclusions" prematurely. The successful subjects assigned genotypes to test their hypotheses and attempted to identify common patterns (critical cues) which would aid them in describing the mode of inheritance. They seemed to follow the production rule that if one condition seems to exist,
then a specific explanation is indicated. The successful subjects were more thorough in their consideration of greater numbers of possibilities and sought to falsify all but one acceptable hypothesis.

The unsuccessful subjects seemed to use no rules, or those that were used were either inaccurate or incomplete. They appeared to be looking for patterns in the pedigree but were unable to recognize their significance. Smith (1988) recommended that the central focus of problem solving instruction should be on the processes, not the product. Students should be encouraged to think aloud.

The findings of Smith’s 1988 study appear to correlate directly with those of Tolman (1982), who found that students make consistent and recurring errors when solving genetics problems. While analyzing data from think-aloud expert-novice genetics problem solving, Tolman found that students experienced common difficulties in the solution of monohybrid crosses, sex-linkage, and codominance problems. One of the major difficulties Tolman identified was the inability to determine appropriate gamete types by failing to realize the need for reduction division during meiosis.

Terminology appears to be another area of difficulty in the solution of genetics problems. Radford and Bird-Stewart (1982) found that students are not able to relate heterozygosity with a dominant trait. Cho, Kahle, and
Nordland (1985) showed that definitions from one text to another vary considerably. This can lead to what Novak (1977) calls "cognitive dissonance" which results when a learner is exposed to two meanings of the same term that appear to be contradictory. Cho, Kahle, and Nordland (1985) stated that the most commonly misused, therefore misunderstood, terms in textbooks are allele, gene and mutation. Mahadeva and Randerson (1982) recommended that the definition of mutation be changed in textbooks. Students need to understand that the effects of mutations are related to the environment in which the organisms live. The same mutation can be an advantage in the arctic and a deficit in the tropics. Stewart (1983) believes that vocabulary in biology should not be memorized, but should emphasize the construction of generalizations which "give the students the power to make explanations and predictions. The inability to describe how concepts are related indicates a lack of understanding of how genetics is structured" (p. 539).

Tolman (1982) maintained that many difficulties could be eliminated if meiosis were directly incorporated into genetics, rather than being isolated in a separate chapter as it was in most texts he examined. Longden (1982) argued that the delay between the introduction of meiosis and the teaching of genetics concepts leads to confusion because the
students do not relate chromosomal division with DNA replication. Ausubel, Novak, and Hanesian (1978) suggested a sequence which progresses from genetics, to meiosis, to chromosome theory. Smith (1989) concluded that the most frequent recommendation made to biology teachers from genetics problem solving research is that the relationship between meiosis and genetics be made explicit.

Further study is recommended by Stewart (1982) on whether learning would increase if students were asked to justify their answers to problems. He proposed that a meaningful solution to a problem should require the student to explain, in terms of genetics, why a particular procedure was used in the solution process. As noted earlier, students in the experimental treatment classes of the present study articulated the rationale they used in making their predictions so that the teacher could identify areas of difficulty or misunderstanding. They were required to explain the reasons for their predictions both in written form on the prediction sheets, and during the dialogue with the teacher and the other students.

**Cognitive Demands and Genetics**

The results of Mitchell and Lawson's study (1988) indicated that hypothetic-deductive reasoning ability was the major predictor variable that limited non-major college biology students in genetics problems solving. An
Interesting finding was that prior knowledge was the only variable that did not account for a significant amount of the variance. The researchers posited that a high correlation appears to exist between general problem solving ability and ability to solve Mendelian genetics problems. Mitchell and Lawson believe that teachers need to be sensitive to students' reasoning ability, and to sources of difficulty to them.

In Mitchell and Lawson's study (1988) a preponderance of females served as the subjects (74 out of 86). The reason for the large number of females was because the students were taking a biological science course for the elementary teacher which traditionally has a small male representation. This reviewer believes additional studies are needed which include a more equitable representation of males.

There appears to be controversy as to whether formal level thinking is required for the solution of genetics problems. While Mitchell and Lawson (1988) found that hypothetico-deductive reasoning was important in the successful solution of genetics problems. Smith's (1983) study indicated that formal operational thought was not necessary, or even sufficient, to successfully solve Mendelian genetics problems. Costello (1984) found that certain topics in genetics are highly correlated with
Piagetian schemata of proportions, inductive and deduction reasoning, and ability to visualize. However, a study by Gipson (1984) found no significant correlations between success on Piagetian tasks and proportional, combinatorial, and probabilistic reasoning during students' performance on genetics problems which were intended to require these cognitive abilities. "It seems appropriate to conclude that formal operational thought is conducive, but not essential to success in problem solving in genetics. In fact, including genetics in high school might be well advised if it provides the mild disequilibrium known to promote development to the formal level" (Smith, 1989, p. 74).

Walker, Mertins, and Hendrix (1979) found that level of cognitive development was directly correlated with successful solution of genetics problems at the college level. A study of biology students revealed a significant relationship between students' abilities to perform Piagetian formal tasks and their abilities to analyze and solve problems in genetics. The researchers suggested that since many students lack the critical analysis skills needed to solve these problems, the presentation of the concepts should be systematic and sequential so that the students can be guided step-by-step through the solution process.

In a study conducted by Walker, Hendrix, and Mertins (1980), college students utilized a self-learning guide
which was designed to facilitate the application of formal level thought patterns in the solution of classical genetics problems. The guides were developed to assist students through inductive processes, allowing them to derive their conclusions independently, and not through a memorized algorithm. The researchers used a Piagetian basis for sequencing the self-learning guide. They observed that a mild state of disequilibrium was produced in the students as they attempted to assimilate the new information. "The student is presented with unfamiliar genetics data and led through the process of predicting consequences consistent with the concepts derived previously through inductive analysis" (p. 106).

The results of the study indicated that students in the experimental groups which utilized the guides scored significantly higher (p<.001) than those in the control group. The researchers concluded, "The logical sequencing of instructional materials employed in this study can effectively facilitate students' abilities to apply Piagetian formal thought patterns to genetic analysis" (Walker, Hendrix & Mertens, 1980, p. 108). They recommended that genetics instructors become informed about Piagetian theory and apply it to their teaching.
Alternative Conceptions

For over 100 years educators have been interested in student misconceptions (Trembath, 1984). However, diSessa (1987) noted that it has only been in the last decade that misconceptions have been seriously investigated by educational researchers. Piaget (1951) used the term child artificialism to describe the prescientific theories children hold about the phenomena in their world. The term alternative conception is preferred by Lawson, Abraham, and Renner (1989). Because these beliefs represent a personal effort to construct models from personal experience, they feel the term alternative conception carries less negative connotations than does the term misconception.

A number of recent studies have revealed that students often hold views about natural phenomena that differ from the consensus of scientists. Champagne, Klopfer and Anderson (1980) and Champagne, Klopfer, and Gunstone (1982) found that common misconceptions in physics were difficult to correct because they are the result of how students interpret their personal experiences. Browning and Lehman (1988) noted that student misconceptions often resemble once valid concepts in the history of science. An example of such a concept is the Aristotelian view of physics. In chemistry, Ben-Zvi, Eylon, and Silberstein (1986) identified similarities between ancient Greek perceptions of the
chemical nature of matter and those of high school students. Clough and Wood-Robinson (1985), Wandersee (1985), and Bishop and Anderson (1986) reported the identification of premodern views in the biological sciences.

Other studies have shown how resistant alternative theories are to eliminate (Johnstone & Mahmoud, 1980; Okeke & Wood-Robinson, 1980). These views are difficult to rectify despite formal instruction (Barrass, 1984; Cho, Kahle, & Nordland, 1985; Griffiths & Grant, 1985). Browning and Lehman (1988) offered the following reasons for the failure of students to replace alternative conceptions: "The fault may lie in instruction that is too simplistic, too cognitively advanced, inconsistent, or insufficiently oriented toward conceptual linkages and the proper sequencing of concepts" (p. 748).

An area of current interest is investigating student alternative conceptions in genetics. A number of techniques have been used to identify these commonly held views. Lawson and Thompson (1988) used essay questions to solicit levels of understanding, while others used the think-aloud technique (Smith & Good, 1984; Stewart, 1982, 1983; Tolman, 1982).

A relevant study was conducted by Hackling and Treagust (1984) using a researcher-developed partially standardized interview protocol, the Inheritance Concepts and
Propositions Interview (ICPI), designed to identify high school biology students' understanding of important genetics concepts. One of the most revealing misconceptions identified was the belief that gametes from both parents carry the full complement of chromosomes. The researchers maintained that monohybrid crosses need to be taught in a way that clearly illustrates the independent assortment of chromosome pairs during meiosis. Another common misconception found was the role probability plays in inheritance. The researchers stated that the teaching of phenotypic ratios may be harmful to the understanding of the role chance plays in inheritance. The subjects displayed a lack of comprehension of what Good (1977) calls the "law of large numbers." They simply failed to understand that the small number of offspring produced by human families will markedly deviate from predicted phenotypic ratios. Hackling and Treagust (1984) believe that instruction should de-emphasize phenotypic ratios because they have little relevance for human genetics.

The results of Lawson and Thompson's study (1988) indicated that formal reasoning ability is essential for the removal of some biological misconceptions. They found that significantly smaller percentages of formal level thinkers held genetics misconceptions relating to acquired characteristics and genetically transmitted traits. The
researchers concluded that virtually all "naive" students, regardless of cognitive level, will adopt the theory of acquired characteristics. Concrete-operational students did not reject this naive theory, even when presented with correct scientific principles. Lawson and Thompson (1988) suggested that this was because they did not have the reasoning patterns to evaluate competing hypotheses. The researchers noted that the more subtle the concept, the more often the concrete thinkers evoked their naive theories. They simply fail to utilize appropriate and relevant information to generate scientifically correct predictions, even though they may "have 'understood' the theory of natural selection in a limited sense . . . " (p. 743). The subjects in Lawson and Thompson's study were from the same teacher's seventh grade classes. Perhaps if the sample had been randomized across teachers and grade levels the results would have been more generalizable for varying age groups.

Lawson and Thompson (1988) concluded that it is very important for teachers to provide students with opportunities to discuss their prior conceptions so that they can be compared with the new scientific concepts. This is necessary to assist students in identifying why their alternative conceptions are not scientifically correct. "If understanding these reasons requires formal reasoning patterns, it would seem necessary for the students to be
formal operational; hence instruction must be designed to promote its development in concrete operational students' (p. 745).

Students in the present study were encouraged to dialogue with both their teacher and their fellow students about their predictions. The teachers identified alternative conceptions by the analysis of both written and verbal student responses concerning their predictions; instruction was implemented to address these specific misunderstandings.

Computers and Genetics

Smith (1988) maintained that one of the more promising instructional techniques is the microcomputer and software programs that challenge students to solve genetics problems. The computer generates data, and the student is required to analyze and interpret the results. Smith feels students should be given multiple opportunities to practice and apply what they have learned; the microcomputer provides such opportunities. A study done by Schuytema, Carter, and Eshler (1980) would support this contention. The researchers found that practice accounted for 89 percent of the differences between successful and unsuccessful problem solvers.

Genetics microcomputer programs such as CATLAB (Kinnear, 1982a) and BIRDBREED (Kinnear, 1982b) hold great
promise as an instructional tool (Smith, 1989). Peard (1983) identified several reasons why microcomputer programs have positive effects. First, they assist in identifying what the learner already knows, as well as areas that seem to be giving the greatest difficulty. Second, the computer has the capacity to generate data randomly on different levels of knowledge and reasoning. Third, the microcomputer requires that students be active and involved in their own learning. Fourth, the programs require students to think analytically as they interpret data and design experiments to test their hypotheses. Finally, students seem to enjoy learning with the use of microcomputer programs.

Computers can also be used as diagnostic and evaluation tools. In a study described earlier by Browning and Lehman (1988), three consistent subject errors were identified using a computer program to measure genetics problem solving abilities in college students. First, there were mistakes in the numeric predictions of offspring. The researchers observed that this appeared to be related to lack of appropriate computational skills. A second error identified was the inability of subjects to determine the appropriate genetic composition of the parental gametes. As noted earlier, this deficiency was also found by Tolman (1982), Stewart (1982, 1983), and Hackling and Treagust (1984). The third common mistake was that subjects applied inappropriate
algorithms to new situations. There seemed to be a reliance on memorized heuristics without any thoughtful consideration of their application. Smith and Good's study (1984) supported this finding.

Summary

An understanding of the basic concepts of genetics is important because its principles underlie many other biological concepts such as natural selection (Stewart, 1982). In the past decade there has been research interest on genetics problem solving both at the high school (Stewart, 1982, 1983) and college levels (Browning & Lehman, 1988; Smith, 1988; Smith & Good, 1984). One of the primary findings was the difficulty students have with linking the mechanisms of meiosis while solving genetics problems (Stewart, 1982). Another area of research in science education has been in comparing the approaches experts and novices use in solving genetics problems (Hackling & Lawrence, 1988; Smith, 1988; Smith & Good, 1984). Experts tended to break the problem into parts using an organized approach in the solution, whereas, the novice often used "means-ends" analysis (working-backward) or random trial and error (Smith & Good, 1984).

Level of cognitive development and successful solution of genetics problems has also been investigated (Lawson & Thompson, 1988; Mitchell & Lawson, 1988; Walker, Hendrix, &
Mertins, 1980; Walker, Mertins, & Hendrix, 1979). Walker, Mertins, & Hendrix (1979) found a direct linkage between level of cognitive development and success in the solution of genetics problems. The results of Smith's study (1983) indicated that formal level thinking was not required for the solution of Medelian genetics problems. Smith (1989) concluded that "formal operational thought is conducive, but not essential, to success in problem solving in genetics."

There has been increased research interest in science education on alternative conceptions students hold about inheritance and genetics (Hackling & Treagust, 1984; Lawson & Thompson, 1988). Browning and Lehman (1988) believe the results of their study, along with others on misconceptions in genetics problem solving, indicated that curricular revision may be required, as well as modification of teaching approaches. Stewart (1980) would concur. He argued that teachers and science education researchers need to identify common alternative conceptions so that subsequent instruction can be designed to target these misunderstandings or misinterpretations.

Browning and Lehman (1988) stated that biology instructors cannot assume that students have basic computational skills or clear understanding of the mechanisms of genetics. They also maintain that "educators need to take full advantage of the instructional potential
of computers and other promising technologies. The development of an 'intelligent' genetics problem-solving tutor should be a step in that direction" (p. 760).

There appears to be a need for research in science education whose end is to develop instructional strategies which assist students in gaining mastery of the complex mechanisms operating in the inheritance of genetic traits. The purpose of the present study was to test the effectiveness of an instructional strategy which required students to make predictions about the mechanisms of inheritance as an introduction to the genetics topics. Smith (1989) observed that mastery of genetics and problem solving performance appears to be affected by several factors including student motivational level and cognitive style. The experimental treatment prediction activities used in the present research effort were designed to promote critical analysis and increase student interest and involvement in the lesson, thereby elevating levels of motivation.

Recommendations included in this literature review of genetics problem solving research assisted this researcher in refining the experimental treatment prediction activities used in the present study.
Student Motivation

Studies are reviewed in this section which describe the multi-faceted dimensions of student motivation. By reviewing previous research, a sense of direction was gained as to how the present study could further knowledge in the field by including both quantitative and qualitative evaluations of this construct.

Achievement Motivation

Achievement motivation generally refers to "an enduring disposition to value learning as a worthwhile and satisfying activity, and then to strive for knowledge and mastery in learning situations" (Brophy, 1987, p. 181). Kremer and Walberg (1981) operationally defined achievement motivation as "any measured intrinsic drive or extrinsic reward that influences student performance during an instructional treatment or test situation" (p. 13).

Intrinsic versus extrinsic achievement motivation.

Workman and Williams (1980) described achievement motivation as most characteristic of persons who find intrinsic rewards in learning. "Learning for learning's sake" is an often sought goal by educators, yet multiple studies have shown that attainment is not realized in most classrooms. "Teachers resort to a variety of external payoffs such as grades, tokens, trinkets, edibles, free-time activities, and praise to get children to engage in academic activities"
They believe extrinsic rewards can be used to encourage the reestablishment of intrinsic motivation which was lost when students became discouraged by criticism or lack of success.

Both positive and negative extrinsic reinforcers have been used in the classroom. Eldredge (1983) described positive reinforcers as those which are perceived as being needed or valued by the learner. Negative reinforcers are those which have consequences that are seen by the learner as neither needed nor desired. Eldredge maintained that both types may be used during instruction, but if negative reinforcers are used, they should be immediately followed by suggestions on how to improve.

Gender differences and achievement motivation. Data collected both in the United States and around the world indicated that boys scored higher on achievement tests in science. By age 14, females showed significant differences in achievement and began "to see science as the domain of males" (Peltz, 1990, p. 46). Dweck (1986) observed that a number of studies have shown that in grade school girls and boys have comparable mathematical achievement, and the girls surpass the boys in verbal skills. However, during the junior and senior high school years boys pull far ahead. Maehr and Nichols (1980) found that females have a tendency to be seen as "well intentioned" in most classroom settings.
It was suggested that this compliant style may be detrimental to both science achievement and to career choices in science. The researchers also contended that females do not have as strong a sense of competence as males when approaching the learning of science concepts. Goldberg (1988) found that females solve problems in a manner that causes the "least disruption" among people. Girls want their work to look good, so they spend significantly more time and energy focussing on format" (Peltz, 1990, p. 47).

Significant differences between bright boys and bright girls were found by Licht, Linden, Brown, and Sexton (1984). The females tended to prefer familiar tasks in which they already had competence. The males chose activities which required hard work to master. A study by Leggett (1985) revealed that junior high girls had a greater tendency to view intelligence as a fixed trait than did boys. Dweck (1986) believes achievement variances can by explained by the different motivation patterns which the two sexes display. It was noted that girls tend to avoid challenge, yet most mathematics courses in high school present information which is new and challenging. For this reason, these courses may be avoided by many females. Dweck maintained that gender differences do not display themselves in verbal areas since the content tends to build slowly and gradually on past activities.
Peltz (1990) observed that many researchers have attempted to explain gender achievement differences. Even though a number of causes have been studied such as sex role stereotypes and genetic potential, cultural biases appear to have the greatest impact.

Achievement motivation and science education. Although there is a great deal of research on the general topic of motivation, only a small part directly relates to motivation in the classroom (Brophy, 1987). Slavin (1984) conducted a literature review on motivation and found that most of the research is theory based with little practical application on how it should be applied to increase student motivation. Even though motivational processes are known to influence students' acquisition of knowledge and skills, "educationally relevant conceptions of motivation have been elusive" (Dweck, 1986, p. 1040).

Maehr (1983) believes the reason for American students' poor showing in recent international testing in science "is a motivational problem as much as it may be a social, economic, cognitive, or instructional problem" (p. 185). He contended that motivation theory has not been applied in any systematic way to achievement in science.

Kremer and Walberg (1981) also observed that research in science education has neglected student motivation as an area of emphasis. The researchers reviewed refereed science
education journals from 1964-1979 to identify studies relating science achievement and learning with three constructs, student motivation, home or family environment, and peer-group influences.

As a result of their analysis, Kremer and Walberg (1981) found the mean correlation for student motivation as a predictor for science learning to be .37, higher than for either of the other two constructs (home environment or peer-group environment). "The science teacher can raise motivation . . . but such changes require the cooperation of other agents such as the students themselves and their families" (Kremer & Walberg, p. 12). Bloom (1976) and Uguroglu and Walberg (1979) reported similar correlations with achievement in reading and mathematics. It would appear that the relationship between student motivation and achievement appears to be independent of subject content.

Lavoie and Good (1988) found that motivation and persistence affected predictions and problem solving success. Low motivation levels were identified in students who made incorrect predictions. Smith and Good (1984) also suggested that motivation plays a role in successful genetics problem solving. The researchers observed that motivation may be affected by successful problem solutions, which in turn may lead to continued success and motivation.
Attitude toward science and achievement motivation.

As much as 25% of the variance in school achievement can be accounted for by students' attitudes toward what they are studying (Bloom, 1976). In the summary of the 1982 National Association of Educational Progress, Rakow (1983) noted that students' favorable attitudes towards science decreased the longer they stayed in school. Teachers were viewed as "question-askers" and "providers of information." An interesting finding was the more academic preparation a teacher had, the less motivation and excitement students displayed. Perhaps the most alarming finding was that as students progressed through the science program they did not feel more successful or curious.

Attitudes toward science appear to be established by the age of 11. Science is viewed by males as a "masculine subject," while the females "must walk a tight rope between pride in their achievement and a threat to their feminine self-image and social support" (Peltz, 1990, p. 46). More enthusiasm is shown by boys in attitude toward science surveys, especially about the physical sciences (Peltz, 1990).

Simpson and Oliver (1985) conducted a multi-dimensional long-term study on attitude toward and achievement motivation in science with 4,000 students in grades 6 through 10 in 12 randomly selected schools. The
researchers developed a 7-item attitude toward science scale and a 4-item achievement motivation inventory composed of short, simple statements. Both evolved from a larger pool of items. These measures were included in the present study (see Appendix B).

The students in Simpson and Oliver's study (1985) completed these inventories at the beginning, middle, and end of the school year. The primary findings were that favorable attitudes toward science declined in grades 6 through 8. Also, attitudes toward science declined for all grade levels from the beginning to the middle of the school year. Males were shown to exhibit significantly more positive attitudes toward science in all grades, whereas, females displayed significantly higher achievement motivation. Motivation scores declined for both genders with each grade level, and also from the beginning to the middle of the year.

Simpson and Oliver (1985) stated that if this trend continues, the United States will lose its place of leadership in the scientific and technological communities. They believe that science should be emphasized more during the elementary grades. As a result of poor elementary preparation, many adolescents enter their first serious science course with an inadequate background. If the middle school experience is not favorable, then it is highly
probable that many of the students will take only a minimum number of science courses.

As an extension of their 1985 study, Oliver and Simpson (1988) tracked achievement in high school science students over time. They identified students whose science achievement was higher or lower than their achievement in other areas. The rationale was that these students would exhibit attitudes towards science that would have the highest correlation with achievement. The researchers believe that achievement motivation, along with attitude toward science, and science self concept (which describes the extent the student believes success in science is possible) affect student achievement. The results of their study indicated that both achievement motivation and science self concept were predictors of achievement. Attitude toward science was not found to be a significant predictor.

A disturbing finding of Simpson and Oliver's long-term study (1990) was that from grades 6 through 10, attitudes toward science dropped consecutively. Decline in both attitude and motivation was most marked among students with middle ability. The researchers suggested that the reason for the decline was those above and below the middle level received additional attention either in enrichment or reinforcement.
One of the most revealing findings was that the science classroom had a strong influence on attitude toward science. Also, students' attitudes were highly correlated with those of their friends. Science self concept at the 10th-grade level was found to be a good predictor of the future selection of science classes. Students with less positive attitudes towards science were found to have selected fewer science courses.

Results from the 10-year study (Simpson & Oliver, 1990) support the idea that attitude toward science and achievement motivation, in combination with science achievement scores in required science courses, are the primary contributors toward the student's science self concept. These, in turn, affect their future attitude and commitment toward science and their lifelong interest in learning science. The researchers concluded that educators must acknowledge that presently our school science programs are not producing scientifically literate citizens across the board.

Simpson and Oliver's long term study (1990) provided insight into the design of the present study. Because of their findings that attitude toward science and achievement motivation changed over time, inventories which measured these constructs were pre- and posttested to determine whether changes occurred during the four-week study.
Qualitative Versus Quantitative Measures of Student Motivation

Even though pencil-and-paper assessments of motivation exist, they generally have not shown as high validity as instruments that measure achievement or ability. Most of the self-report group measures of academic motivation use Likert-scaled formats in which the student selects which one of the descriptions is more like himself or herself. This type of instrument is highly susceptible to influencing socially-desirable responses on the part of the test-taker. Most of these measures are concerned with predicting future success in school. In some cases they are auxiliary to other evaluations such as those that measure achievement; they primarily look at discrepancies (e.g. high motivation and low achievement) (Naccarato, 1988).

Many of the self-report measures of motivation do not show sufficient depth in the description of the validity and reliability of the instruments, and a majority of them do not have nationally normed comparisons. This was not the case for Simpson and Oliver's (1985) achievement motivation inventory included in the present study. The researchers reported a reliability of .88. Naccarato (1988) called for "higher quality investigation of instrument validity as well as discriminate validity studies, where several measures may
be compared in an effort to determine differences in motivation constructs" (p. 7).

A recent interest in cognitive theories for motivation to learn was noted by Naccarato (1988). He believes the construct of motivation has both cognitive and affective dimensions and contends that research is needed to determine which has the greater effect. Naccarato maintained that educators should not rely totally on pencil-and-paper assessments of motivation, but should also include other measures such as qualitative observations and descriptions of classroom behaviors.

Ames (1987) noted that when the quantitative perspective is used, the emphasis is usually on enhancing achievement. Qualitative descriptions of motivation, on the other hand, often focus on student cognitive processes—how they think about themselves and their task. The emphasis is on modifying how students think in order to enhance personal competence in directing and maintaining their own learning.

Enhancement of Student Motivation

Thompson (1987) reviewed the literature concerning motivation and identified five areas that have been shown to increase student motivation: (a) incentives, (b) unusual activities, (c) goal setting (d) students motivating other students, and (e) parents motivating students to learn.
Concerning unusual activities ("the novelty factor"), Madsen and Madsen (1983) suggested that constant routine such as habitual use of the textbook is unmotivating. They recommended that teachers vary their classroom activities and include innovative and enjoyable experiences to promote learning. Such things as games, cooperative grouping, and peer tutoring were suggested by Thompson (1987) as extrinsic motivators of student involvement and interest in the lesson.

Mathison (1989) reported that even though multiple strategies such as graphic organizers, mapping, summarizing techniques, and questioning strategies have been used to stimulate student interest, motivation levels still appear to be low. Resolving a paradox or presenting conflicting information are two teaching strategies that she recommended to enhance student motivation.

Lowry and Johnson (1981) found that controversy enhanced achievement more than concurrence. They identified a need for research on how "perspective-taking ability" can be promoted in the classroom. Johnson, Johnson, Pierson, and Lyons (1985) showed that "structured academic controversies" resulted in greater involvement in the learning situation. "Participating in controversies seems to promote positive and constructive interaction among participants rather than the negative interaction often
feared by teachers and inexperienced students" (p. 846).
The researchers suggested that argumentation and controversy resulting from supporting personal convictions facilitates learning. Students in their study were selected from grades 4, 5, and 6 on a stratified random basis. Perhaps a limitation was their study included only younger children.
The present research effort provided opportunities for high school students to participate in structured controversy. Students in the experimental classes were encouraged by their teachers to defend their predictions during a time of classroom discussion.

Mathlison (1989) concluded that level of personal involvement in any task appears to influence learning. She contended that if students can be assisted in acquiring a positive and anticipatory attitude toward an activity, student motivation can be enhanced.

