1995

The Chemist in the College Chemistry Classroom: A Case Study of Excellence.

Anthony Quilah Zehyoue Jr
Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Recommended Citation
https://digitalcommons.lsu.edu/gradschool_disstheses/6080

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Historical Dissertations and Theses by an authorized administrator of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.
INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
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

Anthony Quilah Zehyoue Jr.
B.S., Cuttington University College, Liberia, 1974
M.S., Marquette University, Wisconsin, 1979
December, 1995
ACKNOWLEDGEMENTS

I am gratified to express my sincere thanks and appreciation to all my supervisory committee members (Dr. Ron Good, Dr. Jim Wandersee, Dr. Barbara Strawitz, Dr. Earl Cheek and Dr. Randy Hall). They contributed innumerable and invaluable services throughout all the various phases and aspects of my study here at LSU, culminating in this dissertation.

Specifically, I would like to express thanks to my major professor, Dr. Ron Good, for his very insightful comments and words of encouragement from the beginning to the end. Also, in similar manner, I must single out Dr. George Stanley of the Chemistry Department, who was always more than willing to allow me into all his classes and who is, in fact, the active chemistry professor and research focus in this entire study.

At this juncture, I deem it quite necessary to express profound appreciation to Mr. and Mrs. Ted Holmes of the University Baptist Church in Baton Rouge. They always accepted me and my entire family into their home as members of their own family, and in fact helped me so much with the typing and printing of this manuscript, using their home computer at no cost to me.

Finally, I would like to express thanks to my dear wife Annie Banti and our five children for their patience and perseverance of hardships throughout my work at LSU.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ..................................... ii  
LIST OF FIGURES ....................................... v  
ABSTRACT ............................................ vi  

CHAPTER

1 INTRODUCTION .......................................... 1  
Purpose of this Study ................................ 1  
Background: Problems Relative to Chemistry  
Teaching/Learning in the U.S.A. ...................... 3  
Significance of the Study ......................... 7  
Research Questions ............................... 8  
Some Comments/Notes on Teacher  
and Teaching ......................................... 12  

2 REVIEW OF LITERATURE ............................... 16  
Introduction ......................................... 16  
Theoretical Base for Research .................... 16  
Relevant Studies .................................... 22  
A Broad Overview ................................... 22  
Studies Specific to  
College Science Learning ......................... 23  
Other Studies Specific  
to Precollege Science Learning ..................... 29  
Summary ............................................... 32  

3 METHODS AND MATERIALS ............................. 34  
Research Methods: An Overview  
and Rationale ....................................... 34  
Overall Procedures: Data  
Sources/Participant(s) ......................... 39  
The Study ........................................... 41  
Triangulation of Data Sources .................. 43  
Participants ......................................... 44  
The Professor, Dr. G .............................. 45  
Students Taking Dr. G’s Courses .............. 48  
Graduate Students Working With Dr. G ....... 50  
Academic Setting .................................... 52  
Louisiana State University ....................... 52  
Chemistry Department ............................. 53  
The Courses and Classrooms ...................... 54  
Chemistry 4571 ..................................... 54  
Chemistry 1202 ..................................... 56  
Data Sources/Collection ......................... 57  

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
LIST OF FIGURES

1. Chemistry shown as a central science and linked to other sciences ............. 107

2. Core branches of chemistry linked to other engineering and scientific professions ........ 108
ABSTRACT

Prominent in the agenda of science education research nowadays are studies focusing on the science teacher/professor. Consequently, this study focuses on a particular chemistry professor at Louisiana State University. He was chosen because of his outstanding and award-winning teaching activities; his voluntary workshops for area high school chemistry teachers; and his active involvement with a college chemistry curriculum reform committee, serving as chairman of the committee. Additionally, his continuing accomplishments and engagements with inorganic chemistry research activities are noteworthy.

He was studied for three semesters in his teaching of introductory level chemistry to a large freshman class and his teaching of upper level chemistry to graduates and senior undergraduates as well as during his interactions with his own graduate students and postdoctoral fellows. Other activities aimed at educational efforts at the precollege level and the overall academic environment of the area are included.

As a qualitative case study, it employs the interpretive methods of participant interviewing; field-note taking in and outside the classroom, from participant observations; collection of documents/artifacts from the professor's classes.

vi
This case study provided new insights/findings concerning excellence in college chemistry teaching, which includes the following:

(a) Cooperative group work among students taking college chemistry courses, especially introductory level courses, promoted some significant academic, personal and social as well as other affective outcomes necessary for college students to succeed in chemistry.

(b) Frequent use of history and philosophy of chemistry in college chemistry classrooms as well as numerous references to current human and societal efforts in chemistry was well embraced by students and as such sustained their interest in chemistry learning.

(c) The use of multiple traditional and non-traditional assessment techniques adequately accommodated the learning needs/styles of the diverse student population in the classroom.

(d) The overall establishment of a non-threatening and accommodative learning environment appeared to be a crucial factor in success at recruiting and retaining students in chemistry.

Based upon the findings, it is recommended, among others, that research activities and instructional activities in college chemistry departments need to be equally embraced and should not be dichotomized.
CHAPTER 1
INTRODUCTION

It has been documented for several years that the U.S.A. is failing to produce the requisite numbers of scientific and engineering professionals that are necessary to cope with the increasing demands of a world becoming more and more dependent on science and technology (A Nation at Risk, 1984; Project 2061, 1989; Project Synthesis, 1981). Moreover, it has been reported that students in the U.S.A. are not on a par with their counterparts in other industrialized countries in standardized science test scores (Aldridge, 1989; Lapointe et al., 1989; National Science Board, 1989; National Science Foundation, 1983, 1987). Indeed, precollege science education is in a dismal state, and college science education itself too needs improvement. Thus, concrete efforts are being directed at remedying these undesirable states of science learning/teaching in the U.S.A. As such, this study focuses on chemistry teaching/learning at the college level, drawing into the limelight a specific chemistry professor.

Purpose of this Study

It is the intent of this study/research to investigate and document the teaching practices of a particular chemistry professor at a large state
university (LSU) in the Deep South of the U.S.A., examining closely his instructional strategies/techniques in the classroom, and his overall interactions with students and others in the university and academic environment. This professor was selected because, in spite of his continuing accomplishments and engagements with inorganic chemistry research activities, he holds both teaching and research activities on equal footing as attested to by the fact that he had already won teaching awards. Also, other departmental colleagues had become interested in his teaching activities, so much so that in 1992 he was requested twice by his Department of Chemistry to present two seminars to the entire faculty and graduate students concerning his instructional strategies. Moreover, despite his very busy schedule, which included chairmanship of a college chemistry curriculum reform committee in Louisiana, he had willingly volunteered to conduct workshops and other learning activities for area high school chemistry teachers.

Consequently, a detailed description of all the classroom activities and other interactions of this professor will be provided so that a model of effective instruction in chemistry at the college level can be developed and proposed. Moreover, this research hopes to identify and pinpoint certain specific teaching practices.
of this professor deemed quite exemplary and noteworthy, so that other chemistry teachers/professors may become aware of them for implementation, scrutiny and insight regarding their own practice. It is also believed that this research will seriously inform and be of benefit to chemistry teacher education programs at the college level.

**Background: Problems Relative to Chemistry Teaching/Learning in the U.S.A.**

Many studies have reported that American high school students regard chemistry as one of the most difficult subjects in school (Fisher & Lipson, 1986; Gabel, Sherwood & Enoch, 1984). Numerous factors have been attributed to such difficulties. Some researchers assert that since the understanding of basic chemical concepts involves the complex interplay between macroscopic and microscopic levels of thought and discussion as well as novel ways of viewing the body of chemical knowledge, many students become overwhelmed when studying chemistry (Johnstone, 1982; Krajcik, 1991). Other researchers report that many students lack the basic knowledge to be able to meaningfully link mathematical and chemical information/ideas, and so they resort to the use of algorithms when studying chemistry (Gabel, Sherwood & Enochs, 1984).
Another group of researchers report that since chemistry involves many abstract ideas, some students poorly visualize chemical events and concepts because they lack formal reasoning abilities (McDermott, 1988). As a result, many students rely only on memorization of a lot of facts, which becomes tedious and unproductive.

Additionally it has been found that the common ways of teaching science is a major factor responsible for students' difficulties in learning chemistry. Teachers/professors expect students to do lots of tedious and low-level intellectually undemanding tasks involving the teaching of basic facts and definitions from science textbooks, and they (teachers) stress individualized work while perhaps interacting with few of the students—usually the higher achieving ones (McDermott, 1988; Stake & Easley, 1978; Treagust, 1991).

Although most of these reports relate directly to high school students, college freshman and some upper level students face the same challenges in learning science and especially chemistry. In fact, it has been stated (Dini, 1992) that many college freshmen in American universities are only glorified high school students still exhibiting many of the qualities, habits, characteristics and frames of mind of their former high school peers. As Dini (1992) again has noted, "Students may not know how to balance their newly found
independence with their need to study. Students [freshmen] may not yet be convinced that college science courses require more thought and time than high school courses" (p. 2). Moreover, there has been a transformation occurring among undergraduate science majors, especially over the last 25 years, resulting in a high attrition rate of aspiring and advanced science majors and a nearly 50 percent reduction in the number of college freshmen opting to major in science and mathematics (Green, 1989; Tobias, 1990).

Therefore, it is important that college students not be abandoned to function and succeed in science classes. College professors/teachers do have a significant role to play, just like their precollege counterparts, if successful science learning is to occur because it is from college that all scientists, science educators and teachers come.

Consequently, due to the somewhat dismal status of science teaching/learning in the U.S.A., concrete efforts are being made to remedy these situations regarding science learning/teaching. In efforts at restructuring and reforming science education, there are today numerous interesting and worthwhile topics filling the research agenda of science educators. One such topic has been referred to as "The Missing Paradigm in Teacher Education" (Good & Wandersee, 1991). In this regard, they
wrote:

The study of science-content pedagogy interface has received added emphasis with the "discovery" by Lee Shulman and others in the U.S.A. that expertise in teaching includes both subject matter knowledge and pedagogy. How a novice teacher adapts the contents of science to facilitate learning by particular students is a major focus of this research (Good & Wandersee, 1991, p. 3).

In consonance with the views expressed by Good and Wandersee (1991), there exists the need for research targeting the science teacher/professor as a whole person in order to enhance the pedagogical content knowledge (PCK) of science teachers. Therefore, a chemistry professor/teacher is the focus of this research since he apparently had achieved excellence in teaching based upon numerous factors to be elucidated in this study. More and more, the classroom teacher is gaining research attention and status. Hurd (1986) has called for the active participation of teachers in science education research. Similarly, Kyle and Shymansky (1988) have noted that good research on science teaching/learning commences with the classroom teacher. Consequently it has been stated that "if we want to improve science teaching (and national reports are calling for just that) and science teaching depends on teacher thinking, then research on experienced teachers is needed to inform the goals of science teacher education and professional development programs" (Hewson et al., 1993, p. 1).
Significance of the Study

So far, most of the research in the area of chemistry education has been concentrated at the precollege level. Moreover, most of this research has centered around the difficulties in learning various chemistry concepts and contents. However, there is need now for more research in chemistry education at the college level involving college chemistry professor and teachers. Lee Schulman (1986), in keeping with his ideas of Pedagogical Content Knowledge (PCK) has stressed the need for case studies of expert teachers so as to inform the knowledge base of science teacher educational programs in the universities. As such, this research would highlight some of the kinds of urgently-needed instructional methods, tools and overall teacher-student interactions that could be helpful for other teachers to use. Moreover, such improved and innovative instructional techniques and interactions are necessary so as to ensure that the 21st century will have the highly trained scientific and engineering professionals and generally scientifically literate citizens demanded due to the increasing technology of our world (Project 2061 (1989)).

In tandem with ideas already advanced, this study also has salient implications for chemistry teachers/professors, curriculum developers, other future science educational researchers and science teacher
educational programs in colleges and universities. Using some of the techniques of this professor exposed in this research, chemistry teachers may be able to teach chemistry in a more meaningful way to students (Osbourne & Wittrock, 1983; 1985; Resnick, 1983). Also, curriculum developers reading such a study might be inspired to change the sequencing of topics in chemistry texts and perhaps modify and rearrange content in a way to have less materials but have these materials explored in greater depth so that "less actually becomes more" (Project 2061). Finally, teacher education programs at various colleges and universities may use the study for identifying master teachers/professors as well as other requisite criteria whenever necessary and expedient in tandem with the scope and goals of such programs.

Research Questions

For too long now in the U.S.A., the process of science teaching has been described as "assign, study, discuss (lecture) and test" (Project Synthesis, 1981, p. 62). Rote memorization has been highly encouraged and expected from students by teachers. Teachers usually see themselves as causing learning and, in fact, as knowledge dispensers, with the learning process revolving around them (the teachers). In an interview by P. G. Gough (1989), William Glasser reported that "teachers are constantly saying, 'Keep your eyes on your own work,
don't share, don't talk, don't help each other’" (p. 659).

It is this same sort of attitude that was reported by Gunstone and Ameh (1988) when they conducted a study with Nigerian science teachers. They found that many teachers relied very heavily on science textbooks and were less able to discriminate between meaningful and meaningless themes; also it was reported that they (teachers) were very unlikely to generate original ideas. Surprisingly, based upon my personal experiences, all these same characteristics have been observed too with Liberian teachers at all levels—precollege to college.