Summary

Most current research on motivation seems to suggest that intrinsic motivation can be influenced by teaching strategies, yet these techniques have not been comprehensively identified nor described. The problem is compounded by the fact that motivation appears to be composed of both cognitive and affective components, and the interactions between these two dimensions have not been adequately described (Nacarrato, 1988). Kremer and Walberg
(1981) stated that motivational factors in science education have been neglected in research studies. Lavoie and Good (1988) recommended research to identify strategies that affect motivation during the solving of different kinds of problems. They called for the development of valid and reliable instruments to measure student motivation.

Research has centered primarily on analyzing cognitive skills that affect learning, rather than those that affect motivational processes. Dweck (1986) noted that for the past 15 years a remarkable change has taken place in the study of motivation. Emphasis has shifted from external and intrinsic influences on motivation to more qualitative social-cognitive approaches which describe how children interpret their situations and experiences.

Ames (1987) observed that even though motivation has been shown to be a significant influence on student learning, adequate measures of this complex phenomenon do not exist. Qualitative studies could assist in describing this multiple-dimensioned construct, and from these descriptions effective measures could be developed to evaluate student motivation. The end of such measures would not be merely the description of motivation, but would lead to the development of teaching and learning strategies that could address identified deficiencies. The present research included such an effort. The experimental treatment
prediction activities used in this study were designed to promote student involvement and interest in the lesson, thereby enhancing levels of motivation.

The studies included in this literature review represented a variety of dimensions of student motivation in order to gain an overall understanding of the present state of knowledge concerning this construct. The general conclusion that this researcher was able to draw from the review was that studies are indicated which specifically investigate how activities utilized in the classroom affect student interest and motivation. Because of the call for both qualitative and quantitative evaluations, both approaches were included in the present study to more completely describe the experimental treatment effects on student motivation.

**Research Methods**

**A Comparison of Qualitative and Quantitative Research Methods**

Educational research has historically utilized the quantitative measurement tradition rather than naturalistic qualitative methods. Firestone (1987) observed that there are basic epistemological differences between quantitative and qualitative research. The former is based on a positivistic philosophy which posits that social and behavioral activities can be described objectively. The
latter has its roots in a phenomenological paradigm which maintains that reality is constructed socially through individual or collective definitions of the situation which cannot be comprehensively described quantitatively.

The purpose of quantitative research is to explain causes through objective measurement and analysis. Qualitative research emphasizes understanding the social phenomenon through the perspective of the participants (Taylor & Bogdan, 1984). The design of quantitative research is typically experimental or correlational to reduce error and bias (Cronbach, 1975). The protocol of the qualitative method is to describe the situation of those studied (Goodenough, 1971). The researcher's role in quantitative research is detached to avoid bias. The qualitative researcher is encouraged to express tacit and intuitive feelings in the descriptions of the participants and their situation (Powdermaker, 1966). "Rich description persuades by showing that the researcher was immersed in the setting and giving the reader enough detail to 'make sense' of the situation" (Firestone, 1987, p. 16).

Qualitative and quantitative research methods result in different kinds of constructions. The latter constructs reality in the "formist/mechanist" mode, emphasizing precise quantifications which connect variables. In contrast, qualitative research methods are described as
"contextualist/organicist," constructing reality in terms of real-life situations and emphasizing links between an event and the context in which it occurs. Roberts (1982) describes quantitative research as having much precision, but little scope, whereas, just the opposite is true of qualitative methods.

Criteria for judging quantitative research have been in place for some time; these measures are described in almost any experimental design textbook. This is not the case for qualitative studies. Most of the techniques have come out of cultural anthropology; one has to depend on fairly general analytical skills to evaluate ethnographic studies (Roberts, 1982).

Rist (1982) observed that educators are becoming disenchanted with highly quantified measures which he labels "sterile empiricism." He called for qualitative naturalistic research which utilizes unstructured observation, clinical interviews, and document analysis over extended periods of time. Qualitative research was summarized by Smith (1982):

The crux of naturalistic research and what makes it different from the traditional and more familiar research methods of experiments, correlational studies, and surveys is the logic of discovery. That is, the data come first. Out of the data are teased
descriptive patterns, hypotheses, perhaps theory, or even a 'story'. (p. 627-628)

Bogdín and Biklin (1982) identified five characteristics of qualitative research. First, it occurs in a natural setting with the researcher as the "key instrument." The assumption is that human behavior is greatly affected by the context of the setting in which it occurs. Second, qualitative research is descriptive in that data is collected in words or pictures and not by quantified numbers. Many records are anecdotal because they contain quotations or specific examples of particular situations. Third, qualitative researchers are interested in process, not just products. Bogdín and Biklin believe this kind of emphasis is extremely useful in educational research. Whereas quantitative data can show that change has occurred, qualitative data describe how these changes are transferred into daily activities. Fourth, data analysis is done inductively by qualitative researchers. Their intent is not to extract data that evidences a particular theory. Instead, ground. ted theory is derived from the descriptive data that has been collected. "The process of data analysis is like a funnel: things are open at the beginning (or top), and more directed and specific at the bottom" (p. 29). Finally, "'Meaning' is of essential concern . . ." (p. 29).
The goal is to understand "participant perspectives" from their own point of view.

**Combining Qualitative and Quantitative Methods**

Qualitative methods have evolved from being "scoffed at" to being accepted as valued research approaches. Yet, there are those who cannot accept the compatibility of the positivistic, quantitative paradigm with the interpretivist qualitative paradigm (Roberts, 1982). They believe the two research modes are at opposite ends of a continuum. "Those who pursue the one tend to eschew the other. Moreover, it is highly unlikely that many individual researchers are expert at using both methodologies—partly, of course, because of the amount of training required to do high-quality research . . . " (Roberts, 1982, p. 277).

In spite of this, Roberts (1982) believes that qualitative and quantitative research have "complementarity" since both contribute uniquely to the research effort. Project Synthesis (Harms, 1979) was produced by a "synergistic" effort of both research approaches. Roberts contended that complementary information was provided which assisted in better describing the reality of science education than either could do alone. Howe (1988) argued that no incompatibility exists between the two methods either in epistemology or practice. He maintained that in practice, educational researchers can combine both
qualitative and quantitative data, even though distinctions are made at the epistemological, design, and analysis levels.

Firestone (1987) also expressed the feeling that qualitative and quantitative research are complementary. He examined two studies that addressed the same topic, one using qualitative descriptions and the other quantitative measures. The issue being researched was whether leadership affected organizational outcomes. The two studies essentially corroborated each other. Both found that leaders have important effects only at certain critical times. Where results are not mutually supportive, Firestone believes more research is indicated; important lines of inquiry can be described in the areas of disparity.

Combining qualitative and quantitative evaluations is not without precedent in science education. Lawrenz and McCreath (1988) used both methods to compare the effectiveness of two physical science inservice training programs for teachers. The quantitative measures included pre- and posttesting for science content. The questions were drawn from physical science items provided by the National Assessment of Educational Progress (NAEP, 1978). Attitudes toward science were measured by the Wareing Attitude Toward Science Protocol (WASP) (Wareing, 1986). These measures were administered to both groups of teachers,
and to selected sections of their students. The teachers also completed Beliefs about Science and Science Education (BSSE) (Good, 1971; Lawrenz, 1984).

Lawrenz and McCreath's (1988) qualitative efforts included observations of the teachers in their classrooms, interviews, and questionnaires. The interviews included open-ended questions concerning the teachers' reasons for participating in the program, how effective they felt the experience had been, and how it could be improved. The questionnaires were also open-ended and contained demographic items as well as descriptions of "best" and "worst" parts of the program.

The two methods revealed different results. Qualitatively, the programs were quite distinctive in atmosphere and emphasis. An analysis of the qualitative descriptions showed that the teachers in the 1984-85 study were more enthusiastic; they felt the inservice experience had a significant effect on their teaching. There seemed to be more camaraderie in this group and a willingness to report on how the activities had worked in their classrooms. In the 1985-86 study, teachers were more content oriented and their sessions were more formal. The 1984-85 teachers were described as being more low-key; the participants seemed to enjoy the program more. The 1985-86 group indicated that the class was interesting, and even helpful,
but they did not feel it was enjoyable, nor did they view it as having a significant influence on their teaching.

Lawrenz and McCreath (1988) stated that the two evaluation procedures "provided a much clearer picture of the strengths and weaknesses of the two programs" (p. 397). The researchers concluded: "In summary the qualitative components provide richness to the data and are a valuable source for identifying potentially relevant variables. The quantitative components provide the 'hard' data necessary to document the degree of the effects" (Lawrenz & McCreath, 1988, pp. 406-407).

Both qualitative and quantitative descriptions and measures were included in Quackenbush's (1985) study. The researcher developed and tested guidelines for biology teachers desiring to prepare their own science text-lab manuals. Students were pre- and posttested on both cognitive (mastery of subject matter) and affective (attitude toward subject matter) dimensions to determine any differences in these constructs. Qualitative aspects of the study included narrative comments by the experts (professional teachers) and the students concerning the lab manual's strengths and weaknesses. Selected quotations from the surveys were included in the summary of data.

Significant differences (p<.01) were found on the cognitive dimensions between the students who utilized the
manual and those who did not. Attitudes toward the subject matter showed less positive results. The qualitative comments about the manual by both experts and students were generally favorable. By triangulating the qualitative and quantitative results, Quackenbush felt that he was able to more completely describe the effectiveness of the manual.

Summary

Butts (1982) stated that research in science education should have as its highest priority to determine how the science curriculum and instructional strategies can be used to enhance student learning. The literature reveals a disenchantment with totally quantitative research (Rist, 1982). Butts (1982) believes researchers should first use ethnographic strategies to describe what is happening in the classroom prior to any modification. Denzin (1978) would concur, for he commented, "The researcher who has not yet penetrated the world of the individuals being studied is in no firm position to begin developing predictions, explanations, and theories about that world" (p. 39). The argument continues that naturalistic studies should be included in educational research to assist in "discovering the cognitive and social interactions mechanisms that underlie the learning process in classrooms" (Easley, 1982, p. 91). Studies in science education have utilized qualitative descriptions in tandem with quantitative
measures (Lawrenz & McCreath, 1988; Quackenbush, 1985). In both of these studies the researchers indicated that by combining the two methods more complete descriptions were made.

Although quantitative and qualitative methods provide different types of information, if triangulation of the two types of data show them to be mutually supportive, robustness is added to the findings (Jick, 1979). Roberts (1982) stated that he feels both quantitative and qualitative methods are necessary for the evolution of science education research. There are "equally legitimate sets of metaphysical presuppositions lying behind the two different approaches..." (p. 291). The call is for science education to accommodate high-quality work from both research modes (Firestone, 1987; Howe, 1988; Jick, 1979; Lawrenz & McCreath, 1988; Roberts, 1982). The present research effort attempted such an accommodation.

Final Summary

The studies which were reviewed in this chapter offered a sense of direction and focus for the present research effort through specific recommendations that were discussed in previous sections. As noted by Lovoie and Good (1988), and also this researcher, only limited educational research emphasis has been placed on the process skill of prediction, especially on the development of teaching and learning
strategies that incorporate this process into content-specific curricula. Such was the intent of the present study.

The literature review also revealed a paucity of studies which specifically addressed the development and use of teaching methods to assist students in gaining a mastery of the mechanisms of inheritance. Most of the studies on genetics problem solving reviewed in this chapter were diagnostic. There appears to be a need for research whose purpose is to develop and describe instructional techniques that enhance the learning of the complex mechanisms involved in inheritance. The present study assisted in this effort by investigating the instructional effectiveness of incorporating into a high school genetics curriculum prediction activities designed to augment learning, class participation, and higher-level thinking.

The limited amount of research in science education on student motivation indicates that more emphasis should be given to this area (Kremer & Walberg, 1981; Maehr, 1983). Kremer and Walberg (1981) concluded that motivation can be manipulated, "and the value of attempts to manipulate these constructs experimentally in the hope of making science-education more productive is indicated" (p. 21).

By combing qualitative and quantitative research methods Lawrenz and McCreath (1988) believe "a much clearer
picture" is presented of the program being evaluated. Jick (1979) argued that "robustness" is added when the two evaluation methods are mutually supportive. For this reason, both research approaches evaluating student motivation were included in the present study in the hope of adding to our understanding of this complex construct.
CHAPTER III
Research Procedures and Methods

This chapter presents an account of the methods used in the present study based on the rationale established in the previous chapters. The overall purpose of this research project was to examine the effects of prediction activities on instructional outcomes in a high school genetics unit. The researcher-developed prediction activities were designed to stimulate student interest and critical thinking prior to formal instruction on the concepts. Enhanced levels of classroom discussion and interaction, higher achievement motivation, more positive attitudes toward science, and greater mastery of genetics concepts were identified as the areas of effectiveness being evaluated.

Pilot Study

A pilot study was conducted for a six-week period with a biology class (n=18) in a high school with a student enrollment of approximately 1300 during the spring of 1990. It was necessary to conduct the study during the second semester with Biology II (second-year) students because genetics had already been taught during the first semester in Biology I (first-year). A teacher with over twenty years of experience instructed the pilot class.

The purpose of the pilot study was to field-test the researcher-developed prediction activities (see Appendix A).
Several aspects of their effectiveness were of interest. First, were the directions and explanations given on the sheets clear and unambiguous? Second, were the students able to make predictions and explain them based on the directions given? Third, did the making of student predictions appear to affect student interest and promote discussions about the topics? Finally, was the teacher able to identify alternative conceptions through the use of the prediction activities?

Students in the pilot study made written predictions using the prediction activities. They were asked to discuss these with the class and explain the reasons why they were made. Following the discussion of the predictions, the genetics concepts were further developed using multiple instructional strategies including the working of sample problems, cooperative grouping, and laboratory experiences.

The teacher kept a qualitative log similar to the one used in the larger study (see Appendix E). The primary difference between the logs was that the pilot teacher did not instruct a control treatment class, therefore she could not compare the two groups (experimental and control). Using the open-ended format, she cited specific examples of student involvement and interest in the lesson, and described any alternative conceptions which were identified as she analyzed the students' predictions. The teacher also
Indicated in her log what aspects of the prediction sheets proved particularly helpful, or were confusing.

The Biology II students who participated in the pilot study completed genetics achievement pre- and posttests. Analysis of the pretest scores indicated that their knowledge of genetics was far from mastery level. The mean score on the pretest was 12.67 out of 25. The mean score on the posttest was increased to 19.59 out of 25. No control group was included because the teacher taught only one Biology II class.

Results of the Pilot Study

Informal observations were made by this researcher, and an informal interview was conducted with the teacher following the completion of the pilot study. She voiced primarily positive opinions about including prediction activities in a study of genetics. The teacher stated, "The thing I liked best about the students making predictions was that it really challenged them to think. It really seemed to improve their ability to reason." She also felt that the students enjoyed making and discussing their predictions. They served as a springboard for many "animated" discussions.

An analysis of the teacher's log revealed that for almost every topic there was spirited discussion of the students' predictions. The only activity that did not
promote discussion was "Mendel's Principle of Dominance and Recessiveness." The teacher felt the reason for this was because the students were already familiar with these concepts from their Biology I course. She recommended that several of the sheets (i.e., "Genetic Engineering," and "Applied Genetics") be simplified and shortened for the Biology I students who would participate in the larger study. Because the average time spent on the genetics unit in Biology I rarely exceeds four weeks, it was her suggestion to abbreviate the larger project by at least one third.

On the last day of the pilot study the students were asked to make written comments concerning how they felt about including predictions in the study of genetics. Most of the students' comments were favorable. A representative sample is cited below:

Quotation 1:

"I felt that these were very easy to understand, even though they contained a lot of information. They made it easier to comprehend the stuff, instead of just memorizing it and not knowing what it meant."

Quotation 2:

"The genetics sheets were a very good method of instruction. The students were able to learn but also have fun."
Quotation 3:
"... they're a lot better than taking notes. Also, it is easier to study them than notes because you don't have to shuffle through the material."

Quotation 4:
"The worksheets were great for a change of pace, but sometimes confusing."

Quotation 5:
"I felt like it did not help me that much. I do better when it's taught the other way."

The teacher was able to identify a number of alternative conceptions. One of the most noteworthy was the belief that "many more" human males were born than females. One of the most positive effects of the study noted by the teacher was that she was able to address these misunderstandings during instruction as a result of their being revealed through the students' predictions.

Summary
The results of the pilot study indicated that the making of student predictions enhanced interest in the topics and encouraged student discussion and argumentation. The teacher and the students had primarily favorable opinions about the prediction activities. The teacher was able to identify a number of alternative conceptions from the students' predictions which were addressed during the
Instruction which followed. She stated, "It was particularly helpful to the students when they were able to understand why their original approach was inappropriate."

Most of the explanations and directions on the prediction activities were understood by the students. Upon the teacher's recommendations, a number of the prediction sheets were simplified, shortened, or reworded for greater clarity. She also suggested that the control classes be taught prior to the experimental classes so that the teacher would not experience carry-over effects from the prediction activities. The data and descriptions collected during the pilot study were used to refine the research design of the larger study.

The Research Sample

The research sample for the larger study consisted of biology students in three racially balanced public high schools in a metropolitan area of Louisiana. Each of these schools had a student enrollment of approximately 1,200. Because of the difficulty of randomized sampling in the scheduling of student bodies of this size, students were assigned to the biology classes by the regular scheduling process at the beginning of the school year in August, 1990. The research sample for the larger study initially consisted of 201 biology students; due to attrition and missing data, 179 students constituted the final sample.
Each of the biology classes was composed of students who were heterogeneously grouped according to ability, race, and gender. Table 1 summarizes the student demographic information. Separate chi square analyses of age, grade in school, race, and gender revealed no statistically significant differences between the experimental and control students. It should be noted that the schools participating in this study are part of a large system which operates several magnet high schools for academically talented students. Primarily students with medium and low abilities attend the three schools in this study because of the removal of the higher-achieving students to the magnet schools. The mean scores on nationally-normed tests for all three of the student bodies were well below the 50th percentile. The study lasted for four weeks during the months of November and December, 1990.

**Description of the Teachers**

Four experienced biology teachers participated in the study. To protect their identity, they will be referred to in the masculine gender and by code-letter designations (A, B, C, and D). In actuality, two of the four teachers were females. All were experienced biology teachers, with tenures ranging from 6 to 20 years. Each was recommended to this researcher by his principal as an effective biology teacher with classroom management skills and knowledge of
Table 1

Summary of Student Demographics

<table>
<thead>
<tr>
<th></th>
<th>Control Students (n=82)</th>
<th>Experimental Students (n=97)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Age</strong></td>
<td>15.5</td>
<td>15.6</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
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<tr>
<td>9-10</td>
<td>64</td>
<td>82</td>
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<tr>
<td>11-12</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>35</td>
<td>54</td>
</tr>
<tr>
<td>Female</td>
<td>47</td>
<td>43</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>39</td>
<td>43</td>
</tr>
<tr>
<td>White</td>
<td>43</td>
<td>54</td>
</tr>
</tbody>
</table>
subject matter. The teachers' familiarity with individual student characteristics made their comments invaluable while evaluating the effects of the prediction activities on student participation.

The teachers taught one class which received the experimental treatment and one control treatment class. As was suggested by the pilot study teacher, to lessen any carry-over effects from the prediction activities by the teacher, the control classes preceded the experimental classes during the school day.

The following section of this chapter contains a brief description of the four teachers based on observations made by the independent observers involved in the study.

**Teacher A**

Teacher A was described by one of the observers as "friendly but business-like." Another depicted him in the following manner: "He is eager, like a sheep dog guiding the flock, working hard to move them in the right direction. He really wants the students to learn, and he probes and questions to find better ways of conveying ideas. He was interested and enthusiastic about the concepts being presented."

His classroom was orderly, and there were few behavioral problems. An observer wrote, "Time-on-task was high mostly because of much note taking." The teacher
primarily lectured, giving many relevant examples, analogies and anecdotes. As he lectured, he used either the overhead projector or the chalkboard to explain specific ideas. He asked many closed questions with one answer in mind. Most of the students were called on during a single class meeting. They seemed to feel free to ask the teacher questions as the lesson progressed, but very few student-student interactions were observed.

One thing noted by this researcher while visiting in Teacher A's classroom was the respect he gave the students. Each was shown individual attention and interest; they felt comfortable to dialogue with him, but always in a respectful manner. He often dressed up in costumes, celebrating particular events sponsored by the cheerleaders at his school. The students were amused by his antics, and a spirit of fun permeated his classroom. Yet, when the lesson began he conveyed to them that he was ready "to get down to business" and they responded accordingly.

Teacher B

The metaphor that comes to mind when describing Teacher B is "drill sargent." He spoke often in a "booming" voice and was in complete control of his classes. All dialogue and discussion came through him. The atmosphere was courteous and business-like. There was regimentation of classroom routine; the students lined up to turn in their
papers. Little student-student interaction was observed even before the class tardy bell rang. Misbehavior and off-task behavior was simply not tolerated and the students seemed to know this. One student was corrected for saying, "Yea."

Routinely, Teacher B lectured and the students took notes. There was some student questioning, and the teacher positively reinforced them by saying, "Excellent." He often turned to the students and asked, "Are you with me?" There was limited dialogue between the teacher and the students. One of the observers wrote, "He works hard at teaching, keeping interest up and covering the material so that all understand. He interjected a thought occasionally that would perk up the interest level."

The teacher displayed sensitivity. On one occasion an observer described him dealing kindly and patiently with a student who seemed to be "lost"; he quietly walked over to the student and suggested that they work one-to-one on the concept whenever the student could arrange to come back.

**Teacher C**

Teacher C was knowledgeable, self-assured, and confident. He had a strong personality and was definitely in charge of the classroom. The metaphor that seems appropriate is "autocrat." The tone of his voice was sometimes harsh as he directed comments to specific students.
such as, "That's not right," or "You ought to know that."
There were a few off-task behaviors observed, but the
teacher addressed them immediately when they were noticed.
An observer described his moving two students to other desks
because they were talking too much to their former
neighbors.

During most of the lessons observed, the teacher
lectured with use of the overhead projector while the
students took notes. There was a great deal of
knowledge-level questioning directed to specific students or
to the classroom in general. One observer noted that he
often called on students who had difficulty understanding,
saying, "Are you with me?" They seemed comfortable asking
the teacher questions, and readily responded when he called
on them.

Often the students were observed completing individual
worksheets at their desks as the teacher walked around
answering specific questions. Teacher C then went over the
correct responses with the entire class. At other times he
was observed having students read from their textbook. "He
really works hard at seeing that they understand," wrote one
observer. "His eyes were constantly moving around the room,
watching to see if the students were comprehending the
information."
Teacher D

A small ship in a boisterous sea comes to mind when describing Teacher D. He was the only one of the four teachers who was not in control of his classroom. Much of his time was spent correcting students who were misbehaving. It seemed he was "fighting all the time for control," stated one of the observers. Even though he was knowledgeable and well prepared, one had the feeling that the ship might be swamped at any moment. His demeanor was not assertive; he tried to be firm, but as one researcher wrote, "It is not in his nature." An observer noted that he seemed to like teaching and really tried very hard.

The students in his classes were "spoon fed." It was evident to the observers that they were not often challenged to think, and when they were, there was "constant complaining." The teacher often lectured using the overhead; the students were required to write down the notes he gave them. They also completed many study sheets which he pulled from his well-stocked files. As the students worked he would walk around, questioning them individually. They would then go over the work sheets as a class, correcting invalid responses.

There was much off-task behavior observed. One researcher concluded, "The students just did not seem focused."
Subject Matter

The subject area chosen for this study was genetics, specifically, the mechanisms and patterns of inheritance. The prediction activities used in the experimental treatment classes were developed for 19 genetics topics selected from the course content, instructional objectives, and parish and state curriculum guides. Each of these topics involved multiple factors influencing the operation of the mechanism. Lavoie and Good (1986) stated that any dynamic physical or biological system that involves several variables is amenable to the making of predictions about the relationships and influences that operate within the system.

Prediction Activities

Students in the experimental treatment classes participated in 19 researcher-developed prediction activities (see Appendix A). The activities used varied formats such as multiple-choice responses or open-ended essays. Others involved genetic crosses requiring the use of Punnett squares. Some of the prediction activities were content related and the students responded based on specific mechanisms of inheritance. An example of this type was "Dihybrid Crosses and Mendel's Principle of Independent Assortment." Using this activity, the students predicted the types of offspring that would result from the two-trait
crosses. Other activities promoted thoughtful consideration, requiring the students to make predictions based on personal beliefs and values. One such opportunity was presented during the "Finding and Treating Human Genetic Disorders" activity. They were asked to make predictions about what options would be available to them if serious genetic diseases were identified in their own family. Still other activities, such as "How Blood Types Are Inherited," "Pedigrees," and "Polygenic Traits," were designed to promote analysis and critical thinking.

Genetics Achievement Test

The researcher-developed 20-item multiple-choice genetics achievement test measured the students' mastery of the patterns and mechanisms of inheritance. A panel of biology teachers, as well as the teachers participating in this study, determined the content validity of the test. Criterion validity was established by the criterion referencing of each test item with the instructional objectives of the state and parish curriculum guides. Item reliability was established for the genetics achievement test at .53 for the control students and .63 for the experimental students.
Achievement Motivation and Attitude Toward Science

Inventories

Achievement motivation and attitude toward science were measured in this study by scales developed by Simpson and Oliver (1985) (see Appendix C). Each is composed of short, simple statements to which the students respond using a 5-choice Likert format. The 7-item attitude toward science questionnaire evolved from an original pool of some 30 items piloted and revised in a large study involving 4,000 students grades 6 through 9, 178 science classes, 57 teachers, and 12 randomly selected schools. The response options for these measures range from strongly agree (1) through undecided (3) to strongly disagree (5). The 4-item achievement motivation inventory was developed from an original pool of 12 items. Item reliability was established by Simpson and Oliver at 0.94 for the attitude toward science scale, and 0.88 for the achievement motivation inventory.

Teacher Behavior Inventory

The researcher-developed Teacher Behavior Inventory (TBI) (see Appendix D) used in this study was adapted from the Virgilio Teacher Behavior Inventory (Teddle, Virgilio, & Oescher, 1990). The Likert-format response options range from far below average (1) to average (3) to far above average (5). Using this measure, the independent observers...
quantitatively compared and contrasted the teaching style of each instructor during the experimental and control classes. The observers were also encouraged to give a narrative explanation of their responses if they felt clarification would assist the researcher in interpreting their evaluation.

Teacher Log

Using an open-ended format developed by this researcher (see Appendix E) the four teachers participating in this study kept a daily log qualitatively comparing and contrasting their experimental and control classes. The general guidelines of the log were designed to assist the teachers in focusing on relevant occurrences in their classroom.

Field Notes

Independent observers made qualitative field notes using an open-ended format developed by this researcher (see Appendix F). Following these general guidelines, they compared and contrasted the experimental and control classes on evidence of student interest and involvement in the lesson.

Interviews

The format for the interviews conducted with the experimental and control students (see Appendixes G and H), as well as with the teachers (see Appendix I), was the
general interview guide approach suggested by Patton (1989). Using this protocol, the interviewer develops a checklist of relevant topics to be covered which serves as the interview guide to insure that common information is obtained. "The interviewer is thus required to adapt both the wording and sequence of questions to the specific respondents in the context of the interview" (p. 198). Two experienced science educators confirmed that the checklist included relevant items.

**Design and Procedure**

**Experimental Treatment**

Students in the experimental treatment classes participated in the prediction activities prior to formal instruction on the genetics topics. They made written predictions about the patterns and mechanisms of inheritance using the activities developed by this researcher and field-tested during the pilot study. An important aspect of their prediction making was the requirement that the students explain the rationale they used. Following the making of written predictions, the teachers engaged the experimental treatment students in dialogue about their responses, encouraging them to rationally justify their predictions.

The students were requested to keep the prediction sheets which they had just completed (stamped "Original") on
the side of their desks in order to refer to them as the discussion proceeded. They were asked not to make any additional marks on these sheets. These original responses would be turned in at the end of the discussion for analysis by the teacher. An identical set of sheets (stamped "Student Copy") was provided each student in the experimental treatment classes. They were encouraged to take notes on this copy as the predictions were discussed with the teacher and with the other students. The students were allowed to keep this second set for further study and consideration.

The teachers identified and recorded in their logs any alternative conceptions held by the students through their written predictions, as well as their verbal explanations. The instruction which followed the time of discussion addressed specific alternative conceptions that were revealed by the students' predictions. Activities were implemented to assist them in recognizing the scientifically correct explanations. Research has shown that teacher intervention is essential. When students are left alone, they are likely to seek confirmation of their alternative conceptions (Lawson & Thompson, 1988).

**Instructional Sequence**

The only activities from which the control treatment
classes were excluded were the prediction activities used to introduce the genetics topics in the experimental treatment classes. In place of the predictions, the control treatment students usually took notes as the teacher lectured about the topic. The order of the presentation of the genetics concepts was left up to the individual teachers, as were the instructional strategies they used to further develop the ideas. The teachers were encouraged to teach the two classes similarly so that the primary variable was the prediction activities used in the experimental treatment classes.

Each of the teachers, because of their idiosyncratic styles, included a variety of activities in their genetics unit, but the experiences were common to both classes. Instruction in the control treatment and experimental treatment classes (following the introductory prediction activities) included multiple strategies such as questioning, the presentation of examples and analogies, guided practice in problem solving, microcomputer simulations, laboratory experiences, and cooperative grouping. The following activities are examples of the varied experiences the students participated in during the genetics unit. Teacher B's students raised three generations of *Drosophila* and determined the phenotypic ratios for each generation. Students in Teacher A's classes
made microscopic slides of *Drosophila* salivary chromosomes. Teacher C's students raised corn and bean seedlings to compare growth patterns (all factors were controlled except genetic traits). Library reference reports were done by Teacher D's students describing how purebred lines are established in domesticated species.

**Quantitative Measures**

A pre- and posttest control-group experimental design was used to evaluate the quantitative measures (genetics achievement, achievement motivation, and attitude toward science). Slavin (1984) maintained that pretests are essential so that the achievement level of students can be determined prior to treatment. Identical pre- and posttests for these three measures were administered to all experimental and control students prior to the genetics unit, and again at the completion of the study.

Using the TBI, the independent observers quantitatively compared and contrasted the teachers during their experimental and control classes. They objectively described the classroom climate, teacher-student and student-students interactions, lesson development, and teaching style of each teacher during instruction of the two classes.

**Scoring.** Each of the 20 items on the genetics achievement test was weighted with a value of one,
therefore, the maximum score attainable was 20. For the other two inventories, lower scores indicated more positive attitudes since the statements were worded in the positive direction. Options were selected from a 5-choice Likert scale. The least score on the 7-item attitude toward science inventory was seven, while the maximum possible score was 35. The lowest score possible on the 4-item achievement motivation measure was four, while the highest was 20.

The students recorded their responses for the three quantitative measures on answer sheets. The responses on these sheets were read and scored by an optical mark scanner. The data were transferred to magnetic tape and transcribed to a system network computer center for analysis.

The observers' responses on the Likert scale for each of the items surveyed by the TBI were weighted corresponding to the number of the choice (one through five). A mean score for the experimental and control classes was calculated for each of the teachers on the items assessed.

**Qualitative Descriptions**

**Teacher Log.** The teachers kept a log qualitatively comparing and contrasting the experimental and control classes on evidence of student interest and involvement in the lesson. Such evidence included participation in class
discussions, questioning by the students, their responses to the teachers' questions, argumentation for one's own point of view, and other displays of interest in the topic.

The professional judgment of the teachers was an integral part of this qualitative aspect of the study because they were knowledgeable about individual student characteristics. Reliability of the teachers' observations was increased by involving the teachers in three training sessions which emphasized making qualitative anecdotal descriptions. As part of the training, the teachers viewed a video of a science class (instructed by this researcher) during the discussion of student predictions about the genetics topics. The teachers were asked to record their observations relevant to student participation and displayed interest. These observations were shared with the other teachers and this researcher in order to consider the salient aspects of making and recording qualitative descriptions.

**Independent Observers.** In addition to the teachers' descriptions, independent observers visited the four teachers at least once each week during the study. The primary observer was a teacher with thirty years of secondary classroom experience in science and home economics. A professor of science education and this researcher also observed the teachers as often as their
schedules would permit. The observers made their descriptions using an open-ended format comparing and contrasting the experimental and control classes on evidence of student interest and involvement in the lesson.

**Interviews.** At the completion of the genetics unit, this researcher interviewed 16 randomly selected students (eight from the experimental classes and eight from the control classes). Students from the experimental group were asked to describe how they felt about the prediction activities, as well as the genetics unit. Those in the control classes were questioned about their attitude toward the genetics unit. Interviews were also conducted with each of the four teachers. The teachers were asked to tacitly describe their feelings about including prediction activities in a high school genetics curriculum. Researcher-generated questions arose out of the context of the teachers' responses to the topics identified by the general interview guide. All of the interviews were audio-taped and later transcribed for analysis.

**Data Analysis**

The following research questions were analyzed using the experimental treatment and control treatment groups as the primary units of analysis. Statistical significance was set at the .01 alpha level.
**Question One:** Will high school students who participate in prediction activities during a genetics unit demonstrate a greater mastery of genetics concepts on an achievement test when compared to students who do not participate in these activities?

The pre- and posttest genetics achievement scores of all students participating in the study (both experimental and control) were analyzed using a repeated-measures analysis of variance to determine whether significant differences occurred between the two groups.

**Question Two:** Will high school biology students who participate in prediction activities during a genetics unit demonstrate enhanced achievement motivation when compared to students who do not participate in these activities?

Again, the scores from the pre- and posttests on the achievement motivation questionnaire were analyzed using a repeated-measures analysis of variance to determine whether the experimental and control groups displayed differences on this construct.

**Question Three:** Will high school biology students who participate in prediction activities during a genetics unit demonstrate enhanced, subject-related attitude when compared to students who do not participate in these activities?

Scores from the pre- and posttest attitude toward science inventory were analyzed using a repeated-measures
analysis of variance to determine if there were any differences between the experimental and control classes in their attitude toward science.

**Question Four:** Will high school students who participate in prediction activities during a genetics unit demonstrate a higher correlation among greater mastery of genetics concepts, enhanced subject-related attitude, and enhanced achievement motivation when compared to students who do not participate in these activities?

Regression analyses were performed on the experimental and control groups’ pre- and posttest scores for the three quantitative measures (genetics achievement, attitude toward science, and achievement motivation) to determine the extent of the linear relationships between these variables within the group.

**Question Five:** Will high school students who participate in prediction activities during a genetics unit demonstrate enhanced levels of classroom interaction (i.e., classroom discussion and content-related argumentation) when compared to students who do not participate in these activities?

The qualitative descriptions (which included the teachers’ logs, the observers’ field notes, and the interviews with the teachers and students) comparing and contrasting the experimental and control classes were
analyzed using the techniques suggested by Bogdan and Biklen (1982). They recommended that the researcher read through the qualitative field notes in order to describe coding categories. "As you read through your data, certain words, phrases, patterns of behavior, subjects' ways of thinking, and events repeat and stand out" (p. 156). Lincoln and Guba (1985) called this process unitizing and categorizing. The former involves describing units of recurring importance that can stand by themselves. The latter classifies these units into categories which can be characterized by a propositional statement describing the essence of the category.

All qualitative field notes, teachers' logs, and interviews with the teachers and the students were analyzed in this manner by this researcher, with the assistance of the primary observer. The coding categories were identified by reading through the qualitative descriptions searching for regularities, and then writing down words and phrases which described these patterns. Each emerging unit was written on an individual note card; the cards were then sorted into categories, and a propositional statement was made describing the category. This technique assisted the researcher in summarizing the qualitative information.
Summary

The purpose of this study was to examine the effects on instructional outcomes of including prediction activities in a high school genetics unit. The researcher-developed prediction activities required the experimental treatment students to make predictions, prior to formal instruction, about the patterns and mechanisms of inheritance, as well as to explain and justify their responses. The primary differences in the instruction of the experimental and control groups were that students in the former classes made written predictions as an introduction to each of the 19 genetics topics, and then explained their predictions during a time of classroom discussion. The teachers taught the two classes similarly following the prediction activities, utilizing a variety of experiences including laboratory activities and guided practice in the solution of problems.

The study incorporated both quantitative measures and qualitative descriptions. A repeated-measures analysis of variance examined any quantitative differences between the experimental and control groups on genetics achievement, attitude toward science, and achievement motivation. Regression analyses were performed to determine the extent of the linear relationship between the three quantitatively evaluated variables.
Qualitative descriptions were made by the teachers and the independent classroom observers comparing and contrasting the experimental and control students as to classroom participation and other evidence of involvement and interest in the lesson. These descriptions, along with the interviews with the teachers and the students, were analyzed using Bogdan and Biklen's (1982) coding categories. The categories were designated by reading through the field notes and identifying events of recurring importance. These were used by the researcher to compare and contrast the experimental and control groups.
CHAPTER IV

Results

Introduction

The purpose of this study was to investigate the instructional effects of including prediction activities in a high school genetics unit. Analyses of the data were performed on the following areas of effectiveness being evaluated: (a) mastery of genetics concepts, (b) enhanced achievement motivation, (c) enhanced attitude toward science, and (d) augmented levels of classroom interaction. Results will be presented relative to these identified areas of effectiveness in response to the research questions stated as subproblems in Chapter I of this study. Additional findings will also be described. As noted earlier, in order to protect the identity of the teachers involved in the study, each is referred to in the masculine gender and by code-letter designations (A, B, C, and D).

Genetics Achievement

The first research question concerned whether including prediction activities in high school genetics would result in greater mastery of genetics concepts. Scores on the genetics achievement pre- and posttests for both the experimental and control students were analyzed to determine whether differences existed between the two groups.
Table 2 presents a summary of the repeated-measures analysis of variance for the factors teacher, group, and time. No statistically significant group effects or group by time interactions were found. Time effects were statistically significant ($p<.0001$). Both the experimental and control groups experienced statistically significant increases in genetics achievement from the pre- to the posttest. Table 3 summarizes the descriptive statistics for the pre- and posttests for the experimental and control classes. The mean scores for the two groups on these measures were statistically equivalent. The results indicate that the mastery level of the genetics concepts was essentially the same for the experimental and control classes.

Table 2 shows that statistically significant teacher effects ($p<.0001$) and teacher by time interaction ($p<.0007$) were found. A breakdown of the pre- and posttest least squares means for each teacher is presented in Table 4. Single degree of freedom comparisons of the teacher by time interaction showed that the difference between the pre- and posttest scores for Teacher A's students was significantly greater than students in the other teachers' classes.

The difficulty discrimination indexes of the genetics achievement posttests for the experimental and control groups are presented in Table 5. The questions indicated by
### Table 2

**Analysis of Variance Table for Genetics Achievement**

(TR=Teacher; G=Group; T=Time)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>3</td>
<td>376.14</td>
<td>14.42</td>
<td>.0001</td>
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<tr>
<td>G</td>
<td>1</td>
<td>5.95</td>
<td>0.68</td>
<td>.4093</td>
</tr>
<tr>
<td>TR * G</td>
<td>3</td>
<td>44.49</td>
<td>1.71</td>
<td>.1677</td>
</tr>
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<td>error a</td>
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<td>1486.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>1</td>
<td>934.32</td>
<td>187.39</td>
<td>.0001</td>
</tr>
<tr>
<td>TR * T</td>
<td>3</td>
<td>89.16</td>
<td>5.96</td>
<td>.0007</td>
</tr>
<tr>
<td>G * T</td>
<td>1</td>
<td>2.65</td>
<td>0.53</td>
<td>.4670</td>
</tr>
<tr>
<td>TR * G * T</td>
<td>3</td>
<td>15.06</td>
<td>1.01</td>
<td>.3912</td>
</tr>
<tr>
<td>error b</td>
<td>171</td>
<td>852.59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

Descriptive Statistics for Genetics Achievement Pre- and Posttests

<table>
<thead>
<tr>
<th></th>
<th>Control Students (n=82)</th>
<th>Experimental Students (n=97)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Mean Score (out of 20)</td>
<td>6.60</td>
<td>10.01</td>
</tr>
<tr>
<td>Variance</td>
<td>5.25</td>
<td>8.94</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.29</td>
<td>2.99</td>
</tr>
<tr>
<td>Reliability (KR-20)</td>
<td>0.23</td>
<td>0.53</td>
</tr>
<tr>
<td>Standard Error of Measurement</td>
<td>2.09</td>
<td>2.19</td>
</tr>
<tr>
<td>Range of Correct Responses (out of 20)</td>
<td>2-14</td>
<td>4-16</td>
</tr>
</tbody>
</table>
Table 4

Least Squares Means of Quantitative Measures by Teacher

<table>
<thead>
<tr>
<th></th>
<th>Teacher A (n=52)</th>
<th>Teacher B (n=48)</th>
<th>Teacher C (n=43)</th>
<th>Teacher D (n=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetics Achievement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest (out of 20)</td>
<td>6.62</td>
<td>7.99</td>
<td>5.75</td>
<td>5.97</td>
</tr>
<tr>
<td>Posttest (out of 20)</td>
<td>11.57</td>
<td>10.93</td>
<td>8.09</td>
<td>8.97</td>
</tr>
<tr>
<td>Attitude Toward Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest* (out of 35)</td>
<td>17.25</td>
<td>17.03</td>
<td>17.76</td>
<td>21.91</td>
</tr>
<tr>
<td>Posttest* (out of 35)</td>
<td>16.34</td>
<td>16.94</td>
<td>18.59</td>
<td>20.86</td>
</tr>
<tr>
<td>Achievement Motivation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest* (out of 20)</td>
<td>8.23</td>
<td>8.36</td>
<td>8.80</td>
<td>7.95</td>
</tr>
<tr>
<td>Posttest* (out of 20)</td>
<td>8.34</td>
<td>9.10</td>
<td>9.74</td>
<td>8.94</td>
</tr>
</tbody>
</table>

Least squares means are reported for all students since no group effects were shown to be significant.

*Lower score is more positive attitude.
Table 5

**Difficulty Discrimination Index for Genetics Achievement Posttest**

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Control Students</th>
<th>Experimental Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>.89</td>
<td>.18</td>
</tr>
<tr>
<td>#2</td>
<td>.34</td>
<td>.28</td>
</tr>
<tr>
<td>#3*</td>
<td>.70</td>
<td>.61</td>
</tr>
<tr>
<td>#4*</td>
<td>.55</td>
<td>.19</td>
</tr>
<tr>
<td>#5</td>
<td>.37</td>
<td>.37</td>
</tr>
<tr>
<td>#6</td>
<td>.46</td>
<td>.52</td>
</tr>
<tr>
<td>#7</td>
<td>.28</td>
<td>.30</td>
</tr>
<tr>
<td>#8*</td>
<td>.61</td>
<td>.36</td>
</tr>
<tr>
<td>#9</td>
<td>.52</td>
<td>.61</td>
</tr>
<tr>
<td>#10</td>
<td>.29</td>
<td>.54</td>
</tr>
<tr>
<td>#11</td>
<td>.43</td>
<td>.30</td>
</tr>
<tr>
<td>#12</td>
<td>.78</td>
<td>.22</td>
</tr>
<tr>
<td>#13*</td>
<td>.47</td>
<td>.38</td>
</tr>
<tr>
<td>#14*</td>
<td>.23</td>
<td>.41</td>
</tr>
<tr>
<td>#15*</td>
<td>.68</td>
<td>.36</td>
</tr>
<tr>
<td>#16</td>
<td>.41</td>
<td>.51</td>
</tr>
<tr>
<td>#17</td>
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<td>.33</td>
</tr>
<tr>
<td>#18</td>
<td>.51</td>
<td>.43</td>
</tr>
<tr>
<td>#19</td>
<td>.33</td>
<td>.13</td>
</tr>
<tr>
<td>#20*</td>
<td>.52</td>
<td>.07</td>
</tr>
</tbody>
</table>

*Denotes questions that required application of content-specific information for solution of problems.
an asterisk denote those which required application of content-specific information in order to solve the genetics problems. Consistent differences were not indicated between these items and those which primarily measured mastery of content specific information. The difficulty discrimination indexes for the two groups were similar for the questions on the genetics achievement posttest.

The results of the repeated-measures analysis of variance for the genetics achievement pre- and posttest scores revealed no statistically significant differences for race on any of the factors (group, gender, race, time, and teacher). However, statistically significant gender differences were found within the control group. Females had significantly higher ($p<.0063$) least squares means on genetics achievement averaged over time (females = 9.0 out of 20; males = 7.3 out of 20). No statistically significant gender interactions were found for the experimental group.

**Achievement Motivation**

Research question two asked whether the inclusion of prediction activities in high school genetics would result in greater achievement motivation. Pre- and posttest scores on the inventory measuring this construct were also analyzed using a repeated-measures analysis of variance. No statistically significant differences were found between the experimental and control classes for achievement motivation.
In fact, only time was shown to be statistically significant \( p < .0006 \) (see Table 6). Both groups experienced changes in achievement motivation over time. Table 7 shows the least squares means for the achievement motivation pre- and posttests for the experimental and control classes.

Table 4 displays the least squares means breakdown by teacher for the pre- and post achievement motivation inventory. Each of the teachers' classes showed negative changes over time.

The repeated measures analysis of variance for the achievement motivation pre- and posttests for the factors group, gender, race, time, and teacher revealed statistically significant group differences for race. Black students in the experimental classes showed significantly more positive \( p < .004 \) achievement motivation than did the white students averaged over time. The least squares means for black students was 7.2 out of 20; for white students the least squares means was 9.4 out of 20. No statistically significant race interactions were found for the control group.

Females in Teacher D's classes were found to have significantly more positive \( p < .0014 \) achievement motivation least squares means averaged over time (7.3 out of 20 for females; 11.0 out of 20 for males). No statistically
### Table 6

**Analysis of Variance Table for Achievement Motivation**

(TR=Teacher; G=Group; T=Time)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
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<td>0.86</td>
<td>.4631</td>
</tr>
<tr>
<td>G</td>
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<td>0.01</td>
<td>0.00</td>
<td>.9803</td>
</tr>
<tr>
<td>TR * G</td>
<td>3</td>
<td>90.54</td>
<td>1.57</td>
<td>.1983</td>
</tr>
<tr>
<td>error a</td>
<td>171</td>
<td>3285.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>1</td>
<td>41.24</td>
<td>12.20</td>
<td>.0006</td>
</tr>
<tr>
<td>TR * T</td>
<td>3</td>
<td>11.45</td>
<td>1.13</td>
<td>.3389</td>
</tr>
<tr>
<td>G * T</td>
<td>1</td>
<td>2.75</td>
<td>0.81</td>
<td>.3683</td>
</tr>
<tr>
<td>TR * G * T</td>
<td>3</td>
<td>4.44</td>
<td>0.44</td>
<td>.7259</td>
</tr>
<tr>
<td>error b</td>
<td>171</td>
<td>578.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7

Least Squares Means of Attitude Toward Science and Achievement Motivation Inventories

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=82)</td>
<td>(n=97)</td>
</tr>
<tr>
<td><strong>Attitude Toward Science</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest*</td>
<td>18.41</td>
<td>18.56</td>
</tr>
<tr>
<td>(out of 35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest*</td>
<td>17.56</td>
<td>18.81</td>
</tr>
<tr>
<td>(out of 35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Achievement Motivation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest*</td>
<td>8.42</td>
<td>8.25</td>
</tr>
<tr>
<td>(out of 20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest*</td>
<td>8.25</td>
<td>9.12</td>
</tr>
<tr>
<td>(out of 20)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Lower score more positive attitude
significant gender interactions were found for any of the other teachers or for either of the two groups.

An analysis of the qualitative data describing student motivation will be presented in a later section of this chapter.

**Attitude Toward Science**

The third research question asked whether prediction activities included in high school genetics would result in improved attitude toward science. Again, scores from the pre- and posttest attitude questionnaires were analyzed using a repeated-measures analysis of variance. The results of the analysis for the attitude toward science pre- and posttests scores for the factors teacher, group, and time are presented in Table 8. Again, no statistically significant differences were found between the experimental and control groups on this construct, nor were significant time effects indicated. Significant teacher effects were revealed ($p<.0001$). Comparisons of the teachers' means showed that Teacher D's students had significantly higher (therefore less positive) attitude toward science scores. Table 4 displays a breakdown by teacher of the least squares means for the pre- and posttests. The posttest range was from a low of 16.34 (out of 35) for Teacher A's students to a high of 20.86 (out of 35) for Teacher D's. Though not statistically significant, Teachers A, B and D showed
Table 8

Analysis of Variance Table for Attitude Toward Science

(TR=Teacher; G=Group; T=Time)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>3</td>
<td>1209.66</td>
<td>8.56</td>
<td>.0001</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td>42.36</td>
<td>0.90</td>
<td>.3442</td>
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<td>TR * G</td>
<td>3</td>
<td>18.75</td>
<td>0.13</td>
<td>.9405</td>
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<tr>
<td>error a</td>
<td>171</td>
<td>8051.10</td>
<td></td>
<td></td>
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<td>T</td>
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<td>8.08</td>
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<td>.3081</td>
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<td>TR * T</td>
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<td>43.20</td>
<td>1.86</td>
<td>.1377</td>
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<td>G * T</td>
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<td>25.88</td>
<td>3.35</td>
<td>.0690</td>
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<td>TR * G * T</td>
<td>3</td>
<td>4.26</td>
<td>0.18</td>
<td>.9072</td>
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<tr>
<td>error b</td>
<td>171</td>
<td>1321.61</td>
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<td></td>
</tr>
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</table>
Improved attitudes toward science between the pre- and posttests. The least squares means for Teacher C's students became less positive over time but these attitude changes were not shown to be statistically significant.

Table 7 compares the least squares means for the attitude toward science pre- and posttests for the experimental and control classes. Although no statistically significant differences were found, the control classes displayed lower (therefore more positive) least squares means scores on both the pre- and posttests than did the experimental classes.

The repeated measures analysis of variance of the pre-and posttests scores for attitude toward science revealed no statistically significant race differences or interactions for the factors group, gender, race, time, and teacher. Regarding gender, females participating in the study displayed significantly more positive attitudes (p<.0047) over time. Also, females in Teacher D's experimental class scored significantly lower (p<.0007) (indicating a more positive attitude) than did the males in the same class over time. Though not statistically significant, males in Teacher D's control class showed more positive (p<.0176) attitudes toward science over time. As previously noted, Teacher D's students, both male and female, had significantly higher (therefore less positive)
least squares means on the attitude toward science pre-and posttest inventories (see Table 4).

Correlation Among Genetics Achievement, Attitude Toward Science, and Achievement Motivation

Research question four queried whether students participating in prediction activities in high school genetics would demonstrate a higher correlation among greater mastery of genetics concepts, enhanced subject-related attitude, and enhanced achievement motivation. Correlation analyses were performed on the three measures to determine the extent of the linear relationships among these variables.

Table 9 shows the posttest Pearson correlation coefficients matrix for the three constructs (genetics achievement, attitude toward science, and achievement motivation) for the experimental and control groups. No significant correlations were found between genetics achievement and either attitude toward science or achievement motivation for the control group. A significant relationship ($p=.0019$) was indicated between genetics achievement and attitude toward science, but not for achievement motivation for the experimental classes. The negative correlations between genetics achievement and the other two variables, attitude toward science and achievement motivation, is expected since higher scores on the former
Table 9

**Pearson Correlation Coefficient Matrix for Posttest Quantitative Measures**

<table>
<thead>
<tr>
<th>Attitude Toward Science</th>
<th>Achievement Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td><strong>Experimental</strong></td>
</tr>
<tr>
<td>Genetics Achievement</td>
<td></td>
</tr>
<tr>
<td>( r = -0.0188 )</td>
<td>( r = -0.3119 )</td>
</tr>
<tr>
<td>( p = 0.8671 )</td>
<td>( p = 0.0019 )</td>
</tr>
</tbody>
</table>

Attitude Toward Science

| \( r = 0.3480 \)       | \( 0.4099 \)            |
| \( p = 0.0014 \)       | \( 0.0001 \)            |
showed greater mastery, while lower scores on the other two inventories were indicative of more positive attitudes.

Significant positive correlations were found between attitude toward science and achievement motivation for both the experimental ($p=.0001$) and control groups ($p=.0014$). There appears to be a positive relationship between these two variables for students participating in this study.

**Classroom Interaction**

Research question five sought to determine if any differences could be described in levels of classroom participation, discussion, and argumentation between the experimental and control classes when prediction was included in a high school genetics unit. The qualitative descriptions of classroom interaction consisted of teachers' logs (see Appendix E), observations by independent classroom observers (see Appendix F), and interviews at the end of the study with students in the experimental and control classes (see Appendixes G and H), as well as with the teachers (see Appendix I). Data from each of these sources were perused and categorized using Bogdan and Biklen's (1982) and Lincoln and Guba's (1985) approaches for analyzing qualitative descriptions. Summaries were made for each of the data sources; the data were then triangulated by this researcher and the primary observer to develop a generalized portrayal
of the instructional effects of including prediction in a genetics unit.

Class Participation

The experimental classes were generally described by the teachers, as well as the independent observers, as displaying higher levels of student participation. During only one observation was an independent observer unable to note differences between the experimental and control classes. Yet, Teacher A noted in his log, and also during the interview, "remarkable" differences between the two classes on the same day that the observer was present. Teacher A described several experimental students displaying interest in the lesson and asking "perceptive" questions. He stated in his log that they were "turned-on" for the first time. "One student, who is a meek, mild little girl who never says a word in class is now up there defending what she believes. That is something to see!" Teacher A wrote in his log about another student, "[Student's name], who has been a problem student all year discipline-wise and academically, loved the prediction activities. He would come in and argue about his answers, and he made some very astute comments and predictions." Another student was described: "He actually made correct predictions. He hasn't passed anything or answered anything this six weeks. He may be turning around." Teacher A concluded during the
interview, "It is really hard for an observer to know the
dynamics of the classroom."