Many college science teachers and their classrooms are no different. Navarra, Levin, and Navarra (1992) in their description of archetypal traditional classrooms wrote:

College science teaching is typically organized around discrete topics dictated by the contents of the required textbook. Such courses are fact-oriented and the didactic tendency is to deliver content knowledge through the expository lecture. Students generally have little or no opportunity to engage the professor in meaningful dialogue about the concepts and principles presented. Large lecture rooms demand silent and attentive students who listen passively. (p. 35)

Indeed, this is typically how many introductory level chemistry courses and some upper level courses are organized and taught.

These attitudes of teachers/professors are considered to be unhelpful to students, producing an
inconducive and unfavorable environment for any kind of meaningful learning to occur. Such an approach to teaching described above, being quite individualistic and competitive, is intimidating to most people. Thus, people (students) tend to shun such an environment unless they perceive a higher chance of success in the competition. Concerning this, William Glasser, in an interview with P.G. Gough (1987) said:

Many students feel that they have no chance while others are making little or no efforts to learn because they don’t feel that their needs are being satisfied and they don’t have a sense of belonging.... Teachers are not giving leadership and encouragement to students (p. 661).

Science teachers/professors definitely need to change some of their beliefs and practices.

With this basic background information provided concerning the general reported attitudes of science teachers/professors, when the study initially began everything was somewhat open-ended. The researcher was going into this professor’s chemistry class not knowing at all what to expect or find out. All that was known at the time centered around some notions relating to novel instructional techniques that the professor was initiating and had been willing to try out in his college chemistry classes and had achieved quite a bit of success, too. The researcher was going in with an open mind as a participant observer to conduct a case study focusing on this professor.
Moreover, Sheila Tobias's (1990) book had been read by the researcher and his major professor as well as by the chemistry professor focused on in this research. In addition, all of these persons had attended a seminar that Sheila Tobias presented at LSU in 1992. Consequently, interest in her work and her ideas by the researcher became quite apparent, especially after it was learned that there were concrete attempts by this chemistry professor at LSU to incorporate some of Tobias's ideas and concerns into day-to-day real classroom practices and habits. Also, as the possibilities of such real-life chemistry classroom teaching practices were envisioned for transferral to other teaching situations, such as in Liberia, there developed an enhanced interest in the study/project. As the study proceeded, certain major questions, issues and themes began to unfold day by day. At this juncture, it is necessary to emphasize that it has been reported that case studies are primarily suited to address questions of "how" and "what," sometimes including "why" questions, too (Yin, 1989). The questions developed in this study are mostly related to "what," "why" and "how" things occur. These questions, issues and themes which this study addresses and answers constitute the following:

A. What are the hallmarks of this professor's instructional techniques and interactions with students?
B. Why and how did this professor become interested in the works and ideas of science education scholars and other scholars like Sheila Tobias who are concerned about improving/reforming college science (chemistry) teaching/learning?

C. Why is this professor open and willing to try out the ideas from science education scholars/reformers in his college chemistry classrooms?

D. Why is this professor interested in sharing with his departmental colleagues his ideas and practices as well as success stories from the classroom?

E. How and why is this professor concerned about chemistry teaching/learning in general at all levels, including precollege?

F. Why is this professor particularly interested in students liking and learning/knowing chemistry?

Some Comments/Notes on Teacher and Teaching

Since this is teacher-centered research focusing on a single teacher, highlighting the instructional techniques used in his college chemistry classes and his over-all interaction in the academic environment, some broad discussion relative to the concept of teaching and the teacher seems necessary in order to explain the entire notion of teacher and teaching. By so doing, a definition and proper perspective will be provided so that the whole notion of the teacher and their teaching,
as well as all the inherent ramifications pertinently associated therewith, can become somewhat reified.

Some scholars have argued that the entire notion of teaching and teacher is a rather difficult concept and, as such, hesitate to advance any meaning or basic framework for the notion of teaching and teacher. Others have attempted to define teaching and teacher in terms of the tasks involved. Accordingly, it has been asserted that:

Teaching involves the act of instructing the learner on the procedures and demands of studenting; selecting the materials to be learned and adapting these materials so that it is appropriate to the level of the learner; constructing the most appropriate set of opportunities for the learner to gain access to the contents of subject matter; and servicing the learner as one of the sources of knowledge and skills (Baird, 1987, pp. 55-56).

This is indeed a powerful assertion.

In tandem with this same trend of thought, it was further written:

Teachers have the primary responsibility to train the learner how to learn and, considering that teaching is done by individuals with their unique collection of ideas, thoughts, beliefs, aspirations, values, concerns, perceptions and abilities, one always needs to take into account what teaching means to the individual teacher and how they describe how they go about doing it (Baird, 1987, p. 59).

Surely, focusing on the teacher/professor in science education cannot be over-emphasized. The above ideas and views advanced by Baird (1987) are extremely noteworthy if anyone is to fully appreciate the teacher and teaching
in its entire perspective and ramifications. This is precisely why all research focusing on the teacher at all levels and stages of the educational spectrum is crucial.

Since Baird (1987) has stated that teachers are engaged in training learners how to learn, this notion definitely implies efforts at meaningful learning and assisting/promoting the active construction of knowledge by the learner. Considering the full ramifications of teaching, it seems crucial that one fully conceptualizes and internalizes the overall impact as well as the power and influence that teachers and their teaching can and do exert on students, our children. Moreover, the situation becomes even more compelling as it is further internalized that these same students, our children, are to become the future scientists, science educators and scientifically literate citizens of the technologically sophisticated world of the 21st Century. The effects of teachers and their teaching are not restricted to the confines of the school, college or classroom. Instead, they extend far beyond the formal years of schooling, having both fruitful and damaging outcomes forever on the lives of students and people in general as mandated by the prevailing set of situations and events associated with whatever are the teaching phenomena. Indeed, teachers are at the heart of attempts at improving or reforming science teaching/learning in the U.S.A. and in
all countries, as a matter of fact. Anything less than this is surely a disservice to science education, as teachers are the lifeblood of education.
CHAPTER 2
REVIEW OF LITERATURE

Introduction

In this chapter, a synopsis of the most significant related studies will be provided. Although this study is about excellence in chemistry teaching at the college level, other significant studies of exemplary science teaching at different levels will be included. Other studies pertaining to the problems of college science teaching as a whole and, whenever possible, those specific to chemistry teaching will also be discussed in this section. Moreover, the specific theoretical framework and paradigm undergirding this research will be discussed. Included here will be some comments about the strengths and shortcomings of the related literature, and some ideas concerning the potentially interpretive and integrative capabilities of this study within the overall boundary of the appropriate literature highlighted.

Theoretical Base for Research

The theoretical base directing this research is Ausubel’s theory of meaningful learning, which is, in fact, constructivist in nature. Ausubel emphasized the structural aspects of knowledge in the educational process, pinpointing these structural aspects and roles in science concept learning and problem solving (Ausubel,
1963). Ausubel's theory of meaningful learning helps to explain how new concepts are incorporated into an individual's cognitive framework (Ausubel, 1963). Thus, it is now well accepted that science learning and, for that matter, all learning involves the direct and active process of knowledge construction and reconstruction whereby new knowledge is linked to old and prior knowledge within the memory framework (schema) of the individual learner/knower (Bodner, 1988; Resnick, 1983; Wheatley, 1991). The tenet of constructivism is that, in order for any meaningful learning to occur, the learners must actively construct their own meaning out of the materials being learned (von Glasersfeld, 1989).

Constructivism, however, has been regarded as both a methodological perspective and a cognitive position. In regard to the methodological perspective, humans are seen as cognizing (knowing) subjects whereby their behavior is organized and purposeful. Embedded here implies research methods related to naturalistic inquiry of ethnography such as a case study because of the need to expose the behavioral nature of humans. Since this is the method used in this study, a detailed discussion will be presented later in the method section of this report.

The broad foundation of constructivism embodies the fact that all learners construct their knowledge from experiences with the world, with individuals and within
social frameworks. There are specific terms for different kinds of constructivist views, and Good (1991) has noted that more than fifteen such terms are in use nowadays. Constructivism, therefore, means different things to different people (Wheatley, 1991). Lythcott and Duschl (1990) noted, "... to some it may be an epistemological view of public domain science knowledge; to others, it may be the psychological view of the learning process used by individuals; it may even carry both connotations" (p. 456).

As a theoretical framework or view, however, constructivism surely attempts to conceptualize certain pedagogical events in science learning. The central themes of constructivism reside in and revolve around the notion that all human knowledge is constructed through a series of intricate and interwoven processes involving social interaction with the environment (objects, people and culture). As such, it has been noted that "knowledge is based on complex interactions of innate structures and functions, exploratory movements, biological motivation and cultural influences" (Good, 1989, p. 4, from Schlagel's Contextual Realism). In the views of von Glasersfeld (1989), known as the radical constructivist:

All human knowledge processes and acquisition involves very dynamic interactions, incorporating all aspects of the human being (sensed experiences, social and cultural interactions as well as the biological component); thus as such the human knower can only know what she/he (the human knower) has
constructed for themselves, which makes all learning the product of self-organization" (p. 136).

In consonance with this same trend of thought, Osborne and Wittrock (1983) believe that the "brain is not a passive consumer of information; instead it selectively attends to some information while ignoring other; thus actively constructing its own interpretation of meanings and drawing inferences from them" (p. 492). Implied here is the fact that, in order to learn with understanding, the learner must actively be involved in the learning/knowing process, constructing his/her own learning.

Although constructivism does not directly convey any information about models of instruction and it is not a well-defined and elaborated learning theory such as those posited by Piaget (1929) and Ausubel (1963), it has many implications for classroom activities and interaction in the views of some scholars/researchers.

Pea and Hawkins, in their work, tried to transfer the ideas of constructivism into actual classroom practices. They realized that:

Adults must collaborate with children in getting the tasks done and in the process 'scaffold' children's learning in ways that reveal the structure of the task and supplement children's developing abilities to accomplish tasks.... In schools, whether recognized as such or not by teachers, children are active interpretative learners who bring their prior understanding and frames of interpretations to make sense out of pedagogical presentations and interchange, as well as other events occurring during the learning situation/setting and in
Although it is not necessary to provide further details, other scholars have also translated the constructivist ideas into actual classroom practices (Miller, 1989; Newman et al., 1989; Tobin et al., 1990).

It must be emphasized that regardless of where one may find oneself on the constructivist ladder or scale, the central and crucial issue inherent within the constructivist perspective is the dynamic interplay and interactions of events, objects, people and society within the entire sphere of knowledge acquisition. Vygotsky (1978) was indeed acutely and keenly sensitive to these same issues in developing his notions of the zone of proximal development (ZPD). There is thus surely no doubt that the constructivist ideas attend to the very critical role of the science teachers/professors in any successful science content learning. The science teacher is indeed extremely invaluable and indelible in any attempts at successful science education reform, restructuring and science teaching/learning (Duschl, 1990).

Consequently, it is no surprise that numerous and various studies in chemistry education and all science education have been impacted/influenced by the ideas of constructivism and Ausubel's learning theories, which have in many ways been found to be quite compatible,
homologous and complementary to each other (Bodner, 1988; Breathner & Hewson, 1988; Driver & Easley, 1978; Graber, Means & Johnson, 1972; McClelland, 1982; Novak, 1988, 1989; Wheatley, 1991). It appears that constructivism shall somehow remain a theoretical base directing much of the current and future research topics in science education even though it is now receiving some criticisms from scholars such as Michael Matthews (1993). However, it does provide the foundation of this research because as teacher-focused research, constructivism wholeheartedly embraces the teacher/professor as the cornerstone in any successful science learning/teaching.

The above discussion about constructivism is rather general and broad. The specific aspect of constructivism relating to this research has been described by Coburn (1991) as "contextual constructivism." It is a two-way dynamic involving the learner's/knower's knowledge construction relative to the learner's learning and the social environment. In other words, the cultural context or social situation in which the learning occurs is extremely important. The social contribution to learning is crucial here and all learning is analyzed within the overall cultural environment of the learner. Indeed, this is where the teacher's role is significant because the necessary classroom interaction and activities must be created to facilitate the individual student's knowledge
construction in an unhindered and unencumbered manner. Moreover, since during my fieldwork I observed and interviewed the participant(s), sometimes in their classroom setting, and tried to understand the underlying influences of their classroom practices and interactions through which the learning of chemistry was negotiated, Cobern's (1991) views on "contextual constructivism" are appropriate.

Relevant Studies

A Broad Overview

The literature in chemistry education is quite voluminous and there was quite a deluge of studies in recent years. Most of the appropriate research occurred over the past 30 years or so, beginning in the early 1960s. A recent landmark article by Garnet and Treagust (1992) provided a splendid review and highlights of the main research studies in chemistry education. However, most of the research was focused on students' difficulties in learning various chemistry contents and concepts such as electrochemistry, mole concept, stoichiometry, redox reactions, chemical equilibrium, and thermodynamics.

Also, Pfundt and Duit (1988) highlighted many important studies in chemistry education over the previous 30 years relating to students' difficulties in learning various chemistry concepts. There are also many
other studies in chemistry education dealing with various topics such as textbook analysis/explanation (Chiapetta, 1991; Yore, 1991) and classroom explanations and interactions as well as other whole class activities (Treaugust, 1988). Still, there are numerous other studies focusing on students' misconceptions in chemistry (Lee, et al., 1993; Muthukrishna, et al., 1993), and still more studies concerning the use of history and philosophy in science teaching (Bybee, et al., 1992). All this literature has featured primarily the situational, physical and cognitive conditions in students and classrooms. They seem to have also taken for granted that the culture of the classroom is competitive, combative and individualistic.