Similar comments were made by Teacher C in his log
following the prediction activity "How Inheritance Occurs." He stated, "The discussion of the predictions was very good. Several students that usually don't participate did offer their explanations and didn't seem inhibited to give their views since it was just a prediction." He further observed that making predictions caused the students to be more vocal. The teacher described them as "eagerly" wanting to give their predictions. "There was more enthusiasm and competitiveness," wrote Teacher C while describing his experimental students.

The control classes were depicted by both the teachers, as well as the independent observers, as being interested and moderately involved in the lessons. There was some student questioning, but certainly not the level of the experimental classes. One of the observers wrote after visiting in Teacher B's classroom, "Students in the control class only answered questions when called upon. It [the lesson] was strictly teacher lead, developed and completed." On the same day the observer described the class in the following way: "Students in the experimental class showed more interest, seemed more relaxed, were more anxious to
answer questions and discuss their predictions, and seemed to enjoy the lesson more."

Although some off-task behaviors were reported for both the experimental and control classes, more overt displays of disinterest were described in the latter group. The behaviors ranged from head-scratching to placing one's head on the desk. Teacher B characterized the control class during the lesson on the inheritance of sickle cell anemia: "There was some questioning by the students, but most students appeared to be 'in space'." Teacher A commented following a Monday lesson on codominance in the control class: "Several students were sleeping. They were very passive. It is no fun to teach when they are like this."

The lessons in the control classes were presented by the teachers in a more traditional manner, involving lecture and questioning with use of the overhead or the chalk board. The students took notes on the information presented. Student-student interaction in the control classes was described as minimal by both the observers and the teachers. The primary occasions when conversations between students were reported were during the laboratory activities. One observer stated that she felt the reason there was less discussion and participation in the control classes was that so much time was required in writing down the "vast amount of information" being covered. "No time seemed to be left
for dialogue or discussion. They were busy copying notes rather than giving much thought to what was being said."

At the beginning of the study, students in the experimental classes were described as being a little apprehensive about sharing their predictions, but as time went on, they became more comfortable discussing their ideas. One of the observers wrote:

At first the teacher had to call on students for their predictions, but as the discussion progressed, students responded more freely. The teacher could tell those wishing to answer by the looks on their faces. Many of the students' predictions were incorrect, but the teacher handled it well and no one was made to feel bad.

During the student interviews, several of them admitted that they had never made predictions in any of their classes at school, and it was very hard for them at first. Yet, all of the experimental students interviewed expressed a desire to participate in prediction activities in other biology units.

Teacher C's comments seemed to summarize the experimental treatment effects on classroom participation. When comparing the two classes, the teacher described the control class as having quite a few good students who enjoyed discussing and questioning. Such was not the case
in the experimental class. He stated, "Discussion is not usually so good in the experimental class, so these prediction activities do help students talk and discuss."

**Questioning**

A consistent theme described in the qualitative field notes was enhanced questioning by both the teachers and the students during the prediction treatment activities. Two of the independent observers noted that the level of questioning in the control classes was primarily at the knowledge level. They stated in their field notes that more thoughtful questions were asked in the experimental classes by the four teachers. Generally, students in both groups readily responded to the teachers' questioning, but the observers felt that the experimental students displayed a greater desire to answer. It was suggested by both the teachers and the observers that the reason for this was the students' desire to verify whether their predictions were correct. During the interview, Teacher A stated that he felt the experimental students had some "stake" in what was taught. "It wasn't just my asking questions. They got to be in charge. By making predictions they had to justify or refute what others said. They had an opportunity to explain."

Each of the teachers was described by the observers as "probing" to a greater extent in the experimental classes.
More students were questioned individually than in the control classes. Describing Teacher B an observer wrote, "In the experimental class the teacher came from behind the desk, walked around the students, questioned more directly, worked at getting the students to respond, rather than answering for the student and moving on." The observer noted that during the experimental class the teacher asked more open-ended questions and seemed to value student participation more.

Teacher B described student questioning during the experimental class as improving steadily as they moved further into the genetics unit. When comparing the two classes during the lesson on genetic pedigrees, the level of questioning by the experimental students (while using the "Pedigrees" prediction activity) was characterized as being "much higher." The teacher cited a question asked by an experimental student that showed thoughtful consideration: "What can we do to show when we have step-parents in our family tree?" There were other examples of thoughtful questioning by experimental students concerning eye color when the lesson included the "Polygenic Traits" prediction activity. One student asked after making his predictions, "Can two green-eyed people have a blue-eyed child? Let me see if I can predict how this can happen." Another asked, "Can two tall people have a short child?" The teacher felt
that both questions evidenced enhanced levels of interest. Each of the students attempted to set up, or asked for assistance in setting up, polygenic crosses to show whether these phenotypes could occur.

Teacher A also felt the experimental students asked more questions, particularly more "insightful" questions. He cited an example when a student, while discussing his predictions about "Mendel's Principle of Dominance and Recessiveness," asked, "How do you get spots on a dog when one color is dominant and the other is recessive?"

**Dialogue and Discussion**

During the interviews with the teachers, each was asked to describe the effects of the prediction activities on classroom dialogue and discussion. Teacher A responded:

There was definitely a difference, especially with some topics such as the day we were talking about how traits were inherited [the prediction activity utilized was "How Inheritance Occurs"]. I had trouble trying to get through the lesson for they wanted to discuss. On a scale of 1 to 10, as far as dialogue was concerned, the experimental class would be on an average day about an 8. The control class was about a 5. In both classes the same students are anxious to respond.

Teacher B stated that he saw a "noticeable difference" between the experimental and control classes concerning
classroom discussion. "There is no doubt in my mind that the prediction activities promoted dialogue. I think they promote critical thinking and give each individual a chance to express himself or herself."

Two of the observers attended Teacher B's experimental and control classes on the same day when the lesson topic was human blood types. "The interest level clearly was higher. There was more active participation and interest," stated one of the observers about the experimental class. The other observer wrote:

There definitely was much more student involvement in the experimental class. They quickly made their predictions [using 'How Blood Types Are Inherited'] and were ready to enter into the discussion. The experimental class showed more interest in the lesson, volunteering to work on the board while the rest of the class watched.

On another occasion the same observer wrote, "No doubt the prediction activities encouraged student participation in the class discussion."

**Student-Student Interaction**

An interesting finding was that the teachers' logs generally described student-student interaction as improving or good, while the independent observers indicated that it was poor or moderate. The following is an example
of such a comment made by Teacher A: "Student-student interaction has improved tremendously." He cited a specific case in his experimental class when one student queried another student about the genotypes of his aunts and uncles on the pedigree chart. The "Pedigrees" prediction activity seemed to promote student-student interaction in all four of the experimental classes. The teachers described students arguing over whether a particular individual was heterozygous or homozygous on the pedigree chart.

The greatest incidence of student-student dialogue occurred during the "Population Sampling and Human Genetic Traits" prediction activity. The students were described by the teachers as being interested in whether others displayed the trait, whether it was carried as a simple dominant or recessive, and who in their family displayed it. Teacher A wrote, "They loved going over the traits and calculating the percentages. They wanted to discuss with their neighbors and were very excited. There were many student-generated questions. The prediction activities were a great motivational tool. The lesson went very well." Concerning this same topic, Teacher B described his experimental class in the following way: "Student-student interaction was excellent. It was the best that I have seen."

The independent observers were more conservative in their descriptions. Most often they wrote that the lesson
was teacher-centered with limited student-student communication. One of the observers noted that dialogue in Teacher B's classes was mediated through him; student-student interaction was generally not promoted. In these same classes the observer indicated that 90% of the students looked at the teacher during classroom discussion, but only a few would turn and look at other students when they spoke. It should be noted that good eye contact was described by the observers between the teachers and the students in both the experimental and control classes.

In spite of the disparity between the teachers' and the observers' descriptions, it would appear that the prediction activities generally promoted enhanced student-student interaction in the experimental classes. As one of the observers stated in his field notes, "Prediction seems to force more interaction." While discussing the students' predictions, Teachers A and B were described as frequently asking, "Do you agree with his or her prediction?" This seemed to encourage reciprocity of ideas between the students. An example of such an exchange was described by an observer: "One student had an error in his dihybrid prediction. Several students were interested in helping him find his error. They really showed concern."

The observers' field notes did not reveal that argumentation was greatly enhanced in the experimental
classes by the prediction activities. They noted that when there was disagreement concerning the students' predictions, the teachers "took charge" to settle the differences. Student-student exchange was not promoted during these times except in rare instances. One such incident occurred in Teacher A's experimental class when students argued about their predictions concerning the probability of having three daughters in a row.

Summary

Triangulated data from the interviews, field notes, and logs supported that prediction activities augmented student involvement, particularly in Teacher A's and Teacher B's classrooms. Quotes from these two teachers summarize the overall treatment effects for their classes. "Students were more involved and had the freedom to be wrong and explore and ask, 'why'. This is learning at its best," stated Teacher A. Teacher B wrote in his log after the prediction activity "Polygenic Traits," "There was simply no comparison. The control class was dull and uninteresting. The experimental class was active and interested. This was really a much better lesson."

Ancillary Treatment Effects

There were a number of ancillary treatment effects described by the teachers, the students, and the independent observers that occurred as a result of prediction making.
These effects were not addressed specifically by the subproblems stated as research questions in Chapter I of this study. Yet, each of the effects appeared repeatedly in the qualitative descriptions comparing the experimental and control classes. Because of their frequent occurrences in the field notes, they were included in the results of this study.

**Student Interest and Motivation**

The four teachers expressed their endorsement of including prediction activities to promote student motivation and interest in the lesson. Teacher B stated during the interview that he felt the most positive effect of including prediction in the lessons was the motivational factor. "I am convinced that some students who usually did not pay attention were motivated by the activity. When I gave them the sheets it caught their attention and they looked forward to working with the prediction activities on a daily basis." One observer noted this same effect. A student was overheard saying, "All right!" when the teacher announced that they would be making predictions about two-trait crosses using the "Dihybrid Crosses and Mendel's Principle of Independent Assortment" activity.

During the interview, Teacher A expressed his feeling that the prediction activities had enhanced student motivation.
The thing that I look for is eagerness to respond. They want to share with you. It is hard to keep focused, for they all want to talk. It is hard to pick the kids to call on. Also, when they are interested, you can tell by the expression on their faces. You can tell if they are confused. Honestly, the prediction activities were wonderful this time of year [right before the Christmas vacation]. Some have already given up passing, yet they still seemed to enjoy genetics.

Overt evidence of student interest and motivation were recorded in the field notes and logs. Teacher A wrote several times that the experimental students asked more insightful questions. Because of this, he felt that the lesson including the prediction activity "How Inheritance Occurs" (which emphasizes the importance of reduction division) "was the best lesson on meiosis I have ever taught based on student comprehension and interest." Teacher B noted, "Even those who didn’t wish to share their prediction, you could observe the expression on their faces, whether they were in agreement or disagreement, or if they understood or didn’t understand." One of the observers described students in Teacher B’s experimental class answering the questions posed by the teacher about the predictions "without hesitation."
Several entries in Teacher A’s log stated that the prediction activities had served as a "motivational tool," particularly when students who never participated were enthusiastic and volunteered responses. The independent observers also noted a difference between the experimental and control classes as to the number of students who volunteered. One of them wrote, "During the control class the teacher did most of the work on the board while the students took notes. But in the experimental class the students volunteered to do most of the board work."

During the interviews, every one of the experimental students said they enjoyed sharing their predictions. One stated, "It was kind of fun because if you were wrong you could learn by your mistakes, and if you were right it was really fun!" Another said, "I was not too embarrassed to share my predictions. I wanted to make them correct so I would not miss it on a test later." A third student felt the reason he enjoyed sharing the predictions was that "we all have different opinions." Certain activities seemed to be their favorites. For example, the experimental students mentioned how much they had enjoyed the "Polygenic Traits" predictions. Without exception they described how interesting they thought the inheritance of eye color was. They were also intrigued with how two average-in-height parents can have a tall offspring.
At the conclusion of the interview Teacher A described the level of motivation and participation in his experimental class:

I was amazed at how their predictions became more refined. The prediction activities were so well prepared, and the students' participation was so good I got the impression from the students that they were fun. They really enjoyed them. The topics were excellent and they could really relate to them. They thoroughly enjoyed the study, and I can't wait to include prediction in other units and also in next year's genetics. I thoroughly enjoyed it and so did the students. I was amazed at the level of their participation. It was excellent.

Teacher B summarized the motivational effects of the prediction activities when he stated during the interview, "I noticed an overall increased level of attention and interest in the experimental class. Many students were eager to participate."

Critical Thinking

One of the identified themes in the teachers' logs was that the prediction activities caused the students to think critically. Activities which were designated as particularly challenging thinking skills were (a) "Finding and Treating Human Genetic Disorders," (b) "Genetic
Teacher A expressed concern that most of his students have difficulty thinking critically "because they still want to be 'spoon fed.' It is easier to be passive learners. They make me mad! Why can't they think! When I show them the obvious relationships, they say, 'Oh, now I see.' They should be able to do this." This same teacher cited a specific example which occurred during the "Sex Determination: Femaleness and Maleness" prediction activity. There was much student debate, but no one could respond correctly when asked what the predicted ratio of males to females should be. The teacher asked them to solve the problem using a Punnett square; only then could they determine the probability. "They are not able to apply what they know to what they are learning," wrote Teacher A in his log following the lesson.

Teacher B felt the reason why the prediction activities were effective in promoting higher-level thinking was the students had an opportunity to consider the ideas before discussing them, whereas, in the control classes, questions were asked spontaneously. Following observations of Teacher C's experimental and control classes, an observer wrote similar comments. The observer also felt the experimental
students were more secure in their responses to the teacher and the other students because they had a chance to think through the problems during the prediction activities. "Students seemed more sure of their answers when called on and more readily defended them. They saw their errors more readily and seemed to understand the correct responses."

Teacher B noted on several occasions that he was so "impressed" with how the accuracy of the student's predictions increased as they got further into the genetics unit. An example of this occurred while using the "Pedigrees" prediction activity. An experimental student actually got up from his desk, went up to the overhead and began drawing a Punnett square to show that the teacher's explanation was wrong. Both the teacher and the student expressed pleasure in this experience. Teacher B wrote in his log:

There is no doubt in my mind that the prediction activities challenged critical thinking. I can remember one instance dealing with pedigree. One student thought one individual was heterozygous and really challenged me and showed me he was actually thinking and actually constructed a Punnett square to show me what he was thinking about. This is what makes teaching fun.
It just so happened that this student was one who was randomly selected to be interviewed. Twice during this time he mentioned that he really enjoyed when he was able to show the teacher "where he had gone wrong."

Teacher A remarked numerous times in his log that the prediction activities promoted "insightful responses and questions." "The kids who turn in everything and do well are not my best thinkers. It is so encouraging to me to see a student who does not normally do well participating and thinking and earning the respect of his fellow students and hearing them say, 'Hey, this kid knows what he's doing.'" Teacher A was describing a particular student who displayed the best thinking skills in the class, yet he rarely participated in discussions prior to this study and performed poorly on tests.

When asked during the interview whether the prediction activities had promoted critical thinking, Teacher D made the following observation:

The class that I used the prediction activities in was not as good a class. I think if I could have "flip-flopped" them [referring to the experimental and control classes], it would have worked much better. I have a lot more students in the control class that think. It is just the nature of the class.
Teacher D stated in his log several times that the students in the experimental class "refused to think." Often they would not even attempt the prediction activities. They were described as waiting for him to go over the correct responses with them. Yet, the students in Teacher D's experimental classes were not always adverse to thinking critically. He stated during the interview that when they did participate, "Making predictions allowed the students to think about the topic--to make 'educated guesses' based on their background." He cited one particular instance in his log when there was good critical thinking displayed while discussing the predictions they made about hybrid vigor during the "Crossing-over and Other Chromosome Mutations" activity. The teacher also identified a female student who "was really into this" (referring to making predictions). This was the first time the student had displayed critical thinking in his classroom; she expressed to the teacher how much she enjoyed making predictions.

In summary, it would appear from an analysis of the qualitative data that one of the main effects of including prediction activities in genetics was the promotion of critical thinking. In all of the teachers' logs, and also during the interviews, there were consistent citings of how thinking was enhanced in the experimental classes. This was also noted many times by the independent observers in
describing the experimental students' predictions, the quality of their responses to the teachers' questions, and the level of questioning by both the teachers and the students.

**Level of Learning**

During the interviews, each of the teachers expressed confidence that the experimental students had a greater mastery of the genetics concepts. One of the reasons, cited by both Teachers A and B, was that the prediction activities assisted the students in staying focused. When queried as to why this was the case, Teacher A stated that he felt by making predictions the students had some "stake" in what was taught, and therefore were more responsible for the learning that occurred. As noted previously, the prediction activities freed the students from taking as many notes as were taken by the control classes, therefore, greater time for personal consideration was both provided and valued. Several of the experimental students interviewed stated that one of the things they enjoyed about prediction making was that they did not have to take as many notes as they usually took. One of them commented, "It [referring to the prediction activities] is a lot better. You learn more than taking notes because you pay attention more."

Teacher A wrote in his log, "I generally got the feeling that they [the experimental students] understood to
a fuller extent. They really wanted to know why. It [the prediction activity] got the students involved." Following the lesson using "Mendel's Principle of Dominance and Recessiveness," the teacher noted, "They did real well on their predictions. They seemed to really understand the law of dominance better than I have ever seen in previous classes." The teacher felt that when incorrect predictions were made, the students became aware of their lack of understanding and wanted to listen to an explanation of why their responses were not correct. Following the "Testcross" prediction activity, Teacher A remarked, "They flew through the test cross. Their previous knowledge and success made them confident in their predictions. Students really seemed to understand."

Teacher A described learning in his experimental class as being "faster and better" during the lesson which included the prediction activity "Genetic Probability." Their interest level was higher as evidenced by more students' volunteering and a greater number of student-generated questions. "We don't move as fast in second hour [the experimental class] due to questions and explorations, but the students are learning more. They understood ratios much better than the control class." A similar comment was made about the lesson which included the "Population Sampling and Human Genetic Traits" prediction
activity: "Students [in the experimental class] appeared to understand better how traits occur. They seemed more insightful and had a greater level of understanding."

During the interview, Teacher A stated, "By looking at the class, you can get a good idea whether they understand, and also by the questions they ask you can tell. There were days when we finished a prediction activity that I knew that at least 90 to 95% of the students understood the concept."

Teacher C observed that the prediction activities assisted the students in presenting their genetics research projects. He stated during the interview, "I wish you could have been here to hear some of their oral reports. I think the predictions helped with that. The papers were not as good as I have gotten in the past, but the orals were good because they understood what they were talking about."

The prediction treatment effects on learning were not as positive in Teacher D's class. The students were described by an observer as "noisy and complaining." One student asked, "How do you make predictions about something you don't understand?" The observer noted that the teacher had done a poor job of giving instructions concerning the purpose of the prediction activities. She wrote in the field notes, "The general look in their eyes was one of confusion. They were not used to thinking for themselves and felt at a loss to try."

During both experimental and
control classes there was much off-task behavior described by the observer. Teacher D told the observer that the control class was a much better class, and as noted previously, he felt the prediction treatment activities would have been more effective with them. The observer concurred with the teacher's observation in her field notes.

An observer stated that after Teacher D's experimental students became more familiar with the format and the purpose of the prediction activities, more dialogue was promoted, but not to the level of either Teacher A's or B's students. Following a lesson toward the latter part of the study, the observer described students in Teacher D's experimental class:

Well, today many more students volunteered. All responded when called on. They wanted to share their predictions. They were definitely more involved than the control students. There were many more student-initiated questions. Predictions helped them to remain on the topic. They desired to confirm their predictions.

Concerning the effectiveness of the prediction activities in promoting greater understanding, Teacher D described a most interesting occurrence:

The control class had a hard time understanding the topic. *I knew I wasn't supposed to*, but I finally used
the prediction activity ["Crossing-Over and Other Chromosome Mutations"] with them. This helped them understand better. The students seemed to catch on better once they did the prediction sheet. They answered my questions quickly and their responses showed their understanding.

A final prediction treatment effect on learning described by the teachers during the interviews was more thorough coverage of the genetics concepts. Teacher B stated that he usually did not go into the concepts as "deeply" as some of the prediction activities did. He went on to explain that this was not a negative comment. In the past, he felt he had presented several of the genetics topics superficially, and he intended to continue using the prediction activities in the future because of their in-depth coverage of the concepts. Similar comments were made by Teacher A.

During the interviews, the experimental students expressed positive comments when asked whether the prediction activities assisted them in understanding the genetics concepts. One student commented, "By making predictions and finding out you were right really made you think." A second student remarked, "By making predictions it really made you question. It really made you learn it."
When asked their overall opinion about making predictions, the experimental students interviewed had a variety of different comments in regard to how learning had been affected. One comment was, "I thought it was a very good way because you got to make your own decisions and not just what the book said. You can say what you want to say. I really felt like he [referring to the teacher] wanted my ideas." Another said, "It really helped me understand when we discussed the predictions." Yet another stated, "It helped me understand. It made it easier for me than the usual way."

All of the experimental students indicated during the interviews that they used their prediction sheets to study for the genetics tests. One said, "It really helps me know what's important--to see the main points." Another said, "It is much easier to study by the prediction sheets because when you write down notes you miss things the teacher goes over." Yet another replied, "They really are easy to study by."

Even though several of the experimental students interviewed felt that genetics and also the prediction activities were hard, perhaps one comment summarizes the general tone of their responses: "It really helped me learn because I like them [referring to the prediction activities] very much. It made me think a lot!"
Instructional Tool

The teachers felt that the prediction activities were effective as both teaching and learning tools. The independent observers' comments also supported this. One wrote after observing Teacher B, "More thought was given to the lesson in the experimental class. The teacher asked more thoughtful questions." The same observer described Teacher A: "He enjoyed the interaction and seemed more relaxed. He liked using the prediction activities and you could tell it."

During the interview, Teacher A made the following comment when asked whether the prediction sheets served as an instructional tool:

I will make up a file and use the prediction activities from now on. They are terrific for keeping us focused on a logical scope and sequence. It was wonderful. It was like giving you a curriculum and saying, 'go forth and do.' I will use them as a guide forever. It really helped us understand the concepts. Such as multiple alleles—the sheets really helped us understand hard concepts such as polygenic traits. That which would have normally taken us two class periods was understood by most of the students in less than a third of the time.
Teacher B stated that the prediction activities assisted him in lesson preparation by providing the agenda for discussion. Similar comments were made by Teacher A when he wrote, "The prediction sheets kept me on track. There were no sharp curves. We knew what we needed to cover and it made the lesson more focused and efficient. It has already spread into my other classes." Teacher C felt that the most positive aspect of the prediction activities on instruction was that they were useful in helping to introduce the genetics topics. He also stated during the interview that they had assisted him in understanding where the students were having problems.

Specific aspects of the prediction activities appeared to assist in instruction. A frequently cited positive effect was the use of graphics. Teacher A wrote in his log following the lesson using the "Population Sampling and Human Genetic Traits" prediction activity, "They loved doing the traits, and since the drawings of each characteristic were right there in front of them, I didn't have to keep telling them over and over as I did during the control class." The graphics on the "Pedigrees" prediction activity was cited by all of the teachers as aiding instruction. One of the teachers expressed a sense of frustration because it could not be used in the control class. This was also a favorite mentioned by the experimental students during the
interviews. They stated that they enjoyed learning about how genetic traits were passed down within a family line.

Another favorite of both the teachers and the students was the "Dihybrid Crosses and Mendel’s Principle of Independent Assortment" prediction activity. The teachers felt that the FOIL method used in making the predictions was very useful. One student said, "It was like putting a puzzle together." Other drawings or diagrams that were cited by the teachers as being particularly helpful in assisting students to comprehend the concepts were (a) "Mutations: Changes in the Genetic Code," (b) "Polygenic Traits," (c) "Test Cross," (d) "Nondisjunction," and (e) "Crossing-Over and Other Chromosome Mutations." Teacher D commented in his log about the latter activity, "The one on mutations is a really good introduction to the topic of evolution."

Teachers A and B maintained that one of the most positive effects of the prediction activities was the information given on the sheets to assist the students in making their predictions. "More detailed information was covered due to the prediction sheet format. It really is a good teaching device. The students are learning to appreciate it more everyday. They can listen and take fewer notes and dialogue with me." Teacher A wrote the previous remarks in his log after the lesson which included the
"Nondisjunction" prediction activity. During the interview Teacher B commented, "The background information on the sheets and the questions generated from their working with them really evidenced interest and involvement. It showed me they were really reading the sheets and thinking about their predictions." The teachers cited the following activities as those which contained particularly relevant and up-to-date information: (a) "Mutations: Changes in the Genetic Code," (b) "Finding and Treating Human Genetics Disorders," (c) "Applied Genetics and Controlled Breeding," and (d) "Genetic Engineering: A New Frontier in Science."

Because many of the ideas presented on the prediction sheets were new to most of the students, careful consideration and analysis were required before rational predictions could be made. Teacher A wrote in his log following the lesson on genetic diseases: "This [referring to the "Finding and Treatment Human Genetic Disorders" prediction activity] was an excellent teaching tool. When the students had to make predictions using the Punnett squares, they clearly understood that all diseases are not recessives. They also understood a person can carry a trait and pass it on and not have the disease."

During the interview, Teacher C summarized his attitude about how the prediction activities had assisted as an instructional tool: "They gave an explanation that you
could expand on. There were some really good examples, good problems, and good graphics. I liked using them a lot."

**Identification of Prior Knowledge and Alternative Conceptions**

All of the teachers stated that the prediction activities assisted in identifying the students' level of prior knowledge. Teacher A commented during the interview: "Yes, the predictions helped in identifying levels of prior knowledge, and unfortunately it wasn't too high. I was basically taking them from 'ground zero.' Their background was minimal." Teacher C commented, "For the most part, they had not had any genetics at all. A lot of these kids had no idea what we were doing when we started. When the prediction sheets were given out, some of them said they had never seen any of this before." The other teachers' statements were similar, although Teacher B felt that several of his students had a good middle school background in genetics. For the most part, prior knowledge was low. Teacher D seemed to epitomize the teachers' attitude when he said during the interview, "Most did not have much prior knowledge except misconceptions."

A number of alternative conceptions were identified through the use of the prediction activities. One of the most often noted by the teachers was that a person inherited a trait from only one parent. Teacher A wrote in his log,
"They hear the expression, 'You have your mother's eyes,' and they think they got their eyes only from their mother. They have a problem accepting dominant and recessive traits. They don't understand that you may carry a whole set of recessives that can be passed on to your children." The students seemed to have a difficult time understanding that one chromosome in each pair comes from the mother and another from the father. During the prediction activity "How Inheritance Occurs," it became evident that the students did not understand genetic variation. Teacher A wrote, "They thought that brothers and sisters were different because one received all dominants and the other all recessives. We got really 'bogged-down' over why brothers and sisters differ."