From the readings it is also apparent that most of these studies have focused on the precollege level. Although the precollege level is quite significant, the college level is equally significant especially regarding the role of the teacher/professor in any science teaching/learning. It is the teacher/professor who will shape and mold the future science educators and scientists in the U.S.A.

Studies Specific to College Science Learning

Since such a broad overview of some of the relevant studies has been presented, it is necessary to embark upon a discussion of certain pertinent studies that have
relevance, implications and ramifications for this research. In a recent three-year study by Hewitt and Seymour (1991), it was revealed that teaching/lecture strategies and the inaccessibility of professors to help students in solving problems in their courses were registered as their greatest qualm by almost 89% of all students at four-year colleges and universities who changed their majors from science, engineering and math to other non-science majors. Furthermore, they reported that a primary concern of science majors revolved around the issue of science pedagogy, more than anything else. A startling 65% of science majors worried about science pedagogy, and many students were inclined to emphasize the personal qualities/characteristics and pedagogical style of professors in their classroom instead of the professor's science content knowledge (Hewitt & Seymour, 1991).

In another report by Sagan (1989), it was found that about 25% of Canadian 18-year-olds knew just as much chemistry as a select 1% of American high school seniors in their advanced program. He also stated that scientists do not make themselves fun to listen to nor understandable. Also, he found that they do not pay special attention to those students who have traditionally been steered away from science. In another report, Cassidy (1989) stated that his chemistry classes
were empty and all the smart kids were going to law school since they hated chemistry, based mainly upon complaints about teaching.

Although it has been recognized that a considerable number of potential science majors are lost during precollege years, a sizable pool of students do still come to college with keen interest in the sciences.

For many science majors and nonmajors, it is the introductory science courses that serve as "the straw that breaks or does not break the camel's back." It has been observed that such introductory courses usually are of poor quality, quite inane, leaving the bulk of the students terribly confused, poorly achieving, downright frustrated, and lacking basic scientific literacy and meaningful science content learning (Dini, 1992; Gregory, 1992).

Thus, there is a drastic reduction in the number of students remaining in science after their freshman year once they have had their introductory science courses, especially chemistry and physics (Dini, 1992; Hewitt & Seymour, 1992; Tobias, 1990). Something severe is definitely occurring in the introductory college science courses, and as Tobias (1990) has rightly asserted, "They're not dumb; they're different . . . . this book is an occasional paper on neglected problems in science education" (p. 1). Indeed, this is truly an area
neglected in science education as attested by the dearth of research focusing on college science teachers/professors, especially in chemistry education.

In regard to these opinions, it has been noted that one of the lessons learned during the years of massive curriculum reform and development in the 1960's was that the teacher played an extremely important role in what students learned (Duschl, 1990). Concerning this same issue pertaining to the significance of teachers, Good (1992) remarked in an editorial, "the central focus of research in science education should continue to be how curriculum and instruction affect science learning" (p. 325). With an enhanced emphasis in science education on scientific literacy and production of more scientists and science educators for the 21st Century (A Nation at Risk, 1984; Project 2061, 1898; Project Synthesis, 1981), the science teacher/professor is being brought more and more into the limelight and is the focus of research nowadays.

In yet another study by Shumba and Glass (1994), it was revealed from a survey of 123 heads and coordinators of freshman chemistry in various U.S. universities and colleges that there is a serious need for college chemistry professors/faculty to collaborate with high school chemistry teachers by conducting workshops and other activities/interaction in a positive manner so as to improve chemistry education at all levels. Implied in
this study is the need for research efforts involving college chemistry professors in the broad area of chemistry education.

Tobias (1990) has noted that it is indeed time that college science professors "rethink" their science instruction and undertake some structural reforms that possibly may prove useful for others who teach science classes. In fact, Tobias's work captioned "They're Not Dumb; They're Different" was one of the main pieces of literature that provided the impetus for this case study. Tobias (1990) revealed that "one third to one half of those freshmen who initially express interest in science leave science well into their major; some even leave after completing their degree" (p. 2). She then stressed the need for scientists "to change the way they recruit and teach their subject" (Tobias, 1990, p. 2). However, scientists and science professors seem so resistant to change. This is disturbing, especially so that the statistics relative to science learning in general and college science majors in particular are not so rosy. It is reported that an estimated 25% of incoming college freshmen in the U.S.A. are interested in science during their first year of college (New York Times, Feb. 1992). Moreover it is said that by the year 2000 the U.S.A. will need between 450,000 and 750,000 more chemists, biologists and engineers than it is expected to
produce (Time Magazine, Sept. 11, 1989). Also, according to A Nation at Risk (1983), nearly half of the newly employed science and math teachers in the U.S.A. are unqualified to teach their subjects.

These not-so-rosy statistics are indicators that science education at the college level in the U.S.A. is in a state of some disrepair, needing overhauling. This change will happen only if appropriate research in college science education is implemented and the subsequent results are made available to college professors, who in turn must be willing to test the research findings for adapting/adjusting their classroom practices and overall interactions with students.

Topics relating to chemistry learning/teaching continue to attract the attention of science research scholars. Basili and Sanford (1991), in their study of chemistry learning in a suburban community college, asserted that teachers need to ask provocative questions to students that link science concepts with commonplace phenomena so as to present students with the opportunity to see science concepts as being able to solve real-life problems. They then went on to suggest that by so doing, "teachers would be illustrating the utility of science and bridging the gap between 'school' and 'real' knowledge so that students are encouraged to take more responsibility for making sense of science concepts"
Here again, the role of the teacher is significant, and as such their study is calling for research efforts involving science/chemistry teachers.

Other Studies Specific to Precollege Science Learning

Among the extensive literature consulted, there are yet other major readings impacting this study. Lederman's work (1992) reviewed the literature and research regarding teachers and their science teaching relative to teachers' conception of the nature of science. Lederman (1992) concluded that research on students' and teachers' conceptions of the nature of science can and should inform research on pedagogical content knowledge, which influences a teacher's instructional approach. In another article by Brickhouse and Bodner (1992), "a case study was undertaken in order to probe a science teacher's belief about science and science teaching so as to determine how such beliefs influenced or failed to influence classroom instruction" (p. 471). These two pieces of literature are very relevant to this research because of the case study method used in one and the teacher-centeredness of both works, which coincide very well within the scope, goal, design and focus of this study.

Concerning the issue of pedagogical content knowledge which has been discussed earlier, Clermont et
al. (1994) examined the pedagogical content knowledge of five experienced chemical demonstrators and seven novice chemical demonstrators all at the precollege level. This study disclosed the need "to carefully document knowledge growth in science teaching through individual case studies of successful science teachers and the need for follow-up studies that examine factors that have contributed to the experienced science teachers' success and growth of pedagogical content knowledge" (Clermont et al., 1994, p. 439). The study further emphasized that it was necessary to understand how variables such as science content, instruction and student characteristics all interact to produce pedagogical content knowledge that is so evident among experienced science teachers. It was further recommended that science educators identify, support and implement teacher education programs that foster the professional development of science teachers with respect to pedagogical content knowledge. In order to achieve all this, surely research focusing on experienced college science/chemistry professors is a sine qua non.

Since this (my study) attracts attention to the instructional strategies of the professor, pinpointing cooperative group work among the students as being one of the key techniques employed by him, there needs to be some discussion of a few relevant studies concerning
cooperative groupings. In their work, Tingle and Good (1990), investigating the effectiveness of cooperative groups on stoichiometry problem solving in high school chemistry, reported that cooperative grouping was very effective in some non-academic areas of science teaching. These areas include a more supportive climate for learning and an enhanced student ability to organize projects, to divide and assign the work, and to take responsibility for completing their work. There was no difference in the achievement (scoring) of the students in cooperative groups as compared with those working individually, on stoichiometric problem-solving. Yet they emphasized that such attitude of students identified above were significant to the students in helping them to study chemistry.

In their work, Scott and Heller (1991), reporting on the use of cooperative group work among women and minorities, found that the use of such teamwork was necessary to effectively integrate women and other minorities into the physical sciences. Furthermore, Okebukola and Ogunniyi (1984), reported that since many tasks in science classrooms and laboratories demand high levels of cognitive skill and other personal characteristics such as perseverance and a positive attitude toward learning science, cooperative group work had a potential to promote all these attitudes in
students while at the same time aiding students to acquire some practical skills so as to improve their performance in science.

In a more recent article, Lazarowitz et al. (1994), in their work with high school science classrooms, found that cooperative group work indeed registered important academic, personal and social advantages for students in their high school science classes. They went on to further recommend a more pervasive implementation of cooperative methods in science classrooms. Studies such as these and many others have underscored the need for increased use of cooperative work by teachers/professors in their classrooms.

Summary

These studies discussed thus far have all highlighted in one manner or another the very crucial attention that must be directed at chemistry education at all levels from precollege to college. They have also invoked in some instances issues relative to the activities of the chemistry teachers/professors which must be considered in any attempts at successfully reforming/improving science and chemistry learning in the U.S.A. It is definitely clear from this overall literature review that chemistry education at the college level cannot be neglected as it is inextricably interwoven with chemistry and other science education at
all levels. Additionally, the chemistry teacher/professor must be the primary agent of change in chemistry education, and as such any research efforts aiming at a better understanding of teachers and their activities/interactions should be embraced.

Indeed, teaching and learning are no easy or simple matters, but concerted and conscious research efforts in this direction are surely steps geared toward the gradual elucidation of the inherent mystery of same. Moreover, all these studies and related literature cited and discussed above have all dealt with some aspects of science learning as a whole and/or chemistry learning in particular, especially relating to the effectiveness of teachers and their teaching practices, both at the precollege level and the college level science teaching, too. As exemplary teacher studies are gaining prominence nowadays, there exists a need for more of such studies in the area of chemistry at the college level. There exists a few role models in the literature for excellence in college chemistry teaching, but this study hopes to inform and augment this very crucial literature base and body of knowledge.
CHAPTER 3
METHODS AND MATERIALS

Research Methods: An Overview and Rationale

The research methods used in this study are based on the postpositivistic paradigm, which has now gained considerable status in educational research, promoting the use of naturalistic/qualitative methods (Borg & Gall, 1989). Research employing qualitative inquiry is more cyclical, and the method is not viewed as discrete step-like processes; instead, the inherent and overarching tenet here is the recognition of extensive variability over time, setting and period. Moreover, there exists here the embracing of equally important events in education such as internal unobservable characteristics, like feelings, attitudes, and reactions, all of which are extremely worthwhile and invaluable to educational scholars and researchers. Indeed all of these characteristics can be adequately measured by interviews, participant observation, audio-taping, think-aloud protocol, coupled with written and non-written sources identified (Rist, 1982; Smith, 1982).

This particular study is a case study employing many of the qualitative/naturalistic methods described above. The use of such methods in science education research is increasingly expanding as attested by their frequent use
in research articles published in the Journal of Research in Science Teaching (JRST) (Linn, 1987; Rist, 1982; Smith, 1982; Spector, 1984). Regarding teacher-centered research, the case study seems to be more appropriate (Brickhouse & Bodner, 1992; Hewson et al., 1993; Yin, 1989). As a case study, this research focuses on a single bounded system in which a particular chemistry professor and his college chemistry teaching are the focus of the investigation. The researcher has been fully immersed in all the available chemistry classes of this professor and also developed a personal relationship with the professor. All this was geared toward understanding the techniques, strategies, and methods of instruction employed by the professor, as well as toward efforts at understanding/interpreting daily classroom interactions and other pertinent activities of the professor. The concern of this research is to preserve the unity and totality of this professor and his chemistry teaching/classes in the university environment. Accordingly, the social data obtained must be organized to preserve the unitary character of the social objects being studied here so that, by drawing heavily on the personal experiences of the professor and students and looking for patterns, one gets to fully understand what is happening inside this case. It is only this bounded system, this entity that is the focus of this study, and
not anything else exterior to this unique case nor any other population of cases.

Like any other qualitative inquiry, this case study employs methods of ethnography such as participant observations in the natural settings, structured and unstructured interviews, note-taking and recording as well as narrative reporting to some extent (Bogdan & Bilken, 1992; Gallagher, 1991). Being fully immersed in the classes each for one semester, the researcher attended all lecture sessions as well as help sessions and study groups, and sat in on exams and seminars given by the professor in addition to obtaining all text material, lecture notes, homework assignments and keys, grading scales and achievements, other relevant statistics, all printed materials and class handouts. All of these are intended to produce a deep understanding referred to by Geertz (1973) as "a thick description".

However, it must be stated that prediction and control are not the primary focus of this research and, for that matter, of any qualitative work. The goal here is to understand, describe, interpret and make sense of (meaning-making) particular events, situations and settings (Hutchinson, 1990; Lincoln & Guba, 1985; Seidman, 1990). This research attempts to provide detailed contextual and situated meanings and understandings that are derived from the "case" [the
close watch of this specific chemistry professor and his classroom interactions/activities]. Consequently, these understandings are expected to have some applications to other similar situations, times, and conditions, i.e., college chemistry teaching in Liberia. Nonetheless, one must be acutely aware and sensitive to the fact that such applications, whenever possible, will definitely be affected by a myriad of factors to be dictated and determined by the novel context. Again, since strict prediction and control are not the goal of this research, even though it is intended that some exposition and provision of variable understanding of the particular educational setting/environment [the unitary chemistry professor and his chemistry classes], will be derived, one still must remember that other possible understandings and interpretations are equally justifiable alternatives to be gleaned from this case study.