Teacher A believes the heart of their difficulty is they do not understand the concept of homologous pairs. He stated during the interview, "You don't know how I fight that battle. If you knew how many times I have gone over chromosome replication and reduction division!" The students' difficulty with these concepts was evidenced during the "Dihybrid Crosses and Mendel's Principle of Independent Assortment" prediction activity. "They had trouble with the FOIL method because they really didn't relate the law of independent assortment with this method. After doing the dihybrid cross predictions, they were able
to see why brothers and sisters don't look alike. Several students remarked about that," wrote Teacher A in his log.

Another alternative conception was identified by all of the teachers during the "Sex Determination: Femaleness and Maleness" prediction activity. Many of the students did not understand how gender is determined. There was much argumentation over which parent was responsible for the sex of the child during the discussion of the students' predictions. Another identified alternative conception was their misunderstanding that more female babies were born than males. A student in one of the control classes stated during the interview, "I was interested in the fact that there is a better chance of having a boy than a girl. I thought there were more girls."

The prediction activity, "Sex-linked Traits," assisted the teachers in identifying another area of confusion. The students had difficulty comprehending that even though the father is responsible for the sex of the child, males receive their sex-linked traits such as hemophilia or color-blindness from their mother. The teachers expressed real concern that the students' level of understanding of this concept was so poor even though multiple examples were given. This apparent lack of comprehension was evidenced by the low level of concept mastery evidenced by the scores on the genetics achievement posttest (see Table 5, Item #11).
Several students were described as having difficulty understanding how genetic mutations could be beneficial. During the "Mutations: Changes in the Genetic Code" prediction activity, the teachers had an opportunity to discuss with the students how evolutionary processes proceed by selective adaptation as a result of mutations. It would seem that the processes of evolution are extremely difficult for the students to grasp. A control student, when asked during the interview how he enjoyed the genetics unit, stated:

One incident about revolution [the reference was to evolution]—that one theory explaining how modern man dominated other men. I treat it like a theory. A lot of people believe it could be a lie. Then again, people make theories because that's how they feel. This is against the Word of the Lord. We are the kids of the future; we can prove to the world that this is a lie.

The experimental classes seemed to have a better understanding of mutations and the processes of evolution. Teacher A wrote in his log: "Many students did not know or see how mutations can help organisms survive in a changing environment. The "moth" prediction activity ["Mutations: Changes in the Genetic Code"] really helped show this to them."
How genetic diseases are inherited was another area of misunderstanding by the students. For example, prior to participating in the "Sickle Cell Anemia" prediction activity, several students in Teacher C's experimental class believed that the condition was caused by the diet of the diseased person. Teacher D identified a few students in his experimental class who did not realize Down syndrome was inherited. Others, prior to the prediction activity "Sex-Linked Traits," were convinced that more females were color-blind.

During the "Pedigrees" predictions, several students had problems understanding that recessive individuals must be homozygous to display the trait. They had difficulty comprehending that the affected individual had to receive the trait from both parents. Even when the genotypes were filled in under each parent in the pedigree, many could not predict if a particular offspring would be heterozygous or homozygous. One student in Teacher D's experimental class seemed to epitomize the difficulty many students had in comprehending dominance and recessiveness. He expressed to the teacher that he thought recessive parents could have offspring with dominant traits because genes "could skip a generation" and go to the grandchildren from the grandparents.
A number of students were described by each of the teachers as having difficulty comprehending the product rule during the "Genetic Probability" prediction activity. Teacher A noted, "They did not understand that each event occurs independently and doesn't affect others. They have difficulty conceptualizing the product rule and will often add rather than multiply to determine the probability of an event's occurring." Teacher C concluded in his log, "Students still don't understand that the Punnett square represents the probability of each type of offspring's occurring."

This researcher was able to identify an alternative conception while interviewing a student in one of the control classes. When he was asked whether any of the genetics topics had challenged him to think at a deeper level, he responded, "It has good effects, especially when you see about birth defects such as Down syndrome or AIDS." I suggested to the student that the latter was virally induced, but he continued to insist that it was genetical. During his explanation he stated that the mother gives the baby AIDS, and then I realized the source of his misunderstanding. He had heard about infected mothers passing the disease on to their children, and he assumed it was genetical.
Teacher A’s comments during the interview summarize the teachers’ attitude toward identification of alternative conceptions: "If I were able to identify the misconceptions then I could hit it hard and heavy. It is important that they be cleared up early. The prediction activities cleared up a lot of misconceptions."

Cooperative Grouping

Cooperative grouping was used by each of the teachers during selected topics in the experimental classes. Teacher A used grouping during the "Polygenic Traits" prediction activity. The students were asked to make cooperative predictions. One observer wrote, "Because of small group work there is quite a lot of student interaction. Interest level was clearly high throughout the class." During the lesson on this same topic, the observer described the control class in the following way: "Student interest is low. Level of interaction is fairly low and always initiated by the teacher's questions. The main student involvement is taking notes. Interest seems to wane as the class goes on." During the interview with Teacher A, he recalled this lesson. "There is no doubt in my mind that the predictions and the grouping combined enhanced learning that day. The grouping would not have been as effective without the predictions. Many of the prediction activities lend themselves to group work. I wish we had done it more."
Teacher A stated that when students discuss their predictions with other students, often there is a feeling of "validation," and they are more willing to share their responses with the whole class. In his log he expressed regret that he had not used cooperative grouping when the students made their predictions using the "Dihybrid Crosses and Mendel's Principle of Independent Assortment" activity; he felt team effort would have reinforced some students with less confidence.

During several of the genetics lessons, Teacher B included cooperative grouping in the experimental classes. Most of the time the students worked with their lab partners in making the predictions. Following each of the cooperative activities, the teacher wrote in his log that the student-student interaction had been very good, and that the level of predictions had been higher and more thoughtful due to the group effort.

**Effects on Teaching Styles**

While observing in both the experimental and control classes, the independent observers completed qualitative field notes as well as the Teacher Behavior Inventory (TBI) (see Appendix D) which quantitatively evaluated teaching styles. An analysis of the evaluations and descriptions revealed that Teachers A and B displayed more positive differences in style between the experimental and control
classes. Teacher B appeared to have experienced the greatest change. He was generally depicted by the observers as lecturing during the control class, but during the experimental class discussion and dialogue were his primary approaches. One of the observers commented that Teacher B frequently slipped into his "lecture-mode" during the experimental class, but he would soon work his way back into involving the students in a discussion of their predictions. In both their logs and the interviews, Teachers A and B often mentioned that they felt the prediction activities had enhanced student participation in the lesson by promoting discussion. They described their own styles as being more open to dialogue when the predictions were being discussed.

The observers noted few differences in Teacher C's style between the experimental and control classes. Teacher-student and student-student interactions were described as minimal for both. Teacher C's style was depicted by an observer as "teacher-centered." Student discussion was not highly valued. On one occasion an observer described him "cutting off" a good discussion so they could complete one of the worksheets from his file. The teacher's primary agenda, it would appear, was to cover information, although one observer noted that he seemed more "at ease" using the prediction activities as time went on.
Teacher D was described by two observers as being "very insecure" during the experimental class. An observer wrote, "He was more at ease with the control class; clear instructions were not given with the prediction activities." The teacher told the observer, "It is slower with the prediction sheets than straight teaching." In the field notes the following statement was made by an observer: "The problem might have been that he was not really very familiar with the information on the sheets." Following another lesson, the same observer wrote, "The teacher was insecure in the use of the prediction activities; therefore, he did not use it well with the class." Another independent observer noted, "Both classes [experimental and control] were boring!"

The teachers' quantitative scores on the TBI concurred with the qualitative descriptions. Table 10 presents the teachers' mean scores for the experimental and control classes. An analysis of the data indicated that during the experimental classes the teachers generally received higher mean scores on each of the evaluated items, but Teachers A and B had consistently higher means for all of the factors. Teacher A displayed the greatest positive change in encouraging student dialogue in the experimental class. Teacher B's most positive difference was in encouraging student-student interaction in the experimental class.
Table 10

Summary of Mean Scores For Teacher Behavior Inventory

(C=Control Class; E=Experimental Class)
(1=Far Below Average; 3=Average; 5=Far Above Average)

<table>
<thead>
<tr>
<th>Teacher A</th>
<th>Teacher B</th>
<th>Teacher C</th>
<th>Teacher D</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>E</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
<td>Friendly Classroom</td>
<td>5.00</td>
<td>5.00</td>
<td>4.50</td>
</tr>
<tr>
<td>Orderly Classroom</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Level of Questioning by Teacher</td>
<td>4.00</td>
<td>5.00</td>
<td>4.25</td>
</tr>
<tr>
<td>Encouraged Student Dialogue</td>
<td>3.50</td>
<td>5.00</td>
<td>4.50</td>
</tr>
<tr>
<td>Encouraged Student-Student Interaction</td>
<td>2.50</td>
<td>3.00</td>
<td>2.25</td>
</tr>
<tr>
<td>Teacher-Student Interaction</td>
<td>4.50</td>
<td>5.00</td>
<td>4.50</td>
</tr>
<tr>
<td>Evidence of Well Planned Lesson</td>
<td>5.00</td>
<td>5.00</td>
<td>4.75</td>
</tr>
<tr>
<td>Concepts Clearly Presented</td>
<td>4.50</td>
<td>4.50</td>
<td>4.75</td>
</tr>
<tr>
<td>Smooth Lesson Pace</td>
<td>4.50</td>
<td>5.00</td>
<td>4.75</td>
</tr>
</tbody>
</table>
Teachers C and D showed only slight differences between the two classes, and their mean scores on all items were consistently lower than were Teacher A's or Teacher B's.

Negative Treatment Effects

During the interview, two of the experimental students stated that they felt some of the prediction activities were too long. Others expressed that they felt a few of the predictions were hard. The teachers did not voice this criticism. Teacher A stated in his log after describing the students' complaints: "They just didn't want to think. They had the background knowledge needed to make the predictions." Teacher B wrote following the lesson using the "Probability" activity, "Some of the students appeared to be bored with making predictions." Yet, on the same day he stated in his log, "Many students have taken a liking to the prediction activities and can't wait to get started."

The primary criticism Teacher A had about the prediction activities was the amount of reading that was required. He stated during the interview that many of his students were not good readers, and for this reason they did not like to read. "The complaint that I am getting from the students is that the prediction activities are long. They have gotten into the habit that I will eventually give them the correct responses to the predictions." Teacher A stated that when he used the sheets again, he would do them a
section at a time. None of the other teachers felt the
reading level was a limiting factor for their students.

Teacher B's primary criticism of the prediction
activities was the length of the study. As noted earlier,
in previous years he did not cover many of the concepts in
such depth. "Maybe 19 activities will be too many for some
teachers," he stated. "I think maybe the students became a
little fatigued using them on a daily basis." A statement
made by one of the experimental students during the
interview supported this: "I like the prediction sheets if
we don't go too fast and we don't do them everyday."

The teachers recommended that the prediction activities
be used selectively. During the interview Teacher A said,
"I enjoyed tailoring them to my own style. Frankly, by
using all of the sheets, it made the unit so long. I really
had to rush to get through in the experimental class." The
other teachers also felt rushed to complete the genetics
unit in the time recommended by the curriculum guide.
Teacher A stated:

I would liked to have taken a lot more time to cover
this unit, but we just could not take the time. I
don't think shortening the prediction activities is the
answer--they are excellent. I strongly suggest that
the teachers should be selective about which prediction
activities to use. They covered everything. Many
teachers would be afraid to teach something they don't usually teach. We simply can't teach everything.

Teacher B agreed. He explained during the interview that he had really enjoyed including the prediction activities selectively in his other biology classes that were not involved in the study. "I incorporated them in all other classes on a selective basis. I used 'Pedigree,' 'Inheritance of Blood Types,' 'Mendel's Principle of Dominance and Recessiveness,' and several others. I am really planning to use them in the future."

The negative comments made by Teachers C and D concerning the prediction activities were similar to those made by Teachers A and B, except more strident. The first comment they made during the interviews was that the study was too long. Teacher C stated, "I thought it [the prediction activities] really worked well at first, but after a while it got to be a habit with them." Teacher D commented, "There were too many prediction activities. They got tired of them after about two to three weeks." Neither of the teachers completed all of the 19 prediction activities, although they had been requested by the researcher to do so. Both omitted several of the prediction activities, or treated the topics cursorily. It should be noted however, that Teachers A and B, even though they felt
rushed, had no serious problems completing the study in the four weeks that were allocated.

One of the main complaints mentioned by Teachers C and D was the students did not have the background to make the predictions. Teacher C stated during the interview: "But without prior knowledge they had difficulty coming to a reasonable answer. However, when we went back to discuss and I was able to give them vocabulary, they were able to understand."

"I don't understand," was an often heard comment in Teacher D's experimental class. He concluded, "I think it was they really didn't want to do the activities. They wanted me to introduce the topics in the regular way I usually do it."

During the interviews with the experimental students, they were asked what they did not like about the prediction activities. Very few negative comments were made. One student felt that the "Applied Genetics" prediction activity was very confusing. When questioned further, the student admitted that during the discussion of the predictions he was able to understand it better. Another said the prediction activities were hard at first, but they got easier after several days. It was interesting that one of the experimental students said she really enjoyed making her predictions using Punnett squares, while another said his
least favorite activity was using this technique to predict offspring probabilities.

**Summary**

The results of the statistical analyses of the genetics achievement pre- and posttest measures indicated that students in the experimental and control groups experienced similar success. Although no statistically significant group effects were shown, there were significant teacher effects and teacher by time interactions. Teacher A's students displayed a significantly larger increase in their genetics achievement scores over time when compared with the other students' scores.

Although no statistically significant group differences were shown for achievement motivation, scores declined during the four week study in the experimental treatment group, while in the control treatment classes scores became more positive. No significant teacher effects were indicated.

No statistically significant differences were found between the experimental and control groups on attitude toward science. Neither were significant interaction effects reported over time, but statistically significant teacher effects were shown. Teacher D's students had significantly higher (therefore less positive) scores for attitude toward science.
Significantly positive correlations were found between attitude toward science and achievement motivation for both the experimental and control classes. No such relationships were indicated between genetics achievement and attitude toward science or achievement motivation.

Although the quantitative analyses showed no differences between the experimental and control groups, there were apparent qualitative differences. Students in the experimental classes were generally described as displaying higher levels of interest and participation in the lesson. They were depicted as asking more thoughtful questions, and responding with interest to the challenges presented them while making and defending their predictions. Student involvement in the lesson appeared to be augmented by the prediction activities. The teachers were described by the observers as probing more deeply in the experimental classes. More higher-order, open-ended questions were asked.

The educators involved in this study expressed that prediction making promoted learning because the students sought to confirm their responses, resulting in heightened interest. Enhanced learning was also identified by the teachers as a positive effect of the prediction activities. They believed the experimental students had a better mastery of the concepts because they had been challenged to think at
a deeper level. The teachers were able to identify prior knowledge and alternative conceptions from an analysis of the students' predictions. They believed instruction was enhanced when these factors were addressed during the lesson(s) which followed.

An analysis of the triangulated quantitative and qualitative data revealed that significant teacher effects occurred during the study. As noted earlier, Teacher A's students had significantly higher genetics achievement scores, while Teacher D's students had significantly less positive attitudes toward science. Analysis of the results of the TBI indicated that Teachers A and B showed positive changes in their teaching styles in the experimental classes. They asked more open-ended questions and student dialogue was promoted to a greater extent than in the control classes. The qualitative data supported these results. Further conclusions and implications from these findings will be discussed in Chapter V.
CHAPTER V
Conclusions and Discussion

Overview of the Study

This study investigated the effectiveness of prediction making as an introductory activity for 19 selected topics in a high school Biology genetics curriculum. Enhanced classroom participation, attitude toward science, achievement motivation, and mastery of genetics concepts were the aspects of effectiveness being evaluated. Four experienced biology teachers taught an experimental and a control class. Students in the experimental group made written predictions using the researcher-developed prediction activities prior to formal instruction on each of the genetics topics. These activities were designed to promote critical thinking and participation in classroom discussions. The students were encouraged to explain their predictions to the class, justifying the rationale they used in making them. The experimental and control classes were taught similarly using varied techniques including questioning and discussion, guided practice in problem solving, and laboratory investigations. The primary difference was that the control classes did not participate in the prediction activities as an introduction to each of the genetics topics.
Both qualitative and quantitative descriptions and evaluations were utilized in this research effort. The qualitative aspects included daily logs kept by the teachers, field notes taken by independent observers visiting in the classrooms, and interviews with the teachers and randomly selected students at the end of the study. Quantitative data were collected from pre- and posttest measures of genetics achievement, attitude toward science, and achievement motivation. The qualitative and quantitative data were summarized and triangulated to provide a multidimensional analysis of the treatment effects.

Recurring events were identified in the qualitative descriptions made by the teachers, the students, and the independent observers. These consistent behaviors, triangulated with the quantitative results, lead to a number of conclusions and pedagogical implications concerning the instructional effects of including prediction making in a high school biology genetics curriculum.

Conclusions

Low Scores on the Genetics Achievement Posttest

The quantitative results did not support that significant differences in mastery of genetics concepts occurred between the experimental and control classes. The overall low scores by both groups confirmed in this
researcher's mind that patterns which have taken years to establish cannot be easily altered. The difficulty level of the test did not seem to be a factor. An analysis of the results of the difficulty discrimination index indicated that all but one (Item 14) of the questions on the genetics achievement test were within the acceptable range of difficulty (between .25 and .75) identified by Kubiszyn and Borich (1990). Students participating in this study were generally representative of the middle-to-low percentiles on nationally normed tests. Their cognitive skills and intrinsic motivation were described by the teachers as moderate-to-low, as well. There seem to be no "quick-fix" panaceas to eliminate such deficiencies.

This researcher would also suggest that levels of understanding cannot be comprehensively described by a single objective evaluation, nor can competence be evaluated by totally quantitative measures. Perhaps if the genetics posttest had used a more open-ended format which challenged thinking skills in the same way the prediction activities did, the test results might have been different. The teachers expressed disappointment that the experimental students' scores were not higher on the genetics achievement posttest. They were confident their experimental classes had a greater mastery of the genetics concepts because the prediction activities had required them to think at a deeper
level. Teacher B commented, "The prediction activities are an excellent and different approach, and I am thoroughly pleased and can hardly wait to see the outcome on the posttest. I really believe the experimental group did much better."

While going over the posttest, Teacher A discussed with the students in detail every item that was missed. The most common statements heard from the experimental students were, "Oh, now I see," or "Why did I miss that?" The teacher did not describe the control students' responding in this manner; instead, they "complacently" listened as he went over the test.

An interesting finding was the similarity between the experimental and control classes on the difficulty discrimination indexes for the genetics achievement posttest. It did not seem to make a difference whether the questions measured understanding of content-specific information or application of this knowledge to the solution of problems. The students in this study attended three schools, were instructed by four teachers, and were divided into experimental and control classes, yet they scored similarly on the genetics achievement posttest, item by item.

Even though the quantitative results did not support the qualitative descriptions on levels of learning, both
revealed interesting findings worthy of further study. These will be addressed in a later section of this chapter.

**Student Motivation**

Maehr (1983) believes that one of the reasons for the poor showing of American science students on international testing may be due to the level of motivation. The moderate levels of achievement motivation reported in this study support that indeed this may be the case. The educators involved in this research effort expressed how discouraged they were about the low motivation levels many of their students have. Perhaps the reason they have been "turned-off" to science and are threatened when required to think critically is the fault of science educators. We are forced to ask ourselves, what are our instructional goals? Are they to disseminate information, or are they to promote the development of thoughtful individuals who can use their knowledge to enhance their lives and those of others about them? This researcher feels that the present reform effort favors the latter notion, and indeed change is mandated in the present way our science classes are conducted.

**Quantitative results.** The achievement motivation inventory administered in this study asked the students to describe how hard they try to do well in their school work. An analysis of the results indicated that negative effects occurred over time for both the experimental and control
groups. All of the classes showed increases in their scores (indicating a less positive direction). This researcher would suggest that since genetics has been identified by students and teachers as the hardest content area of biology (Smith, 1988), complex factors were operating. During the interviews, both experimental and control students expressed positive attitudes toward the genetics unit they had just completed. For most of the students, genetics was their favorite part of biology so far, even though several indicated that they thought it was hard.

Naccarato (1988) noted that quantitative self-report measures of achievement motivation and attitude toward science can be highly susceptible to being influenced by a need of the test taker to respond in a socially-desirable manner. This did not seem to be the case in the present study, for many students indicated low levels on both of these constructs. Perhaps the difficulty of the subject matter combined with the time of the year that genetics was taught (November and December) adversely affected achievement motivation. The results of this study parallel those of Simpson and Oliver (1990). They found that motivation scores declined as the school year progressed.

Qualitative results. The positive effects of prediction making on student motivation, identified by teachers, students, and observers in their qualitative
descriptions, were (a) interest was enhanced as the students sought to verify their predictions, (b) the challenging and thought-provoking nature of some of the activities promoted involvement, (c) the give-and-take dialogue between the teachers and the students about the predictions enhanced attention and interest, (d) even those not wishing to share their predictions evidenced overt displays of participation such as head nodding or eye contact, and (e) the students indicated that the prediction activities were fun; they enjoyed sharing their predictions and hearing how the others responded. Not only did the students express enjoyment, so did the teachers. A heartening comment was made to this researcher by Teacher C when he stated, "I enjoyed genetics more this year than I have in a long time." Similar comments were made by the other teachers.

Teachers A and B felt another positive effect of prediction making on student motivation was that the experience was nonthreatening. Their students were asked to speculate, based on their present knowledge and understanding; emphasis was not placed on making correct predictions. As Fisher and Lipson (1986) observed, a safe, nonthreatening environment sponsors discussion with no penalty for error. The experimental students stated during the interviews that it was fun when their predictions were correct, but if they were not, no one made them feel bad.
They expressed a desire to understand why their responses were not correct, and the discussion of the predictions allowed them to explore their errors in order to learn from them.

Successful versus unsuccessful predictors. Lavoie and Good (1988) found that motivation and persistence affected the quality of predictions students made. They suggested that a cyclical relationship may occur in that making correct predictions may sponsor motivation, and in turn, enhanced motivation may lead to continued success in the task at hand. The opposite may also be true. Lack of success may lead to low motivation, which may result in low performance. The results of this study corroborated their findings. The teachers in the present study described certain experimental students who were consistently successful in their prediction making as being vocal and enthusiastic about sharing their ideas. On the other hand, Teacher D's experimental students were depicted as having low levels of motivation, often refusing to make predictions if they required thoughtfulness or effort. Lack of former success in responding to challenging activities may have led to the students' reluctance to participate, which may in turn have resulted in their continued refusal to become involved in experiences which required critical thinking.
Von Glasersfeld (1989) believes to be told that one is wrong adversely affects motivation. He contended that when constructivist learning theory is applied to educational practices, the teacher seeks to understand why students respond the way they do. If errors are identified in the present cognitive structure, instruction is implemented to promote accommodation of the new ideas which may be in conflict with former conceptions. Teachers A and B displayed such an agenda. This was not the case with Teachers C and D. Their teaching styles will be discussed later in this chapter.

**Combining qualitative and quantitative methods.** This researcher posits that while quantitative evaluations may reveal important information, they are inadequate in describing the complex dimensions of motivation. Qualitative descriptions are called for as well. As Ames (1987) noted, these evaluations focus on how students think about themselves and their tasks. The overall moderate levels of achievement motivation shown by students participating in this study on the quantitative measure paralleled the qualitative descriptions of this construct.

The two methods were not always mutually supportive. There were inherent differences in the results of the two research approaches when comparing the experimental and control classes on levels of motivation. While no
significant group effects were found on the quantitative measure of achievement motivation, the qualitative evaluations revealed distinctive differences. In their qualitative descriptions, the educators participating in this study observed that the experimental students displayed enhanced motivation. Teacher A stated, "It [prediction making] is a way to get them involved in the lesson and to give them some stake in what will be taught because they are able to generate questions and guide which direction the lesson will take. They know you are not just dumping information on them."

This researcher would agree with Lawrenz and McCreath (1988) that both quantitative and qualitative methods are necessary to provide adequate descriptions. By triangulating the results from both of these approaches, more focused recommendations for future research on student motivation will be described in a later section of this chapter.

Classroom Participation

The qualitative data supported that student participation was enhanced in the experimental classes because of the prediction activities. It should be noted that this was observed more often in Teacher A's and B's classes than in Teacher C's or D's. Teachers A and B expressed enthusiasm over the quality of student-teacher,
and sometimes student-student, interaction which was promoted by making predictions. The independent observers' field notes corroborated the teachers' contention.

An interesting and relevant comment was made by Teacher A during the interview concerning a classroom visit by an independent observer. The latter was not able to distinguish significant differences between the experimental and control classes as to level of student participation during a particular lesson. The teacher commented that it is difficult for an observer to comprehend the dynamics of a classroom unless he or she can be present on a daily basis. While the independent observer was not able to note differences, the teacher described in his log three experimental students participating in the classroom discussion who had never done so before. For this reason, it was beneficial to triangulate data in order to get a more realistic picture of the actual events occurring.

Because of the varied formats of the prediction activities, students with different levels of competency felt "comfortable" (word used by Teacher A during the interview) participating in the discussion of their predictions. As Fisher and Lipson (1986) noted, the need for dialogue is emerging as an important aspect of learning and the elimination of alternative conceptions.
Attitude Toward Science

The finding that Teacher D's students had significantly lower attitudes toward science is noteworthy. He was described by the observers as being very insecure, especially with the prediction activities. Also, his classes were depicted as noisy and complaining. This researcher was not surprised at their poor attitudes toward science, for the overall classroom environment did not seem to promote positive behaviors. The negative teacher effects shown in this study corroborate those of Simpson and Oliver (1990). The researchers found that the environment of the science classroom was one of the strongest influences on attitude toward science.

An interesting finding was that attitude toward science was significantly and positively correlated with achievement motivation, yet neither were found to be significantly correlated with genetics achievement for both the experimental and control classes. This is clearly an enigma to this researcher since one would predict that a positive relationship would be shown between attitude and subject matter achievement. Further research is clearly indicated to investigate more thoroughly the relationships between these constructs.
Critical thinking

An analysis of the results of this study indicated that greater emphasis needs to be placed on critical thinking skills in science classrooms. Each of the teachers expressed discouragement at the overall level of their students' thinking competence. Teacher A noted during the interview, "This [critical thinking] is so hard for them. Perhaps they are so accustomed to having information thrown at them and they get what they can." It was Teacher A's feeling, as well as this researcher's, that activities which promote and encourage critical thinking must become an integral part of every science classroom.

Diverse levels of ability. In the present study, students who were either characterized as having higher-level thinking skills, or being more accustomed to activities which challenged their thinking competence, seemed to experience the most positive effects using the prediction activities. Some were described by the teachers as participating for the first time, and utilizing thinking skills that had not been seen by the teachers previously. One of these students was identified by Teacher A as displaying the best thinking in the class during the prediction activities.

On the other hand, Teacher D described his experimental students as generally having "poor" thinking skills. As
noted earlier, he expressed the opinion that his control class would have benefited more from the predictions because the students were more thoughtful, and effectively utilized their skills more often.

The teachers expressed the belief that their students were not sufficiently challenged to think critically in their former science classes. "Spoon feeding" copious amounts of information, with little consideration of thoughtful or challenging ideas, appeared to be the order of the day. Therefore, when the students were asked to be involved in prediction activities which required higher-level thinking skills, they felt threatened and some refused to participate. Often heard statements were "This is too hard," or "We haven't ever done this before."

Teacher effects. The teachers, especially A and B, were described by the independent observers in this study as "pushing" for critical thinking in the experimental classes. The format of the prediction activities allowed the teachers to ask more open-ended questions requiring synthesis and evaluation. Perhaps there were two reasons for this. First, the students had an opportunity to think through the ideas prior to discussion. Second, since the primary goal of the teachers' efforts was not to disseminate information, it freed them to probe and question at a deeper level.
The independent observers noted that students in Teacher D's classes sometimes refused to make their predictions; they preferred to wait until the teacher gave them the correct answer. The question raised in this researcher's mind concerns whether science teachers are hesitant about presenting challenging experiences to students because they have low-level thinking skills. It would seem that omitting critical thinking opportunities compounds the existing problem. This researcher believes that students have to be intentionally drawn into the lesson, building on what they already know and challenging them to think critically. Often the educator has to assist students in making connections through the questioning strategy. Those "eureka" moments when one can observe students' thought processes are indeed golden moments. The level of questioning is extremely important, and it would seem that the prediction activities enhanced the quality of Teacher A's and B's efforts. This was not observed to any great extent for Teachers C and D.

The prediction exercises were designed by this researcher to promote critical thinking, and the results of this study indicated that this intention was accomplished. The teachers expressed a desire to challenge thoughtfulness in their students; each of them stated during the interviews that the prediction activities had served such an end.
Questioning

As noted earlier, all of the teachers were described by the independent observers as probing and questioning more in the experimental classes. One observer wrote, "The agenda in the control classes was to present the material. In the experimental classes the teachers displayed more effort to elicit student responses through thoughtful questioning."

Not only were the teachers' questions enhanced, so was the level of student-generated questions. The discussion of the predictions appeared to provoke greater inquisitiveness. It was suggested by the teachers and the observers that one of the reasons for this was that the students sought to confirm their predictions. This idea was also presented by Good et al. (1988) following their research with high school physical science students.

Prior Knowledge and Alternative Conceptions

One of the most revealing statements during the study was made by Teacher C when he commented, "Most [referring to his students] did not have much prior knowledge except misconceptions." This seemed to be the consensus of the teachers. Teacher A expressed that he started from "ground zero." This researcher is somewhat perplexed, for the school system involved in the study requires every student to take a life science course during the middle school years, and the curriculum includes basic genetics concepts.
Evidently one of two things occurred. The students either received inadequate instruction during this time, or they did not achieve any semblance of mastery during the exposure. The low scores on the genetics achievement pretest attested to this.

The teachers stated that the prediction activities assisted them in identifying a number of alternative conceptions held by the students. These identified beliefs seemed to fall into two categories. The first could be characterized as misinformation. For example, some students believed that sickle cell anemia was caused by improper diet.

The second type of alternative conception described by the teachers revealed inadequate use of critical thinking skills. The experimental students had difficulty understanding why germ mutations were considered more serious than somatic mutations. It seemed that when students were confronted with analytical problems requiring application of concepts that had been previously taught, such as the law of independent assortment or the law of dominance, they were unable to apply these to new situations.

During the interviews, the teachers expressed belief that deeper levels of understanding occurred in the experimental classes due to errors in thinking or
misunderstandings being dealt with directly and immediately through classroom interaction and dialogue. The importance of identifying alternative conceptions should not be underestimated. Kuhn et al. (1988) contended that the identification of these "inferior strategies" should be given "as much, if not more" emphasis than the instruction that will assist the students in replacing them.

**Student-Student Interaction**

The disparity between the observers' field notes and the teachers' logs while describing student-student interaction was another noteworthy finding. The teachers felt the student-student exchanges were good or improving, but the observers described both the experimental and control classes as teacher-centered. This researcher believes that science teachers often see themselves as having responsibility for all classroom events. It would seem that many science educators believe they are the disseminators of information rather than the arbitrators of dialogue and discussion. This was evidenced in the present study. In both the experimental and control classes the teachers were described by the observers as "taking-charge" whenever there was student-student disagreement; reciprocal student dialogue was not valued.

One of the emphases of the present reform effort in science education is the promotion of higher-order thinking.
It may be that teachers will no longer feel an obligation to be totally in charge. The implication is not that the classroom will be chaotic. On the contrary, the classroom will be filled with on-task individual and group efforts that sponsor intrinsic motivation, autonomous learning, mastery of relevant content, and critical thinking.

**Race and Gender**

It was difficult, if not impossible, for this researcher to draw any conclusions from the quantitative data reported for race and gender. There seemed to be no consistent findings. For example, black students in the experimental group were reported to have significantly more positive attitudes toward science, whereas, white students in the control group displayed the same effects. There were no race effects shown for genetics achievement. For achievement motivation, black students in the experimental group scored more positively for this construct, but no significant race differences were shown for the control group.

The experimental females displayed the greatest improvement in their attitude toward science. One interesting finding was that Teacher D's classes were the only ones which revealed significant gender effects. It was noted earlier that his students, both male and female, had the least positive attitudes toward science on both the pre-
and posttests. Females in his experimental class showed significantly more positive attitudes toward science. Yet, males in his control class were found to have significantly more positive attitudes.

Males in Teacher D’s classes, both experimental and control, had significantly more positive scores on achievement motivation. These findings do not corroborate those of Simpson and Oliver (1990) who found that males displayed more positive attitudes towards science and females had higher achievement motivation. No gender differences for achievement motivation were observed for students in the other teachers’ classes, and no race effects were shown for any of the teachers. There seemed to be no consistent effects for either race or gender.

Changes in Teaching Styles

An analysis of the data revealed that teaching styles had important effects on instructional outcomes. For Teachers A and B, the observers described positive differences in their teaching between the experimental and control classes. This was true to a lesser extent with Teachers C and D. It is this researchers opinion that Teachers A and B more astutely used the prediction activities for the purpose they were intended—to promote class participation and critical thinking. It was difficult for the other two teachers to give up their roles as
disseminators of information. Student dialogue was not highly valued in either their experimental or control classes. Their agenda was to be sure the students understood what the correct predictions should be.

It would seem to this researcher that in spite of three training sessions and numerous conferences while the study was being conducted, the essence of its intent was never thoroughly conveyed to Teachers C and D. An example of this was their insistence during the interviews that the students' lack of prior knowledge limited their ability to make predictions. No such statements were made by Teachers A or B. The prediction activities were designed by this researcher to minimize the need for prior knowledge. In most instances information was presented to the students on the activity sheets before they made their predictions. What was required was that the students think critically about the ideas before they gave their responses. This was shared with the teachers during their training sessions. It was articulated to them that making correct predictions was not the primary objective of the exercise. Instead, the emphasis was on encouraging the students to think critically, to justify their ideas, and to discuss these with the class as an introductory activity to the lesson topic. The teachers were asked to convey this emphasis to their students. Teachers C and D continued to dwell on the
Importance of making correct predictions and felt the reason why the students were not able to do so was lack of prior knowledge.

Teachers C and D have what this researcher calls a "keeper of the gate" teaching style where all dialogue is processed through them first. It was not easy for Teachers C and D to value student predictions unless they were correct. One observer stated succinctly, "This is the way they have always done it, and they are going to continue to do it. They do not seem interested in changing."

Combining Qualitative and Quantitative Research Methods

There is no doubt in this researcher's mind that qualitative and quantitative research methods, when combined, have what Roberts (1982) calls "complementarity." He contended that both approaches assist in describing the reality of the setting better than either could alone. While the quantitative measures used in this study provided numerical information about particular constructs (genetics achievement, attitude toward science, and achievement motivation), the qualitative evaluations described what Easley (1982) termed "the cognitive and social interaction mechanisms that underlie the learning process in classrooms" (p. 191). The qualitative descriptions assisted this researcher in eliciting what Bogden and Biklin (1982) term "meaning" from the participant's own point of view.
As in Lawrenz and McCreath's study (1988), the two research methods used in the present research effort revealed somewhat different, yet interesting and relevant information. By combining the two methods, a much clearer picture was made of the strengths and weaknesses of the experimental treatment. Although the two approaches were not always mutually supportive, they each added unique dimensions which would not have been described unless both had been included.

**Implications for Further Research**

**Cooperative Grouping**

An important result of this study was the positive treatment effects that occurred when cooperative grouping was used during the prediction activities. The primary feature of cooperative learning is the interactions among the students (Webb, 1982). Johnson and Johnson (1983) demonstrated that cooperative grouping promoted the use of higher-order reasoning strategies and critical thinking competence. It has been shown that cooperation has a more positive effect than either competition or individual efforts, especially if a group product is required. Furthermore, helping behaviors exhibited among students have been shown to be positively correlated with achievement (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981).
During the interviews in the present study, the teachers stated that the prediction activities lend themselves to working within cooperative groups. Teacher A particularly expressed strong feelings that the prediction activities were enhanced if they were done cooperatively. The term he used to describe the effects on students with less confidence was that they felt "validated" if they could discuss their predictions within the small group first. Potentially fruitful research is indicated which investigates the effects of combining cooperative grouping and the making of predictions.

**Thinking Skills Instruction**

A desire to promote higher-order thinking skills by science teachers has spread nationally (Chance, 1986), yet, Lawrenz (1990) stated that "little is known about the use and relationships of teaching techniques related to these skills" (p. 835). Smith (1989) identified a need for subject matter instruction to be linked directly with thinking skill instruction. Higher-order cognitive abilities were characterized by Resnick (1987) as "nonalgorithmic, complex, and effortful" utilizing "multiple solutions, nuanced judgment, uncertainty, self-regulation and imposing meaning." Lawrenz (1990) observed that even though these skills are needed for many of today's
technological occupations, they are not necessarily "routine outcomes" of our present education system.

Varying approaches was mentioned by Resnick (1987) as "the most fruitful way" to enhance thinking competence. During this study, Teacher B suggested such a potential variation. He believes computers could be used effectively to enhance students' prediction making skills. Roblyn, Castine, and King (1988) would agree; the researchers contended that when computers are integrated into the curriculum, opportunities are provided to strengthen higher-order thinking skills. Further research is clearly indicated on combining prediction making and computer programs which challenge and utilize higher cognitive abilities.

Mentioned previously was the fact that students involved in this study attended schools where the normed test scores were well below the national average. None of the students participating in the present research effort were identified as being academically superior by their teachers. In fact, the opposite was true. They were generally depicted as somewhat unmotivated, displaying low levels of academic competence and thinking skills. Research is clearly needed to assist teachers in identifying students with thinking skill deficiencies so that these deficits can be addressed directly through instructional intervention.
Further research is also needed to study the effects when academically talented students participate in prediction
making. This segment of the student population was not represented in the schools participating in this research
effort.

**Low Levels of Student Motivation**

Studies are indicated to examine why so many students have such low scores when describing their intrinsic
motivation. Naccarato (1988) posited that the cognitive and affective dimensions of student motivation have not been
adequately described. This researcher believes that complex affective and cognitive dynamics were operating in Teacher
D’s experimental classroom, resulting in frequent lack of participation. Additional research is clearly needed to
explore the multifaceted dimensions of motivation.

As noted earlier, Ames (1987) maintained that qualitative evaluations could assist in describing more completely student motivation. The qualitative descriptions included in the present research effort provided insight into how complex this construct is. Students were described as participating who had never done so before. Why did the prediction activities stimulate their responsiveness? Other students were depicted as refusing to make predictions; they waited for the teacher to assist them. Why did they refuse? These are indeed difficult questions.
It would appear that qualitative descriptions hold a great deal of promise in identifying both dysfunctional and functional factors that affect one's desire to learn. This researcher believes the emphasis of future research efforts which investigate student motivation should not only be on identifying levels of motivation, but also on assisting students in modifying their negative attitudes so that personal competence can be enhanced in directing one's own learning. The intention of such studies would be to develop teaching and learning strategies that would address identified deficiencies in order to promote intrinsic motivation and autonomy.

Smith (1983) noted that only recently have educational researchers included motivation in their learning theories, and Maehr (1983) believes that motivation theory has not been applied in any systematic way in science education. A need for additional research is indicated which investigates deficiencies in intrinsic motivation.

Teaching Styles

The quantitative findings of this study clearly showed that teaching styles affected attitude toward science and genetics achievement. For both the experimental and control classes, Teacher A's students showed a significantly greater magnitude of difference over time for genetics achievement. The qualitative data described the overall classroom
environment for Teacher A's classes as being positive and supporting, especially when compared with Teachers C and D. Significant negative teacher effects were reported for Teacher D's classes (both experimental and control). His students had significantly less positive scores on the attitude toward science inventory. The qualitative data depicted Teacher D's classroom as generally "unfocused" and even disorderly. Teachers A and D in the present study had very different instructional styles. The former's approach could be described as probing and questioning. The latter's agenda appeared to be disseminating information. The quantitative and qualitative findings of this study were mutually supportive concerning teacher effects.

Studies are indicated to identify ways to both encourage and assist science teachers in including prediction making in their repertoire of strategies. Formal prediction activities such as the ones included in this study are not always required. It is this researcher's belief that a gifted educator can astutely include the process skill of prediction in numerous and varied ways to promote critical thinking and student involvement. These areas of investigation hold promise for fruitful research.

Including Prediction Making in Other Curricula

Genetics proved to be an excellent area of biology for prediction making. This researcher had difficulty limiting
the prediction activities because of the number of variables operating within the inheritance mechanisms. Despite the complexity of some of the factors, the results of this study showed that students can make thoughtful predictions when encouraged to do so. A key factor in the success of these efforts was the insistence by the teachers that the students justify their responses.

Other areas of biology would also lend themselves to prediction making. Some suggested topics for including prediction would be ecosystems and populations, evolution and speciation, comparative anatomy and physiology, and health units on drugs and alcohol.

**Limitations**

The fact that students were not randomly selected to participate in this study may be seen as a limitation. Instead, intact classes of the four biology teachers served as the experimental and control students. As noted earlier, the students were heterogeneously grouped by ability, gender, and race as a result of the regular scheduling process. No significant differences between the two groups were shown as a result of a chi square analysis, therefore the lack of randomization did not appear to influence the results.

The lack of effort by Teachers C and D was a limitation to this study. The quality of their logs deteriorated as
the study progressed. For the first few lessons involving the prediction activities they did a good job comparing the experimental and control classes. As the days went by the quality of their observations deteriorated. Toward the end their comments were repetitive and extremely brief, evidencing little thought. This was not the case with Teachers A and B. In fact, the opposite was true. As the study progressed their comments about the lessons became more descriptive and thoughtful; they provided detail and depth to the data. Not only were Teacher C's and Teacher D's logs incomplete, they failed to utilize several of the prediction activities due to poor planning on their part. Some of the topics were covered cursorily, or not at all. They simply ran out of time. Certainly this affected the genetics achievement posttest scores since one question was included from each of the 19 prediction topics. Students in Teacher C's and D's classes had the lowest scores on the genetics achievement posttest.

The lack of student heterogeneity may be viewed as another limitation to this study. As noted earlier, the schools participating in this research effort were part of a system which operates a number of magnet schools for the academically talented. For this reason, there were few, if any, students in the study who were representative of this segment of the student population. A need for further
research using prediction making with high-ability students was indicated in a previous section of this chapter.

Another limitation identified by all four teachers was the length of the study. They suggested that the prediction activities be made available to biology teachers for use on a selective basis because the inclusion of all the topics may extend the genetics study beyond the time allocated in the curriculum guides. It is this researcher's opinion that unbending adherence to curriculum time guidelines is restrictive to quality instruction. It would seem that the competent science educator is greatly limited by such constraining agendas.

The teachers did not recommend that the prediction activities be shortened for they felt the thorough coverage of the topics was a positive aspect. Instead, they suggested that they be made available to biology teachers as an instructional tool to assist in identifying prior knowledge and alternative conceptions, and to promote critical thinking and classroom participation. The teachers could then choose the activities which best meet the needs of their students.

The lack of mutual support between the qualitative and quantitative results may be seen as a limitation of this study, although there were areas where they concurred. Significant differences were not found between the
experimental and control groups for genetics achievement and achievement motivation, yet the qualitative descriptions noted remarkable distinctions between the two groups on observable aspects of learning and motivation. Students in the experimental classes were described as displaying enhanced levels of understanding. During the times of discussion their elevated interest was evidenced by overt displays of motivation such as volunteering and questioning.

The two research approaches were mutually supportive in describing teacher effects. Both the quantitative and qualitative analyses showed differences between the teachers described in an earlier section of this chapter. In the areas of disparity between the results of the two research approaches, further research is clearly indicated.

A final limitation of this study may be the reliability of the genetics achievement test. The posttest reliabilities for the control and experimental classes were modest (.53 and .63, respectively).

Final Conclusions

The most heartening aspect of this study to this researcher was the intention of the teachers to include the prediction activities in their future genetics units and prediction making in their repertoire of instructional strategies. They expressed regret that the activities could not be used in their control classes. On one occasion,
Teacher D resorted to using the prediction activity "Crossing-Over and Other Chromosome Mutations" when students in the control class were experiencing difficulty understanding these concepts.

The teachers stated that the requirement for students to think critically as they made their predictions was one of the most positive aspects. Teacher B commented during the interview, "I had gotten into the old habit of asking questions and giving them two or three seconds to respond and then moving on. I think by having them make the predictions they have to come up with an answer instead of saying, 'I don't know.'" Teacher D stated, "I have already started doing it in other classes. I ask them to predict to get them thinking about it."

One of the most noteworthy findings of this study was that for both genetics achievement and attitude toward science, statistically significant teacher effects were found. The teacher does seem to make an important difference in regards to the level of learning and the development of positive attitudes in the science classroom.

Madsen and Madsen (1983) recommended that teachers vary their classroom activities to include innovative and fun experiences to promote learning. A summary of the qualitative data from this study indicated that making predictions promoted classroom participation, critical
thinking, and student enjoyment. As Mathison (1989) noted, attitude affects personal involvement in a task. Assisting students in developing a positive and anticipatory attitude toward an assignment appears to hold promise for increasing student motivation and the quality of learning.
References


APPENDIX A

PREDICTION ACTIVITIES
HOW INHERITANCE OCCURS

The Chromosome Theory was proposed by Walter Sutton in 1902 and says that hereditary traits are controlled by our chromosomes. To review, recall that chromosomes are made primarily of DNA, and it is the sequences of adenine, thymine, cytosine, and guanine within the DNA that regulate inheritance. Genes are small portions of chromosomes that control specific hereditary traits, and there are literally thousands of genes that compose a single chromosome.

With these things in mind, as well as your understanding of meiosis (the production of egg and sperm), please respond to the following:

---Predict which one of these statements best explains why humans usually do not look exactly like either their biological mother or father: (Circle your prediction and be prepared to explain your choice to the class).

a. The environment primarily determines what we look like.

b. Half of our chromosomes come from our mother and half from our father, so both contribute to our appearance.

c. The egg carries only recessive genes, whereas the sperm carries both dominant and recessive traits.

d. Factors in the cell other than DNA determine hereditary traits.

e. Since the egg is much larger than the sperm it contributes more chromosomes to the offspring.

---Assume you have to explain why two brothers, from the same biological parents, do not look alike. Which one of the following would you predict best explains their differences? (Circle your prediction and be prepared to explain your choice to the class).

(See Next Page for Choices)
a. The boys probably have none of the same chromosomes.

b. They probably do not have the same chromosome combinations because of the reduction division that occurred during meiosis, producing the egg and sperm.

c. There is no genetical explanation as to why the two brothers do not look alike.

d. One boy inherited all dominants, where the other son inherited all recessives.

---Predict why red hair and freckles are usually inherited together: (This is a challenging question so give it some thought)

---Identical twins, separated at birth and raised by different families, grew up to be very similar in appearance except that one is 2 inches taller than the other. Predict how this difference could have occurred:
Parents pass on hereditary traits to their children via the chromosomes of the egg and sperm. As you know, chromosomes occur in pairs, so when the egg and sperm join, one member of each pair comes from the mother and the other comes from the father.

Gregor Mendel, the Father of Genetics, found that certain traits were dominant over others. What do you think Mendel meant by the term dominant trait?

Mendel did most of his experiments on plants, but his discoveries also apply to human inheritance. It was later found that brown eyes in humans are dominant over green and blue eyes (green and blue eyes are known as recessives). Predict what possible eye color(s) the children can have if the father receives only genes for brown eyes from both of his parents, and his wife has blue eyes. Please explain your prediction.

What if the father has brown eyes, but "carries" blue eyes as an unexpressed recessive? His wife has blue eyes. Predict the possible eye color(s) of the children. Please explain your prediction.
DIHYBRID CROSSES AND MENDEL’S PRINCIPLE OF INDEPENDENT ASSORTMENT

Each normal human has a total of 46 chromosomes (23 pairs) in every cell except the gametes (egg and sperm). These sex cells have only 23 chromosomes, or one member from each chromosome pair. To review, during meiosis (which occurs in the ovary and testes) each of the pairs separate and the chromosomes go into different gametes. HOW ONE PAIR SEPARATES HAS NOTHING TO DO WITH HOW THE OTHER PAIRS SEPARATE. This is known as Mendel’s principle of independent assortment. A parent contributes only one chromosome from each pair to an offspring.

To assist you in understanding this principle it will help to perform some DIHYBRID CROSSES (those that involve the inheritance of two different traits found on different chromosomes).

Mendel used garden pea traits to explain independent assortment. In peas, tall plants (T) and round seeds (R) are dominant over short plants (t) and wrinkled seeds (r). A heterozygous plant can produce four kinds of gametes. The diagram shows the four possibilities. F-O-I-L is a memory device for determining the possible types of gametes that can be produced. F is for the first two alleles of each trait; O is the outer two; I is the inner two; and L is the last two.

Perform the dihybrid cross on the next page, predicting the four different types of gametes that can be produced from each parent using the FOIL method. Two of the gametes for each parent have been filled in for you, as well as some of the genotypes of the offspring. Complete the 16-square Punnett and predict how many of the offspring will likely display each phenotype listed for you.

\[ \text{FOIL Diagram: } \begin{array}{c}
\text{F: } \text{Tt} \text{Rr} \\
\text{O: } \text{Tt} \text{Rr} \\
\text{I: } \text{Tt} \text{Rr} \\
\text{L: } \text{Tt} \text{Rr} \\
\end{array} \]
In pigs curly tail (C) is dominant over straight tail (c), and pink skin color (P) is dominant over all other skin colors (p). Cross two pigs which are heterozygous for both traits.

<table>
<thead>
<tr>
<th></th>
<th>CP</th>
<th>cP</th>
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<tbody>
<tr>
<td>CP</td>
<td>CcPP</td>
<td>CCpp</td>
</tr>
<tr>
<td>cP</td>
<td>CCpp</td>
<td>ccpp</td>
</tr>
</tbody>
</table>

Predict the following:

*** How many will likely be pink with curly tails? ____
*** How many will likely be pink with straight tails? ____
*** How many will likely be black with curly tails? ____
*** How many will likely be black with straight tails? ____

What is the phenotypic ratio?
Now perform the following two-trait cross between a pig that is heterozygous for both traits with one that is heterozygous for skin color, but has a straight tail. Determine the types of gametes using the FOIL method and complete the 16 square Punnett showing the types of possible offspring:

\[ CcPp \times ccPp \]

Predict the phenotypes of the offspring:

*** How many will likely be pink with curly tails? ___
*** How many will likely be pink with straight tails? ___
*** How many will likely be black with curly tails? ___
*** How many will likely be black with straight tails? ___

What is the phenotypic ratio:
Most genetic traits are completely dominant or recessive. A few are said to be CODOMINANT. An example of this is seen in domesticated cats. When a Manx cat (one with no tail) is crossed with a cat which is homozygous for a long tail ALL of the offspring have very short tails.

---Some flowers display codominance in the color of their flower petals. Suppose you cross the pollen of a red flower with the egg of a blue flower, and all of the resulting offspring produce purple flowers.

---Predict the kinds of offspring that could result from a cross between two of these purple flowered plants (BB'): (Suggestion - Use the Punnett square below to show the types of offspring produced. Let B stand for the gene that codes a blue flower and B' stand for the gene that codes a red flower.)

---Predict the genotypes of the parents when the phenotypic ratio of the offspring was 2 Blue : 2 Purple. Again, it might be helpful to use a Punnett square to explain your prediction.
SEX DETERMINATION: FEMALENES AND MALENESs

Under column A place a check mark by each statement that you predict is true about human sex determination:

A    B    C

1. Far more females are born than males.
2. Far more males are born than females.
3. Slightly more males are born than females.
4. Slightly more females are born than males.
5. The father determines the sex of the child.
6. The mother determines the sex of the child.
7. The female gets all of her genes for the female traits from her mother.
8. The male gets all of his genes for maleness from his father.
9. Traits for maleness and femaleness come from both parents.
10. The sex of the child is determined the moment the egg and sperm join to form the zygote.

Now consult with another student on his/her predictions. As a result of your discussion you may change your mind about the predictions you made in Column A. Make a second set of predictions in Column B after conferring with another student. Certainly you do not have to change your mind if you feel your original predictions are correct.

Column C is for you to make your final predictions following the lesson on sex determination. After verifying the correct statements checked in Column C, compare these with your original predictions in Column A. How many did you predict correctly? _______. After consulting with another student did you improve your predictions in column B? _______. Do not feel bad if your predictions were not all correct. Studies have been done on adults in the United States that showed over 50% of the population do not understand sex determination.
POPULATION SAMPLING AND HUMAN GENETIC TRAITS

How common are certain inherited traits in the human population? POPULATION SAMPLING involves studying how often genes occur in populations. Data from a random sample for a small part of a population is assumed to be representative of the whole population. Thus, if a random sample of 100 people is taken, and 50 have curly hair, it can be assumed that in the whole population half of the people have curly hair.

Many human traits are controlled by a single pair of genes. In this study you will first determine your own phenotype for each trait, and then assess other members of your class. By doing this, you will be investigating the patterns of inheritance of some human genetic traits.

Complete the table below. The traits have been described for you on the next page. Determine your own phenotype first, based on the descriptions given. Then your teacher will help you gather the information needed from the rest of the class.