Furthermore, the subjectivity of the researcher's very presence in the class, including his intrinsic make-up (intuition, values, knowledge, belief system and cultural background), does contribute to the overall meanings that may be construed or constructed as a result of this study (Anderson & Jack, 1990; Bogdan & Biklen, 1992). So then, an essential feature of this research involves the trustworthiness of this case study; that is,
how truthful are all the findings of this study to the researched participants and the degree/extent of neutrality maintained by the researcher as well as the degree or level of consistency maintained throughout the study, including also the extent of applicability and usefulness of the study for others. Accordingly, it has been argued that all qualitative research be used primarily for theory generation and elaboration of basic social processes that are common to all individuals within the educational setting/events (Glaser & Strauss, 1967).

Indeed the methods employed in this case study will provide deep and factual contextual understanding. In attempting to achieve this, there existed the need for triangulation of the data sources (Patton, 1990). This process involved going back into this same professor’s upper level chemistry class for another semester, this time with carefully planned and systematic activities including detailed field notes and descriptions as well as additional interviews with this teacher/professor, his departmental colleagues whenever feasible, graduate students and post doctoral fellows and other students. All this is also in compliance with the ideas that qualitative researchers need to constantly go back and check or augment their findings so as to expand the scope to which the results are generalizable.
At the conclusion of the data collection phase of this study, all the data obtained from the various sources were systematically analyzed in a rigorous and meticulous manner so as to discern and identify useful and emerging themes for description, interpretations, and understanding the uniqueness of the particular case being investigated. Due to the nature of the case study method itself, there are inherent limitations of this research study even though it does employ "rigorous and systematic empirical inquiry that is databased" (Bogdan & Biklen, 1992, p. 43). However, concerns about the limitations can be reduced by having multiple sources of data.

Overall Procedures: Data Sources/Participant(s)

The discussion so far has been rather broad, relating to qualitative research as a whole and to the case study method. In specific reference to this particular research, the principal method of investigation was participant observation, interviewing and artifact collection/analysis. Upon gaining full access to the classes and with the professor providing his complete cooperation and availability, the researcher was immersed in the classes just like any other student taking the courses.

Many handwritten notes were taken daily, recounting all of the classroom interactions, i.e., number and kinds of laboratory demonstrations; numbers of group questions
and group responses; student daily attendance and their attendance at help sessions; and individual questions and responses in class. Also many artifacts were collected, i.e., all homework, tests and keys; all lecture notes and previous lecture notes as well as previous tests, homeworks and their keys; and all hand-outs and syllabi with the grading system and test score profiles.

There were also many discussions with the students outside of class concerning their impressions and ideas relating to the classroom activities and the daily instructions as well as their views about the courses and chemistry teaching and learning in general. In this regard, some unstructured interviews also were conducted with students who volunteered for such interviews so as to ascertain their direct and personal ideas concerning the instructional strategies and to help assess the impact experienced by the students. During these interview sessions the students and all interviewees (informants) were encouraged to just talk frankly and freely about anything of interest to them concerning the course and chemistry learning/teaching in general. There was no desire to have pre-set questions and look for direct responses to these questions from the informants.

The chemistry professor was the principal participant and he was contacted in class and outside of class as much as possible both for casual conversations
and for much more serious discussion about the instructional strategies and his views about the classroom interactions and activities. All of these discussions and conversations were fully documented and recounted. Since the activities of this professor do impact the students, some of his departmental colleagues, his graduate students and his post doctoral fellows, they definitely become participants in this study, too. As such, the students and other informants were closely observed. They also were frequently consulted and interviewed whenever necessary for confirming and highlighting pertinent issues. The teachers and all the informants are partners integrally united in this research and are vital to the case study.

The Study

It is important that the research questions raised in a study mandate the kind of methods to be used. Since this study intends to describe and explain in detail the instructional strategies and overall interactions of a specific professor, and this involves understanding and reporting human behavior, the ethnographic inquiry is more suitable here. The specific ethnographic design dictated by this research is a case study because, as argued by Yin (1989), the case study method is much preferable when one is interested in finding "why" and "how" things happen and sometimes "what" happens in
complex social situations involving human beings such as in classroom activities/interactions.

The focus of this research is the individual professor, and his personal set of experiences and specific stories relating to college chemistry teaching, which seems quite unique with all its idiosyncrasies and social complexities. So then as this work targets an individual professor, drawing heavily on his experience in the college academic environment and in the chemistry classroom, some portrayal and understanding of a specific educational problem is attained; and all the social data obtained are organized to preserve the unitary character of the professor. One of the characteristics of a case study of this nature is a close personal, cordial, trustworthy, and open relationship between the researcher and the participant(s) so that they can all feel quite free and comfortable around each other in order for the participant(s) to confide and actually expose their fears, frustration, skepticism, other concerns and overall feelings about issues. Moreover, since the researcher had himself been a chemistry professor and student, he could readily and more easily relate to the professor's experiences as attempts were made to bring meaning and to make sense of the data collected. As a result of this study, one hopes to understand what is actually occurring in the professor's teaching life by
looking for patterns. In so doing, it became necessary to invoke discussions and interpretations of issues that emerged from this research, such as the need for innovations, revisions, and improvements in college chemistry teaching and science teacher training programs in universities and colleges. Such discussions and interpretations are deemed necessary and worthwhile so that readers are guarded from any over-generalizations of the findings that may not be relevant or applicable to other situations even though a case study is directly linked to the improvement of practices (Patton, 1990).

**Triangulation of Data Sources**

In this study, there are multiple data sources. These are carefully and systematically planned observations in the natural setting of the participants, involving detailed note-taking as well as numerous interviews and the collection of artifacts coupled with many narrative reports. Consequently, triangulation of all these qualitative data sources required comparison and cross-checking the consistency of all the various and numerous data so as to ascertain how well they matched (Patton, 1990). The whole idea of triangulation is to expose and serve as a kind of check and balance on intrinsic bias that could emanate from using only a single method, a specific observer, or a unitary data source. However, by using these multiple data sources,
the reliability of the data obtained in this study is enhanced.