<table>
<thead>
<tr>
<th>Individual and Class Data</th>
</tr>
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<tbody>
<tr>
<td>Trait</td>
</tr>
<tr>
<td>Tongs Rolling</td>
</tr>
<tr>
<td>Ear Lobes</td>
</tr>
<tr>
<td>Hair on Mid Digits</td>
</tr>
<tr>
<td>Widow's Peak</td>
</tr>
<tr>
<td>Hand Clasp</td>
</tr>
<tr>
<td>Little Finger</td>
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<tr>
<td>Chin</td>
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</tbody>
</table>

Name ___________________ Period ___ Date _____
The ability to roll one's tongue into a "U" shape is dominant (See figure 1). Inability to roll the tongue is recessive. Determine your phenotype and complete the table under "My Phenotype."

Another dominant is free earlobes (See figure 2). Attached earlobes is the recessive trait. Determine your phenotype for the trait and record it on the table.

The presence of mid-digital hair is dominant over the absence of hair on the mid-digit (See figure 3). Notice each of the sections on the back of your fingers. All humans have hair on the section closest to the palm. However, some people also have hair on their middle segment. You should check each finger; if you have hair on the middle digit of any of your fingers consider yourself having the dominant trait. Determine your phenotype and record it on the table.

The presence of a widow's peak is dominant to a straight hair line (See figure 4). If your hair comes to a point in the middle of your forehead, you have a widow's peak. Record your phenotype on the table.

When you clasp your hands, if the left thumb folds over the right one you have the dominant trait (see figure 5). If your right thumb folds over your left you display the recessive. Determine your phenotype and record it on the table.

The little finger in some people has a noticeable inward bend (See figure 6). The bent little finger is dominant over the straight finger. Determine your phenotype for this trait and enter it on the table.

(See next page for dimpled chin)
Figure 7

Some people have a dimple in their chin (See figure 7). This is a dominant trait, while an undimpled chin is recessive. Record your phenotype on the chart.

Now your teacher will help you gather data from the rest of your class. When you have completed your table, recording how many students display each trait, calculate the percentage of students in your class who have the dominant phenotype, and record it on the table. First find the total number of students in your class (Don't forget to count yourself!). Then divide the number of rollers by the total number of students. The answer will be a decimal fraction between 0 and 1. Multiply the answer by 100 to get the percentage. For example, if there are 18 students in the class, and 5 can roll their tongue, then the percentage is:

\[
\frac{5}{18} \times 100 = 0.28 \times 100 = 28\%
\]

Now calculate the percentage in your class that has the recessive phenotype for each trait and record it on the table. (Hint -- all you have to do is subtract the % displaying the dominant trait from 100%. The answer will be the percentage displaying the recessive trait.)

Based on your genetic sampling of the class, make the following predictions:

---Predict which trait will be found most often in the human population, based on your data:

---Predict which trait will be found least often in the human population, based on your data:

---Predict why the same percentage of students does not display the dominant phenotype for each of the traits (Careful, this is a challenging question so give it some thought.)

---Do any of the traits you sampled show more people displaying the recessive phenotype than the dominant? If so, which one(s)?

Predict how this can happen. How can the majority of the population display a recessive trait?
GENETIC PROBABILITY

The principles of heredity are related to the laws of probability. PROBABILITY describes how likely it is for something to occur, and is given as a percentage or a fraction. There is a very useful mathematical equation to calculate probability:

\[
\text{Probability} = \frac{\text{Number of One Kind of Thing}}{\text{Total Number of Things}}
\]

For example, if 1 out of every 4 children in a sample has blue eyes, what is the probability that blue eyes will occur in the general population?

\[
\text{Probability} = \frac{1}{4} = 0.25 \text{ or } 25\%
\]

Probability has two very important rules. The first is THE RULE OF INDEPENDENT EVENTS which says that previous events do not affect the probability of later occurrences of the same event. When you flip a coin, predict what the probability is that it will come up heads? ______. Now apply the Rule of Independent Events. If you flip the same coin again, what is the probability it will come up heads? ______. Apply this same rule to genetics, remembering what you have learned about sex determination in humans.

A couple already has three sons. Predict what the probability is that their fourth child will be a boy: ____________.

Another rule of probability is THE PRODUCT RULE which says that the probability of two independent events occurring together is equal to the product of the probabilities of these events occurring separately. For example, if you toss a penny and a nickel at the same time, what is the probability that they will both come up heads?

\[
\frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \text{ or } 25\%
\]

Prob. of penny being heads \times \text{Prob. of nickel being heads} = \text{Prob. of both being heads}
Now apply this law to genetics.

Predict the probability of a couple having three girls in a row?

STOP! DO NOT CONTINUE UNTIL ASKED TO DO SO

Perform the following crosses, using the Punnett square, and answer the questions about probability:

In humans, black hair is dominant (B) and blonde hair is recessive (b). The mother is heterozygous for black hair, and the father has blonde hair. PREDICT THE PROBABILITY OF THIS COUPLE HAVING A BLONDE-HAIRED CHILD. Please use the Punnett square in making your prediction. Circle the blonde-haired child(ren) in your Punnett square.

The probability of a child having blonde hair is _____%.

In summary, each time a child is born he/she is a result of genetic chance. Predict how it is possible for a red-haired father and a black-haired mother to have a blonde-haired child. Hint -- the gene for red hair (r) is dominant over blonde (b), but recessive to black (B). Please use the Punnett square in making your prediction. Circle the genotype of the child(ren) with blonde hair in your Punnett square.

(See next page for additional responses)
From the cross on the previous page, what is the probability--
that a child will have red hair? _____%  
that a child will have blonde hair? ______%  
that a child will have black hair? ______%
Mothers transmit sex-linked traits to their daughters and sons. Fathers transmit sex-linked traits only to their daughters. Predict which chromosome carries sex-linked traits that are passed on to the children: 

If you predicted that sex-linked traits are carried only on the X chromosome and not the Y you are correct. Because the X chromosome is much longer than the Y, it carries many more traits.

An example of a sex-linked trait is a disease called hemophilia in which the blood lacks a specific protein necessary for the blood to clot. The most seriously affected individuals can bleed to death with just a minor cut! THERE ARE MANY MORE MALE HEMOPHILIACS (those who suffer from hemophilia) THAN THERE ARE FEMALE HEMOPHILIACS. Predict why more males suffer from hemophilia:

There are five possible genotypes and they are represented by superscripts above the X chromosome.

- \( H^H X^X \) - female with normal blood clotting
- \( H^h X^X \) - female with normal blood clotting, but who carries hemophilia as a recessive
- \( h^h X^X \) - female with hemophilia
- \( H^h X^Y \) - male with normal blood clotting
- \( h^h X^Y \) - male with hemophilia
Using a Punnett square cross a female carrier with a normal male and predict the phenotypes of their offspring:

\[
\begin{array}{c}
H \ h \\
X \ X \\
\times \\
X \ Y
\end{array}
\]

Probable Phenotypes of the offspring are:

**** Hemophiliac males: ___ out of 4 children
**** Hemophiliac females: ___ out of 4 children
**** Normal females who are carriers: ___ out of 4 children
**** Normal males: ___ out of 4 children
**** Normal females who are not carriers: ___ out of 4 children

What are the chances that a female carrier will pass the hemophiliac gene on to her children? _____. What are the chances that a male hemophiliac will pass the gene on to his daughter? _____. What are the chances that a male hemophiliac will pass the gene on to his son? _____.

A female can suffer from hemophilia, but this is very rare. The disease is inherited as a homozygous recessive in the female. Using the Punnett square predict what the genotypes of the parents must be to have a hemophiliac daughter. Circle the square that contains the female hemophiliac.

Today hemophilia is treated by administering the Factor VIII drug which assists the blood in clotting. Predict how the use of this medication will affect future generations:
Predict why, until the age of modern medicine, the gene for hemophilia was usually passed on to the offspring by the mother and not the father:

There are more than 50 known sex-linked human traits. You are probably familiar with one because of Jerry Lewis's Telethon each Labor Day. Duchenne muscular dystrophy is a fatal disease destroying the muscles in children. Another less serious and more common sex-linked trait is red-green color blindness, which affects about 8-10% of all males. Both of these diseases are inherited exactly like hemophilia.

Predict whether the following statements are true or false (Circle your answer.) If you believe the statement is false, restate it correctly in the space provided. Be prepared to explain your responses to the class.

T or F A female can be color blind only if her mother and father are both color blind.

T or F Color blindness may be passed on to the son by the father.

T or F Color blindness acts as a dominant trait in the male because he just has to receive the trait from his mother in order to be color blind.

T or F All color blind males will have color blind daughters.
A pedigree shows the pattern of inheritance in a family for a specific trait. Geneticists study family trees by observing the occurrence of a trait over several generations. This helps them understand how dominance, recessiveness, and sex-linkage operate in a family.

Figure A shows a human pedigree for freckles, which is a dominant trait ($F$). The gene for no freckles ($f$) is recessive. Here are the rules for interpreting a pedigree:

1. Each generation is lettered. (See A-C)
2. Each person is numbered. (See 1-11)
3. Males are represented by squares. (See person #2)
4. Females are represented by circles. (See person #1)
5. Marriage is shown by striped lines. (See #1 and #2)
6. Children are shown by a solid black line. (See #3, #4, #5, & #7 -- all children of #1 and #2)
7. Dominant traits are represented by white circles and squares. (See #1 and #2)
8. Recessive traits are shaded circles and squares. (See #5 and #10)

How many generations are shown? _____

How many marriages are shown? _____

How many unmarried individuals are shown? _____

How many males have freckles? _____

Predict the following information using the above Pedigree:

Predict the genotype of person #1 ______.
(Hint--look at #5, her son)

Predict the genotype of person #9 ______. (Hint--look at #5, her father)

Predict the two possible genotypes of person #4, ______
or ______
Now that you have had some practice, predict what all of the genotypes are for the individuals in the pedigree for freckles shown in Figure B. In some cases there may be 2 possible genotypes, since you may be uncertain whether they are homozygous or heterozygous for the dominant trait. If this is the case, put down both possible genotypes.

Figure B

Predict the genotype of each individual in the pedigree (the first one has been done for you).

Person 1  Ff  Person 11 __________
Person 2 ________  Person 12 __________
Person 3 ________  Person 13 __________
Person 4 ________  Person 14 __________
Person 5 ________  Person 15 __________
Person 6 ________  Person 16 __________
Person 7 ________  Person 17 __________
Person 8 ________  Person 18 __________
Person 9 ________  Person 19 __________
Person 10 ________  Person 20 __________

Predict how genetic counselors can use a pedigree when counseling a couple who has a genetic disease in their family.
Polygenic traits are controlled by the interaction of two or more gene pairs which may or may not be located on the same chromosome. Assume that human skin color is controlled by at least three separately inherited genes. The three dark skin genes are A, B & C. The light skin genes are a, b & c. An AABBCC person would have very dark skin, whereas an aabbcc person would have very light skin. A person with AabBCc would have an intermediate skin shade.

Another polygenic trait in humans is eye color which is also controlled by three independently inherited gene pairs. Remember, genes can be dominant or recessive, and they also occur in pairs. Therefore, SIX ALLELES control eye color in every individual:

gene 1 = X or x; gene 2 = Y or y; gene 3 = z or Z

The table below shows how eye color of humans is determined by the number of DOMINANT alleles an individual inherits.

<table>
<thead>
<tr>
<th>Number of Dominant Alleles</th>
<th>Eye Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-5</td>
<td>Dark Brown</td>
</tr>
<tr>
<td>4-3</td>
<td>Brown</td>
</tr>
<tr>
<td>2-1</td>
<td>Green</td>
</tr>
<tr>
<td>0</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Complete the chart below as if it were a regular Punnett Square. THERE IS NO NEED FOR THE FULL NUMBER OF CELLS SINCE ALL OF THE FEMALE GAMETES ARE THE SAME. The cross is between a man who is heterozygous for all of the pairs and a female who is homozygous recessive for all pairs.

-xyyzz X XxYyZz

---Based on the above cross, predict the probable eye colors of the children:

*** Dark Brown eyes: ___ out of 8 children
*** Brown eyes: ___ out of 8 children
*** Green eyes: ___ out of 8 children
*** Blue eyes: ___ out of 8 children
Predict how many students in your class will have each eye color. (Determine how many students are in the room before you make your predictions.) After you have made your predictions the teacher will assist you in actually counting the number who have each eye color. Please fill this information under "ACTUAL NUMBER".

Total number of students in class =

<table>
<thead>
<tr>
<th>PREDICTION</th>
<th>ACTUAL NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Brown Eyes</td>
<td></td>
</tr>
<tr>
<td>Brown Eyes</td>
<td></td>
</tr>
<tr>
<td>Green Eyes</td>
<td></td>
</tr>
<tr>
<td>Blue Eyes</td>
<td></td>
</tr>
</tbody>
</table>

Did your predictions come close to the actual? Your class may or may not be representative of the total population, but it is interesting to note the different eye colors of the people you come in contact with daily. The larger your sample is, the more likely your results are to be representative of the general population.

There are several other human traits that are polygenic. Height, hair color, foot size, and intelligence are also regulated by several different pairs of genes.

Assume height is determined by five independent pairs of genes (H codes tall, and h codes short). Predict whether two average in height parents both having the Hh Hh Hh Hn Hn genotype can have a child who is unusually tall (please explain your prediction by showing the possible genotype(s) of the offspring):
A testcross is used by plant and animal breeders to find out whether an organism showing a dominant trait is homozygous (e.g., BB) or heterozygous (e.g., Bb) for a particular trait.

Suppose you are an animal breeder and someone tries to sell you a "purebred" black Arabian stallion. They have no papers on the horse to prove that he is carrying both genes for black coat (BB). PREDICT WHETHER THERE IS ANYTHING YOU COULD DO, AS A BREEDER, TO TELL WHETHER THE ANIMAL IS PUREBRED FOR BLACK COAT: (Hint - you may want to try the crosses shown below before you make your prediction. Let B represent black coat and b all other recessive coat colors.)

Prediction:
NONDISJUNCTION

Errors occur during meiosis when the gametes (egg and sperm) are being formed which can have a significant impact on the offspring. Whenever there is any change in the normal chromosomes it results in what is called a MUTATION.

Most of the time meiosis occurs without any error, but there is an occasional "accident" termed NONDISJUNCTION. Look at the drawing below showing this phenomenon and predict what you think occurs during nondisjunction:

---How many chromosomes are in the original cell? _____

---How many chromosomes should be in the gametes produced by meiosis? _____

---How many chromosomes are actually in the gametes? _____ and _____.

First meiotic division
(Nondisjunction of sex chromosomes)

Second meiotic division

The cause of nondisjunction is not well understood but it is known that during the second meiotic division, instead of the chromatids separating, they stick together. This results in two kinds of gametes -- one with an extra chromosome and another which is missing a chromosome.

If a cell has an extra chromosome in a pair it is called trisomy, and if it is missing a member of the pair it is called monosomy.
In humans, nondisjunction causes a number of serious disorders (syndromes). One such disorder is Down syndrome. These individuals have an extra chromosome (trisomy) in the 21st pair, giving them a total of 47 chromosomes, rather than the normal 46. Shown below is a karyotype (a display of the paired chromosomes) showing the chromosomes of a person suffering from this disorder. The extra 47th chromosome causes mental retardation, short arms and legs, a noticeable fold of the upper eyelid, heart defects, and a shorter life span.

*Graph adapted from Biology by Campbell (The Benjamin/Cummings Publishing Company, Inc., Menlo Park, California, 1987, p. 300.)*

(see predictions about the graph on next page)
--Predict the 5-year age range of the mother who has the least chance to have a Down syndrome child: 

--Predict the 5-year age range of the mother who has the greatest risk of having a Down syndrome child: 

--Predict why older women have a greater chance of having children with Down syndrome: (This is difficult question, and one that is not completely understood, so give it some serious thought) 

__________________________________________________________

__________________________________________________________
CROSSING-OVER AND OTHER CHROMOSOME MUTATIONS

Any change in the normal chromosome is considered a MUTATION. You have already studied one type of chromosome mutation called NONDISJUNCTION. There are several other types. The diagram below displays some of these. In the section that follows read about the mutation and then predict which of the types it describes.

Types of Chromosome Mutations

Sometimes an unusual thing happens during meiosis. Recall that the pairs of double stranded chromosomes (tetrads) twist together. Sometimes a piece of one may trade places with the other. This phenomenon is called CROSSING OVER. Predict which of the diagrams shows the results of this type of mutation.

Often the pieces exchanged are equal, and at other times one chromatid gets extra genes, while the other gets too few. When a chromosome gets extra genes like some it already has, this is known as DUPLICATION. Predict which of the diagrams displays duplication.

When the chromosome is missing a section this is known as a DELETION. Predict which of the diagrams shows this type of mutation?

Other chromosome mutations occur that do not happen during crossover. Exactly why and how they occur is not well understood. One such mutation is TRANSLOCATION where a section of a chromosome will "break off" and attach itself to another nonhomologous chromosome. Predict which of the diagrams displays translocation.

Sometimes a section of DNA in a chromosome will flip upside down but remain in place. This is called an INVERSION. Predict which of the diagrams shows this phenomenon.
Biologists have learned that some chromosome mutations may be beneficial to the organisms, such as equal crossover which results in NEW GENE COMBINATIONS.

Predict how a greater variety of gene combinations can be helpful to organisms. (This is a difficult question. Give it some thought. A hint would be to look up the meaning of HYBRID VIGOR in your textbook).

Usually, though, when genes are lost or are duplicated the results are not beneficial. The organisms will often display genetic defects such as a poorly formed heart or problems with vision, hearing, mental functions, etc.
MUTATIONS: CHANGES IN THE GENETIC CODE

Any change in the DNA of genes and chromosomes is known as a mutation. SOMATIC MUTATIONS occur only in the body cells and do not affect the gametes. GERM MUTATIONS occur in the sex organs and affect the egg and sperm. Predict why germ mutations are considered to be more serious than somatic mutations:

Yet, somatic mutations can be very harmful to the individual in which they occur. An example of this would be if such a mutation caused cells to divide and grow uncontrollably, resulting in cancer.

Some germ cell mutations can go undetected for many generations. Predict how this can happen: (this is a challenging question -- give it some serious thought)

Nevertheless, based on studies of dominant and codominant mutations, scientists believe the rate of mutations is actually very low.

Some mutations seem to just happen, but others are caused by factors in the environment. Anything that causes a mutation is a MUTAGEN. One such mutagen is ultraviolet light (one of the wavelengths given off by the sun). Overexposure has been shown to cause skin cancer. Other mutagens include tobacco smoke taken into the lungs, short wave length radiation such as X-rays, chemicals used in warfare such as agent orange and mustard gas, and chemicals used in the lab such as formaldehyde and nitrous acid. Joshua Lederberg, a Nobel Prize winning geneticist, estimates that 80% of all mutations today occur as the result of controllable environmental factors.

Another type of mutation is called a POINT OR GENE MUTATION, which affects only a single gene that codes a single trait. An example of such a point mutation is albinism, which results in a person that has no skin or eye pigments. The individual, regardless of race, has white skin and hair, and either pale blue or pink eyes. An albino child can have two normal parents. Predict how albinism is inherited. (Please explain your answer.)
Some naturally occurring mutations, although very rare, are beneficial to the species. One such example is the peppered moth, found throughout England. The variety for which the peppered moth is named was light in color with splotches of dark pigment. As a result of mutation, there was also a very rare dark gray variety. Peppered moths feed at night and rest during the day on vertical surfaces such as buildings, trees or rocks. Against these light colored backgrounds the light colored moths were camouflaged, but the dark ones were easily seen and preyed upon by birds.

As a result of the Industrial revolution during the 1800's millions of tons of dark soot covered the environment turning tree trunks and buildings a very dark color. Study the pictures below and predict why these changes occurred between 1835 and 1900.

---

**Peppered Moth Population In 1835**

<table>
<thead>
<tr>
<th>Moth Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White moths</td>
<td>84%</td>
</tr>
<tr>
<td>Gray moths</td>
<td>16%</td>
</tr>
</tbody>
</table>

Light colored tree trunk

---

**Peppered Moth Population In 1900**

<table>
<thead>
<tr>
<th>Moth Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>White moths</td>
<td>19%</td>
</tr>
<tr>
<td>Gray moths</td>
<td>81%</td>
</tr>
</tbody>
</table>

Soot-darkened tree trunk

---

What do you predict will happen to the color of the future generations of the peppered moths if there is enforcement of strict air pollution laws? (Please explain your response)
Predict how this true story illustrates how some mutations may be helpful to a species.

This story also shows that environmental pollution can affect the hereditary traits of organisms. What is your prediction for our future? What kind of caretakers will we be?
Sickle cell anemia is a serious genetic disorder that occurs often among Black people. It affects the hemoglobin in their red blood cells so that they cannot carry oxygen to the body. Normal red blood cells are disk-shaped, but the abnormal sickle cells are shaped like a sickle (the curved cutting blade seen on the Russian flag).

The gene is thought to have mutated among people in Western Africa many years ago. In the U.S., 1 out of every 350 Black people is seriously affected by the disease. The abnormal hemoglobin causes these irregularly shaped cells to stick together and clog small blood vessels resulting in fever and much pain in the joints of the arms and legs. Blood transfusions can help relieve the symptoms, but THERE IS NO CURE FOR THIS DISEASE.

How is sickle cell anemia inherited? The dominant gene (A) produces normal hemoglobin. The codominant allele (A') produces sickle cells. The chart below describes the three possible genotypes and their resulting phenotypes:

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>All red blood cells are normal in shape</td>
</tr>
<tr>
<td>AA'</td>
<td>10-15% of the red blood cells are sickled</td>
</tr>
<tr>
<td>A'A'</td>
<td>Nearly all of the red blood cells are sickled</td>
</tr>
</tbody>
</table>

A person with the AA' genotype is said to CARRY the sickle cell trait. A person with the A'A' genotype HAS THE SICKLE CELL DISEASE.

People that carry the sickle cell trait (AA') are usually quite healthy except when they are at high altitudes. Predict why traveling to high elevations may cause these individuals to become ill?

______________________________

It is fairly easy to tell whether or not a person is a carrier of the sickle cell trait. Predict how it can be determined whether a person carries the sickle cell trait:

______________________________
In the spaces provided below predict the probability of each of the types of offspring two carriers can have. Use the Punnett square to determine the probability.

\[
\begin{array}{c|c|c|c}
& AA' & & \\
\hline
AA' & & & \\
\hline
& & & \\
\end{array}
\]

What is the probability when each child is conceived that it will --

- carry the sickle cell trait? ____%
- have the sickle cell disease? ____%
- have all normal red blood cells? ____%

In the U.S. about 10% of the Black population are carriers. In Africa as many as 40% of Black people carry the sickle cell trait. It is interesting to note that individuals who carry the trait are resistant to malaria, a serious tropical disease carried by the mosquito. Predict why these AA' individuals are immune to malaria: (This is a challenging question - give it some thought)

__________________________________________________________

GENETIC COUNSELING is an important new field in genetics and medicine. Such counselors help couples determine what the chances are that their children will have genetic diseases. Assume that you are a genetic counselor. A Black couple comes to you for counseling. The mother is found to be a carrier of the sickle cell trait (AA') but the father has all normal blood cells (AA). Predict how you would explain to the couple the probability of passing the gene on to their children. (You may want to complete a Punnett square of the cross before you make your predictions.)

\[
\begin{array}{c|c|c|c}
& AA' & & \\
\hline
AA' & & & \\
\hline
& & & \\
\end{array}
\]
HOW BLOOD TYPES ARE INHERITED

There are four human blood types - type A, type B, type AB, and type 0. The letters A and B refer to types of proteins (antigens) found on the surface of the red blood cells. People that have type A blood have inherited the gene to produce the A antigen on their red blood cells. Individuals with type B blood have inherited the B antigen gene. Those with type AB blood have inherited the A and B genes so that they produce both of the antigens on their red blood cells. Type 0 individuals did not inherit either the A or B genes, and have no antigens on their red blood cells.

Geneticists represent blood type in an unusual manner using the letters I or i. There are 3 alleles that code for blood type. These are:

\[
\begin{align*}
A & \quad B \\
I & \quad i
\end{align*}
\]

The chart below shows how blood types are inherited. Study it very carefully:

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>A A</td>
<td>The person has type A blood</td>
</tr>
<tr>
<td>I I or I i</td>
<td></td>
</tr>
<tr>
<td>B B</td>
<td>The person has type B blood</td>
</tr>
<tr>
<td>I I or I i</td>
<td></td>
</tr>
<tr>
<td>A B</td>
<td>The person has type AB blood</td>
</tr>
<tr>
<td>I I</td>
<td>The person has type 0 blood</td>
</tr>
<tr>
<td>i i</td>
<td></td>
</tr>
</tbody>
</table>

Predict how two parents, both with type B blood, can have a child who has type 0 blood. You may want to show this using a Punnett square.
Blood type can often, but not always, be used in courts of law to disprove whether a person is really someone's parent or child. Mr. Smith had blood type O (ii). He was very wealthy and left all of his money to his children upon his death. A young man claiming to be a lost child had type AB blood. The judge quickly dismissed the case because the geneticist said that it would be impossible for this young man to be Mr. Smith's son. Predict why the geneticist was so certain:

A nurse suspected that the name tags of two babies had been accidentally switched. She performed blood tests to find out. Mother #1 had type A blood, and Mother #2 had type AB. Baby X had type O, and Baby Y had type A. Predict which baby (X or Y) belongs to Mother #1 (Please explain your answer):

Predict which baby (X or Y) belongs to Mother #2 (Please explain your answer):
Some people know that they are at risk for carrying a certain genetic disease because family members display the disorder. For a few of these diseases it is possible to determine whether a person carries the genetic disorder, even though they do not display the condition themselves. Predict how this could be helpful to the individual:

---

Cystic Fibrosis is the most common genetic disease among the White population. It is inherited as a recessive. The disease causes a thick build-up of mucus both in the lungs and in the digestive organs. As a result, the child has great difficulty in breathing, and is very susceptible to respiratory infections. Also, the pancreas and liver are not able to secrete an enzyme necessary for proper food digestion and absorption. Because of this the child suffers from malnutrition, even though he/she is eating nutritious foods. Careful medical treatment and oxygen therapy can help these children, but some may die before they reach adulthood.

A fairly simple test can be run to determine whether you are a carrier for this disease. If both mother and father are found to be carriers, predict what the chances are that they will have a child with cystic fibrosis (you may want to use a Punnett square to make your prediction):

---

Phenylketonuria (PKU) is a genetic disorder that is also inherited as a recessive. It is fairly common, occurring 1 in every 10,000 births in the U.S. Fortunately, it can be treated if caught very early. In our country every Infant must have a simple blood test for PKU before he/she is two weeks old. The babies with this condition cannot break down the amino acid, phenylalanine, common in many foods. A build up of the amino acid in the blood can poison the brain cells and cause severe retardation. Predict how a build up of this amino acid can be prevented:

---
If you said regulating the diet, you are correct. The baby is put on a special formula free of phenylalanine, and must follow a strict diet during early childhood while the brain is developing. By the first grade most children can begin to eat normally, and suffer no damage to their brains. Many women who were treated for PKU as infants are now old enough to have babies. Predict why a woman with PKU must go back on the special died during pregnancy:

_________________________

TAY-SACHS DISEASE is a very serious disorder that is also inherited as a recessive. The baby is born normal, but within a few months begins to display serious symptoms. Due to a build up of lipids (fats) in the brain cells the baby becomes blind, and loses both mental and physical functions. Death comes usually before the age of 2.

This condition is found in Jewish people of northern European origin. Predict why Tay-Sachs disease is found primarily in this group of people:

_________________________

One serious genetic disorder is HUNTINGTON DISEASE caused by a dominant gene. Although the gene is present at birth, the symptoms do not appear until about the age of 40 (but can appear as early as the late teens or as late as the 60’s). It results in almost total destruction of both brain and muscle cells, causing loss of all body functions and lack of mental awareness. Death comes slowly. The person may remain in this "vegetable state" for as long as twenty years. Predict what your chances would be to develop this disease if one of your parents has it.

There is a recently developed, fairly accurate test to determine whether a person will develop this disorder later in life. Predict whether you would choose to have this test run if a member of your family had the disease. Explain your reasons:

_________________________

_________________________

It is interesting to note that most of the genetic diseases described on these sheets have been inherited as recessives; the only dominant condition was Huntington Disease. Even though this disease is inherited as a dominant, it is relatively rare (only 25,000 cases have
been diagnosed in the U.S.). Most serious dominant genetic diseases are quite rare. Predict why this is so:

Predict why Huntington Disease continues to be observed in the human population, even though it is both DEADLY and DOMINANT:

Unfortunately, very few genetic disorders are treatable at this time. Genetic engineering holds great promise for important breakthroughs with many of these diseases in the very near future.
Breeders today use their understanding of heredity to produce offspring with certain characteristics. Seedless grapes and oranges, thornless roses, and smaller turkeys which fit into smaller ovens are examples of selective breeding. Modern breeders use combinations of several methods to develop plants and animals with desired traits. The most important methods of controlled breeding are MASS SELECTION, INBREEDING, AND HYBRIDIZATION.

The Father of Plant Breeding is Luther Burbank, an American biologist who lived around the turn of this century. He frequently used MASS SELECTION to produce better plants. Burbank planted large fields of different vegetables or flowers and from these he would choose certain plants that had characteristics he preferred, such as larger fruit. These few selected plants he would use as the parents to produce new varieties. Burbank used the technique of mass selection to produce hundreds of new varieties of plants including a large white potato. Predict how mass selection operates genetically:

Frequently breeders use INBREEDING to establish pure blood lines. The American Kennel Club registers only inbred (pure-bred) dogs. Predict how inbreeding is accomplished:

How can inbreeding be beneficial? ____________________________________________________________________________________________

Inbreeding is not always beneficial. Predict how inbreeding can be harmful: (This is a challenging question - give it some thought)

HYBRIDIZATION (outbreeding) is the opposite of inbreeding. Over the years some of the greatest advancements in controlled breeding have come about through hybridization. When two different, but closely related species are crossed, the offspring are known as HYBRIDS. The classic example of a hybrid organism is the mule. The father is always a donkey and the mother is always a horse.
Predict why the mother cannot be the donkey:

Many times hybrids are not fertile and therefore are unable to produce offspring. Predict why most hybrids are infertile (this is a challenging question so give it some thought):

The phenomenon of HYBRID VIGOR can also occur during hybridization (outbreeding) in some species. The offspring are healthier, grow faster, and are often more vigorous than either of the parents. Geneticists do not completely understand how this happens.

The opposite of hybrid vigor can also occur. For example, once breeders crossed the radish with the cabbage, trying to produce a plant with both large edible roots (like the radish) and large edible leaves (like the cabbage). Instead, they produced a weak plant with inedible roots and small leaves. Predict how this may have happened:
GENETIC ENGINEERING: A NEW FRONTIER IN SCIENCE

GENETIC ENGINEERING is an area of genetics where scientists purposefully change portions of the DNA in chromosomes. For the past thirty years scientists have been "splicing in" new pieces of DNA into the DNA of certain bacteria. Predict how this technique could be useful.

In 1978 scientists were able to splice in a section of DNA into a certain strain of bacteria that caused it to produce the hormone insulin, an important substance which regulates the sugar level in the body. Predict how this breakthrough was helpful in the field of medicine.

Another hormone which regulates human growth has been produced in a similar way. Children who do not produce enough of this chemical are very short. Genetic engineering has made it possible to produce enough doses of this hormone to treat thousands of children worldwide.

In 1980 scientists produced genetically engineered bacteria that make INTERFERON. This chemical prevents viruses from reproducing in the body. Experiments indicate that when this substance is given to people who suffer from certain cancers, it stops the growth of these diseased cells. So far only limited amounts of interferon are available for this type of treatment. Predict why the amount of interferon is still limited.

A new and promising area of genetic engineering is CLONING. This process results in the production of large numbers of genetically identical offspring from a single type of parent cell. Cells have been taken from a very young frog embryo and have been separated, producing numerous identical offspring with identical DNA. This has also been done in rabbits, mice and rats.
Predict how cloning could be beneficial to farmers and breeders.

A very new and promising area of genetic engineering is known as GENE SEQUENCING. This technique determines the order of the bases (adenine, thymine, cytosine and guanine) in the DNA of chromosomes. While researchers are still far from knowing the 3.5 billion base sequences that make up a set of human chromosomes, they are using modern technology (such as computers) to help identify and catalog the gene sequences in simple organisms such as bacteria. Geneticists hope in the very near future to be able to identify the gene sequences that are responsible for serious genetic defects in humans.

Predict how knowledge about the gene sequence codes of "defective" human genes could be useful (This is a challenging area - give it some careful thought).

Some people believe that scientists should not interfere with natural genetic processes. Why is genetic engineering such a controversial topic? Be prepared to explain your views to the class.
APPENDIX B

GENETICS PRETEST–POSTTEST
INSTRUCTIONS: Choose the best answer and indicate your choice on the ANSWER SHEET. (You may write in the margins of this test if you need to perform crosses before selecting your answer.)

(1) If D represents a dominant gene for dark colored hair and d represents a recessive gene for light colored hair, which of the following statements is correct?
   a. A person with a DD genotype could have either dark or light colored hair.
   b. A person with a Dd genotype has light colored hair.
   c. A person with a dd genotype could have either dark or light colored hair.
   d. A person with a Dd genotype has dark colored hair.

(2) Which one of the following statements is not true?
   a. There are thousands of genes on one chromosome.
   b. A gene is a small portion of a chromosome that codes a specific genetic trait.
   c. Chromosomes occur in pairs in all cells.
   d. The genetic material of chromosomes is DNA.

(3) In determining the color of watermelon, let G = solid green color, and g = striped color. If two heterozygous plants (Gg) are crossed, what is the probability of their offspring having the homozygous recessive genotype (gg).
   a. 0%
   b. 25%
   c. 50%
   d. 75%

(4) In the case of codominance, if one parent is homozygous black (BB), and the other parent is heterozygous gray (BB'), then:
   a. all of the offspring should be black.
   b. all of the offspring should be gray.
   c. half of all the offspring should be black.
   d. half of all the offspring should be white.
(5) Which one of the following is not true of polygenic traits.

a. The traits are controlled by the interaction of two or more gene pairs.
b. The genes for these traits are always found on the same chromosome.
c. The alleles for these traits may be dominant or recessive.
d. They allow for much variation in the phenotypes for certain genetic traits (such as eye or skin color) found in the human population.

(6) Nondisjunction results in:

a. the loss of an entire set of chromosomes.
b. gametes which have too few or too many chromosomes.
c. a chromosome failing to replicate during meiosis.
d. the egg failing to join with the sperm.

(7) A breeder can perform a test cross to determine whether a female guinea pig is homozygous (BB) or heterozygous (Bb) for black coat (black is the dominant trait and white is the recessive trait). Which one of the following males should be used in the test cross?

a. a homozygous black male
b. a homozygous white male
c. a heterozygous black male
d. any male with a black coat

(8) In rabbits, spotted coat (S) is dominant over white coat (s). If a test cross results in both spotted and white coated offspring, what were the genotypes of the parents?

a. SS and SS
b. SS and ss
c. Ss and ss
d. ss and ss

(9) Assume you wish to predict the probability of a certain offspring resulting from crossing genotype AaBb with genotype aaBB. Which Punnett square is set up to correctly show this cross?

\[
\begin{array}{cc}
\text{a) } & \text{b) } \\
\begin{array}{c|c}
Aa & BB \\
\hline
Bb & a \\
\end{array} & \begin{array}{c|c}
A & B \\
\hline
B & a \\
\end{array}
\end{array}
\]
(10) Which of the following statements is true in humans?

a. The parent who carries the most dominant genes determines the sex of the child.
b. The mother determines the sex of the child.
c. The father determines the sex of the child.
d. Neither parent determines the sex of the child since environmental conditions are the controlling factor.

(11) Which of the following is true of a sex-linked trait carried on the X chromosome in humans?

a. The father can pass the sex-linked trait to his sons.
b. The mother can pass the sex-linked trait to her sons and daughters.
c. The sex-linked trait acts as a dominant trait in the female.
d. The father cannot pass the sex-linked trait to his daughter.

(12) Which one of the following is true of crossing-over?

a. It is never beneficial.
b. It is always beneficial.
c. It can result in hybrid vigor as a result of new gene combinations.
d. It always results in equal exchange of chromosome pieces.

(13) If a mother has type 0 blood, and the father has type AB, what is the probability that they can have a child with type A blood?

a. 0%
b. 25%
c. 50%
d. 100%

(14) If the mother and father are both carriers of the sickle cell trait (A\A'), what is the probability of their having a child who suffers severe symptoms from sickle cell disease (A\A')?

a. 25%
b. 50%
c. 75%
d. 100%
(15) If circles represent females and squares represent males, and dark circles and squares represent the recessive trait while white circles and squares represent the dominant trait, which individual(s) in the pedigree shown below are definitely heterozygous (Ff) for the trait?

![Pedigree Diagram]

a. Individual 1  
b. Individuals 1 & 5  
c. Individual 5  
d. Individuals 1, 4, & 5

(16) Hybridization occurs when breeders cross two related species. The mule is a hybrid whose mother was a horse and whose father was a donkey. Which of the following statements is true concerning hybridization?

a. Hybridization always results in offspring that have the best qualities of both parents.  
b. Hybridization may result in offspring that are more healthy and vigorous than either of the parents.  
c. Hybridization usually results in offspring that are fertile and can produce large numbers of offspring.  
d. Hybridization results in offspring that are all exactly alike genetically.

(17) Lung cancer has been shown to be highly related to cigarette smoking. Which of the following statements is true?

a. No one gets lung cancer who is not a heavy smoker.  
b. Mutations can occur in the DNA of lung cells that are constantly irritated by cigarette smoke.  
c. Lung cancer is easily treated and is rarely fatal.  
d. Everyone who smokes cigarettes will eventually develop lung cancer.
(18) Which one of the following activities is an example of population sampling?

a. when you estimate how many students in your school have brown eyes
b. when you determine what percentage of students in your school have brown eyes
c. when you randomly select a representative number of students in your school and determine their eye color

d. when you determine the eye color of every student in your school

(19) Which one of the following is not true about genetic engineering?

a. Genetically identical frogs and rats have been produced by the process of cloning.
b. It is hoped that the techniques of genetic engineering can be used in treating genetic diseases.
c. At the present time genetic engineers have been able to identify most of the gene sequences found on human chromosomes.
d. Human insulin has been produced by certain bacteria as a result of gene splicing.

(20) Huntington Disease is inherited as a dominant trait. Which one of the following statements is true?

a. If either parent has the disease all of their offspring will have it.
b. If either parent has the disease there is a 50% chance that their child will have it.
c. If both parents have the disease all of their children will have it.
d. Since the disease is inherited as a dominant it is unlikely that a person who has the disease will live long enough to have children.
APPENDIX C

QUESTIONNAIRE I (ATTITUDE TOWARD SCIENCE)

and

QUESTIONNAIRE II (ACHIEVEMENT MOTIVATION)
STUDENT QUESTIONNAIRE I

This survey consists of several statements designed to sample your opinions about science. THERE ARE NO RIGHT OR WRONG ANSWERS. What is wanted is your individual feelings about the statements. Please read each statement carefully and decide how YOU feel about it.

Directions: Please mark the response which best represents your opinion about the following statement ON THE ANSWER SHEET, in the following manner:

MARK

A B C D E
strongly agree undecided or disagree strongly agree uncertain disagree

21. Science is fun.
22. I really like science.
23. I enjoy science courses.
24. I would enjoy being a scientist.
25. I think scientists are interesting people.
26. I have good feelings toward science.
27. Everyone should learn about science.

STUDENT QUESTIONNAIRE II

This survey consists of several statements designed to sample your opinions about your schoolwork. Again, THERE ARE NO RIGHT OR WRONG ANSWERS.

Directions: Please mark the response which best represents your opinion about the following statement ON THE ANSWER SHEET, as you did in Questionnaire I.

28. I always try to do my best in school.
29. I try hard to do well in science.
30. When I do not do well, that makes me try much harder.
31. I always try hard, no matter how difficult the work.
APPENDIX D

TEACHER BEHAVIOR INVENTORY (TBI)
TEACHER BEHAVIOR INVENTORY

Please complete this inventory for both the control and experimental classes. A space has been left between the items to allow for any comments or explanations that may assist the researcher. The observer should rate each behavior according to the following scale.

1 - Far Below Average  4 - Somewhat Above Average
2 - Somewhat Below Average  5 - Far Above Average
3 - Average  6 - Not Applicable/Unable to observe

1. Classroom Climate
   a. Was the classroom atmosphere friendly (pleasant and unthreatening)?

   CONTROL
   1  2  3  4  5  6

   EXPERIMENTAL
   1  2  3  4  5  6

   b. Was there an orderly and reasonably disciplined environment?

   CONTROL
   1  2  3  4  5  6

   EXPERIMENTAL
   1  2  3  4  5  6

2. Teacher-Student Interaction
   a. Were the teacher's questions appropriate and challenging?

   CONTROL
   1  2  3  4  5  6

   EXPERIMENTAL
   1  2  3  4  5  6
b. Were students' responses and dialog encouraged and valued?

<table>
<thead>
<tr>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
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</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
</tr>
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</table>

c. Did the teacher encourage student-student interaction?

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<th>CONTROL</th>
<th>EXPERIMENTAL</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
</tr>
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</table>

d. Describe the level of openness and interaction between the teacher and the students.

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<thead>
<tr>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
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</table>

3. Lesson Planning

a. Was there evidence of a well planned lesson?

<table>
<thead>
<tr>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
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</table>
b. Were the concepts presented clearly?

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<tr>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
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</table>

c. Did the lesson move at a smooth pace with logical transitions?

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<thead>
<tr>
<th>CONTROL</th>
<th>EXPERIMENTAL</th>
</tr>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>

4. **Teaching Style**

Please describe the teaching style of the instructor. Did you note any differences in style between the control and experimental classes? Please explain.
Control Class

Describe the students' participation in the classroom discussion. Please include the level of teacher-student interaction in your description. Was there questioning by the students regarding the genetics topic(s) being presented? If possible, please cite specific examples.

Describe other indications of the level of student interest (e.g., eye contact with the teacher, time on-task vs. off-task behaviors, student-student interactions). If possible, please cite specific examples.
Describe the students' participation in the classroom discussion. Please include the level of teacher-student interaction in your description. Did the making of predictions encourage students to discuss and/or defend their own positions? Was there argumentation or questioning regarding the genetics topic(s) being presented? If possible, please cite specific examples.

Describe other indications of student interest (e.g., eye contact with the teacher, time on-task vs. off-task behaviors, student-student interactions,). If possible, please cite specific examples.
GENERAL OBSERVATIONS

Compare and contrast the experimental and control groups as to overall student involvement and interest in the lesson.

Compare and contrast the overall learning environments of the control and experimental classes.

What do you feel were the main effects, if any, of including the making of predictions in the lesson?
Identify any areas on the prediction sheets that proved to be especially helpful during instruction. Please be specific.

Identify any areas of the prediction sheets that need to be improved. Please be specific.

Did the student predictions assist you in identifying any misconceptions? If so, please describe those that were identified and how they were revealed.
APPENDIX F

QUALITATIVE OBSERVATION FIELD NOTES
Qualitative Observation Field Notes

Name of Observer ___________________________ Date ________
Name of Teacher Observed ________________________________
Prediction Topic(s) ___________________________________

Instructions to the Observer: Please observe both
experimental and control classes when the same topic(s) are
being taught in both classes. You may use the back of these
sheets for additional comments. Complete the field notes as
well as the teacher behavior inventory.

Control Class

Describe the students' participation in the classroom
discussion. Please include the level of teacher-student
interaction in your description. Was there questioning by
the students regarding the genetics topic(s) being
presented. If possible, please cite specific examples.

Describe other indications of the level of student
interest (e.g., eye contact with the teacher, time on-task
vs. off-task behaviors, student-student interactions). If
possible, please cite specific examples.
Experimental Class

Describe the students' participation in the classroom discussion. Please include the level of teacher-student interaction in your description. Did the making of predictions encourage students to discuss and/or defend their own positions? Was there argumentation or questioning regarding the genetics topic(s) being presented? If possible, please cite specific examples.

Describe other indications of student interest (e.g., eye contact with the teacher, time on-task vs. off-task behaviors, student-student interactions). If possible, please cite specific examples.
GENERAL OBSERVATIONS

Compare and contrast the experimental and control groups as to overall student involvement and interest in the lesson.

What do you feel were the main effects, if any, of including the prediction activities in the lesson?
APPENDIX G

GENERAL INTERVIEW GUIDE

EXPERIMENTAL STUDENTS
Interviewer: Thank you so much for agreeing to let me interview you about the genetics study you have just completed. I want you to know that what you say will be very important to us and will help us very much. To be sure that I am able to remember everything you say I would like to record our conversation. Will this be all right with you?

What has been your favorite part of biology so far this year? Can you tell me why?

Compare how you enjoyed genetics with some of the other topics you have learned about this year.

What were some things you enjoyed learning about in genetics? What were the things you found most interesting?

Was there anything that you did not like about genetics? Can you describe these?

Will you tell me your opinion about the prediction sheets that were used to introduce you to each of the genetics topics. (Soliciting overall general opinion).

---Did you find the prediction sheets interesting or fun? (If yes) Which ones do you remember that you enjoyed using the most? (If no) Why not?

---Did the prediction sheets help you to understand and to learn about genetics? (If yes) How did they help you learn? (If no) Why not?

---Did you use the prediction sheets to study by for your tests? (If yes) How did they help you? (If no) Why didn’t you use them to study by?

---Were the directions on the prediction sheets easy for you to follow most of the time? (If no) What did you find confusing—can you give me some examples?

---Did any of the prediction sheets challenge you to think about things in a new way, or think about things you have never thought about before? (If yes) Can you give me some examples?
---How did you feel when the predictions you made were correct?

---How did you feel when your predictions were not correct?

---How did you feel about sharing your predictions with your teacher and with the other students?

---Did you ever disagree with other students' predictions? (If yes) Did you want to challenge them about their predictions if you felt they were not correct?

---Did making the predictions make you become more interested in learning about the topic? Why or why not?

---Did the prediction sheets help you to understand the concepts? (If yes) Can you give me any specific examples? (If no) Why not?

---Would you like your teacher to include prediction activities in future lessons in biology? Why, or why not?

---Do you feel using the prediction sheets will help you remember about genetics in the future? (If yes) What things do you think you will remember most? (If no) Why not?

*******************************************************************************

I want to thank you very much for helping us with our study. What you have said has been most helpful.
Interviewer: Thank you so much for agreeing to let me interview you about the genetics study you have just completed. I want you to know that what you say will be very important to us and will help us very much. To be sure that I am able to remember everything you say I would like to record our conversation. Will this be all right with you?

What has been your favorite part of biology so far this year? Can you tell me why?

Compare how you enjoyed genetics with some of the other topics you have learned about this year.

Did you find any of the genetics topics or activities interesting or fun? (If yes) What did you enjoy the most? (If no) Why not?

Was there anything that you did not like about genetics? Can you describe this?

Did using the Punnett Square help you in understanding how genetics works? Can you tell me how it helped you.

Do you feel you really understand how genetics works now? Can you tell me why you feel this way?

How did you study for your genetics tests?

Was there any topic in genetics that really made you think about things in a new way, or think about things you have never thought about before?

Will you remember what you have learned about genetics in the future? (If yes) What things will you remember best? (If no) Why not?

I want to thank you for helping us with our study. What you have said has been most helpful.
GENERAL INTERVIEW GUIDE
Teacher Interview

Will you give me your overall opinion about including the prediction activities in the genetics unit?

What do you believe were the most positive effects of including the prediction activities?

Can you identify any negative effects of including the prediction activities?

What, if any, were the effects on student classroom participation of including the prediction activities? Did they promote more dialogue and argumentation than the traditional method used in the control class?

What, if any, were the effects on student motivation of including the prediction activities?

Did you use the prediction sheets in your other classes? Why or why not? If you were selective, which ones did you use in the other classes?

Did the prediction activities assist you in identifying levels of prior knowledge that the students had?

Did the prediction activities assist you in identifying any alternative conceptions that the students held. (If yes) Can you cite some examples?

Did the prediction sheets assist you as an Instructional tool? If so, how?

Do you feel the prediction activities assisted the students in learning about the genetics concepts? (If yes) How?

Do you feel the prediction sheets challenged students to think? (If yes) Please explain or give specific examples.

Were the prediction sheets clearly worded and unambiguous? (If no) What aspects were confusing?

Will you use the prediction sheets in your future biology classes. Why or why not?

Will you include prediction activities in other biology units? Why or why not?

What aspects of this study would you change, if any, if you could do it again?
APPENDIX J

PARENTAL PERMISSION LETTER
Dear Parent or Guardian:

During the next few weeks it will be our privilege to participate in a dissertation study which will attempt to find better ways to teach high school biology.

Your child is in one of the biology classes which will be participating in this research. I can assure you that the instruction your child will receive during the study will meet all of the local and state curriculum requirements in every way.

It is always necessary to receive parental permission whenever research is done in the East Baton Rouge Parish Schools. I would appreciate your giving us permission to allow your student to participate in this study. If you have any questions please feel free to call me.

Thank you very much for allowing us the opportunity to do research to enhance the quality of instruction in our parish.

Sincerely,

Biology Teacher's Name

I give permission for ____________________________ (Student's Name) to participate in this research project.

__________________________
(Signature of Parent or Guardian)
APPENDIX K

PERMISSION LETTER FOR USE OF

ATTITUDE TOWARD SCIENCE AND ACHIEVEMENT MOTIVATION

INVENTORIES
Ms. Anne Sinclair  
1637 Stoneleigh Drive  
Baton Rouge, LA 70808

Dear Ms. Sinclair:

It was nice to hear from you and to learn of your interest in our research. I have enclosed information about the instrument and our most recent research report. You should feel free to use any of our subscales or items and to modify or change anything you like. The only thing I ask is if you come up with something interesting that you inform me of your findings.

I wish you the best in your doctoral work and research. You are fortunate to have Dr. Good as your major professor as he is highly respected in our field across the country. Thanks for contacting me and let me know if I can help you with the implementation of your attitude instruments.

Sincerely,

Ronald D. Simpson  
Professor and Director

RDS:ch

Enclosure
APPENDIX L

PERMISSION LETTER FROM LOCAL SCHOOL BOARD
Dear Miss Sinclair:

I was very pleased to receive your letter of May 22, 1990 with regard to your entering the doctoral program at LSU. The field in which you are entering is much needed in the educational systems throughout the United States.

You have my permission to work with the selective teachers and/or students that will assist you in your work.

If I can be of any assistance to you during this period, please do not hesitate to contact me. Mr. William Glasper has also assured me that he will be available to lend any assistance to you.

Good luck in your endeavor...and may you soon be signing your name..."Anne Sinclair, Ph.D."

Sincerely yours,

Donald R. Fleet
Assistant Superintendent for Support Services

cc: Mr. William Glasper
VITA
Anne Spratlan Sinclair

Educational History

1991  Doctor of Philosophy (expected in May), Louisiana State University, Baton Rouge, Louisiana.
Specialization: Curriculum and Instruction with Emphasis in Science Education; Content Area--Biology (Genetics); Research Tools--Qualitative and Quantitative Evaluations.

1987  Education Specialist in Administration and Supervision, Louisiana State University, Baton Rouge, Louisiana.


1966  Master of Science in Biology, The University of Alabama, Tuscaloosa, Alabama.

1964  Bachelor of Arts (Biology Major and Chemistry Minor), Judson College, Marion, Alabama.

Experience

1980-present  Honors Biology and Honors Chemistry Teacher and Science Department Chair, Tara High School, Baton Rouge, Louisiana.

1989-90  Teaching Assistant at Louisiana State University. Activities Included Teaching Secondary Science Methods and Serving as the College Coordinator for the Science Student Teachers and Interns.

1976-79  Coordinator of The Gifted and Talented Program (K-12) for The Early County School System, Blakely, Georgia.

1969-76  Human Anatomy and Physiology Teacher and Science Department Chair, Jefferson Davis High School, Montgomery, Alabama.
1966-68 Biology Teacher, Lanier High School, Montgomery, Alabama.

Educational Contributions

1990 Assisted in the Development and Teaching of a New Course at Louisiana State University Entitled "Scientific Literacy and Meaningful Learning."

1985 Developed and Implemented the First Honors Chemistry Course Taught at Tara High School.

1982 Developed and Implemented the First Honors Biology Course Taught at Tara High School.

1976 Developed and Implemented the Gifted and Talented Program (K-12) for the Early County School System, Blakely, Georgia.


1974 Developed and Implemented the First Environmental Science Curriculum in the Montgomery County School System, Montgomery, Alabama.

Professional Honors

1988 Recipient of the Chemistry Teacher of the Year Award from the American Chemical Society, Baton Rouge Chapter.

1979 & 1980 Twice Named Teacher of the Year by the Early County Chamber of Commerce, Early County, Georgia.

Presentations and Publications

1991 Research Paper Accepted for Publication in The Science Teacher Entitled "Forecasting the Future: A Science Classroom Imperative."


1989 Presented Seminar, "Science Education Is Called to Reform" at the Louisiana Science Teachers Association, October.


Professional Organizations

Phi Kappa Phi
Louisiana Science Teachers Association
National Science Teachers Association
National Association for Research in Science Teaching
American Educational Research Association
Louisiana Association of Teacher Educators

Personal Data

Born: Montgomery, Alabama

Married: Dr. Tommy Sinclair

Children: Bryan Thomas (1969) and Collin Bond (1971)
Candidate: ANNE SPRATLAN SINCLAIR

Major Field: EDUCATION

Title of Dissertation: A STUDY OF THE EFFECTS OF PREDICTION ACTIVITIES ON INSTRUCTIONAL OUTCOMES IN HIGH SCHOOL GENETICS

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Earl Cheek

James H. Wundersee

Arnold M. Eaton

March 20, 1991