Participants

Since this is a case study focusing on a particular chemistry professor, known in this report as Dr. G, he is the principal participant in this study. In this report, the term "participant" will now be used so as to reflect the very active and positive role of the professor, students and other persons focused on in this study instead of other terms such as "informant," "interviewee," and "subjects" as are sometimes associated with such qualitative inquiry. Siedman (1991) has proposed that the term "participant" is much more favorable because it denotes the active involvement of people which occurs in extended interviewing and a sense of equity in the researcher-participant relationship, which is in fact a crucial factor in this case study. All the students in the organo-metallic chemistry class and the introductory level class are participants in this study; but some have been identified as participants later, based upon the extent of conversations and interviews with them. Also, some of the professor's graduate students and post-doctoral fellows are participants here too. All the participants' names have been altered to protect their identity.
The Professor, Dr. G

This chemistry professor has been teaching at LSU since 1986. His complete life profile in excerpts is presented in Appendix A. He is a well-known inorganic chemist and does a lot of research work for chemical industries in and around the Baton Rouge area.

He has a keen interest in students and people in general and is always more than willing to talk to anyone at any time. He has already won teaching awards and has expressed interest in the science academic achievement of students.

Although he is also extensively engaged in research, as attested by the fact that he has been awarded several financial grants from major corporations and industries to conduct research, he did not devalue teaching, but seemed to uphold both teaching and research on equal status. It is also quite noteworthy that he had voluntarily offered to conduct seminars on Saturdays and at other convenient times for interested high school chemistry teachers in the area to help them update and improve their chemistry teaching.

There are also many things that seemed quite unique to this professor. Instead of just adhering strictly to the prescribed textbook for the introductory chemistry course and the upper level course, he had written and compiled his own set of lecture materials and notes.
which, although based on materials in the prescribed
texts, are replete with concrete examples and references
to real-life situations and practical implications of
chemistry concepts for the students so as to overcome the
abstractness that seems to be embedded in chemistry.
Also, all previous lecture notes, tests and homework
assignments, as well as their keys, and test score
profiles for previous years in which he had taught the
courses, are made readily available to the students.
Important ideas are conspicuously highlighted in all
lecture notes and classroom lectures and during other
classroom activities and interactions.

For this professor, critical thinking seems to be a
key factor propelling his lecture strategies because he
is not concerned about exact numerical answers to
problems. Once a student is on the right track toward
solving a problem, nearly full credit is awarded. Even
when an exact answer is required, usually it is simple
whole numbers or factors of ten, which anyone with basic
mathematical skills should be able to achieve.

Open office hours are maintained by this professor
and the students are strongly encouraged to see him as
often as possible to discuss any problems they have,
whether or not directly related to chemistry. Indeed
these attributes of this professor and his instructional
strategies provided the motivation for this case study.
This professor is an active member of the Louisiana College Chemistry Curriculum Reform Committee and is, in fact, chairman of that committee (See Appendix B). He maintains an office on the sixth floor of the chemistry-biochemistry building at LSU known as Choppin Hall. Usually, whenever he is around, his office door is left open. He has a distinct voice that is usually quite loud and clearly audible. He is also married and has two young children.

This professor was first encountered by the researcher at a science education seminar presented by Sheila Tobias in 1992 and sponsored by the Physics Department at LSU. Shortly thereafter, when the professor was approached concerning my desire to conduct this case study, permission was willingly granted for full participation in his classroom setting, just like any other student taking the courses for credit. Also, full access to all lecture notes and materials, homework assignments, answer sheets, and class handouts was accorded and these were collected as artifacts. Furthermore, all help sessions, usually for two nights (5-7 p.m. Mondays and Tuesdays) before each of the scheduled tests in his courses, were attended. The test sessions were attended as well.

Additionally, two seminars the professor presented to the departments of Biochemistry and Chemistry were
attended in order to obtain firsthand knowledge from the professor himself concerning his instructional tools/strategies and techniques as he explained to his colleagues the classroom activities.

Students Taking Dr. G's Courses

A. Mrs. M—She is a mature graduate student in Chemistry 4571 working toward a Ph. D. in chemistry, now into her second year of chemistry graduate studies. Coming from South America, both she and her husband are graduate students at LSU and she is taking the course for graduate credit based upon the recommendation of her major professor. She had teamed up with another student in chemistry from China and they work as a cooperative group in the class. Having taken about four other graduate chemistry courses at LSU, she was no stranger to this particular chemistry course. She remembered seeing the researcher at masses in the Catholic Church on the campus. Thus, as soon as she was contacted for an interview, she willingly agreed to converse whenever it was necessary and for as long as possible throughout the study.

She is fluent in English and seems to enjoy talking in addition to having a rich sense of humor. This trait seems quite common to persons from South America, which makes her an excellent data source in this work as conversations with her usually were quite lengthy.
B. Mr. B--He is a senior undergraduate student taking the Chem 4571 course and majoring in chemistry. A young man in his early twenties, he is in fact graduating during the semester in which the class was observed for the study. He, too, remembered the researcher from the Catholic Church on the campus and, in fact, was living with the priest at the time. Having no desire to pursue graduate studies in the immediate future, he was at the time already looking for a job in chemistry to meet his financial needs. He is an American white male and had teamed up with two other white male undergraduate students hoping to major in chemical engineering. His teammates were his friends from their freshman year and they, too, were quite loquacious. They were quite willing for the researcher to sit in on their study group as they solved homework problems together and studied for tests and exams. He and his teammates never hesitated to converse with the researcher whenever he so desired, and usually they would explain and answer questions in detail.

C. Mr. E.--He is a second year undergraduate student in the Chem 1202 class hoping to major in chemical engineering. Coming from East Africa, he intended spending all of his undergraduate years at LSU. This was his first chemistry course and it was a required course for him. Being an African like the researcher himself,
they could easily relate to each other and discuss issues at length almost every day because they frequently met in other situations outside of academics.

He had teamed up in Chem 1202 with two young ladies, one white and an African American. They all were aspiring chemical engineering majors and had been very good friends from their freshman year.

His experiences as a young man from Africa studying in an American institution of higher education were quite insightful for this research, too. His team was also very unique because usually the teams were either of the same sex or the same racial status. It was nice to realize how well they seemed to get along in such a heterogeneously mixed race and sex group.

Graduate Students Working With Dr. G

A. Mr. T.—He is a graduate student of Dr. G., working toward his Ph. D., and usually taught the Chem 4571 course on days that Dr. G. had to be out of town. He is a young white, unmarried male from Tennessee and he himself had taken the Chem 4571 course from Dr. G two years previously. He was quite willing to talk to the researcher and readily volunteered his phone number and other reference points of contact when the researcher consulted him on one of the mornings that he substituted for Dr. G. Without any prior contact, an immediate and cordial relationship developed between us and usually he
too discussed at length and in detail any topic that the researcher deemed necessary. Conversations with him were quite informative and wide-ranging. He does not hope to finish up his Ph. D. until another two or more years.

B. Miss C.--She is a graduating Ph. D. student of Dr. G. at the time of the study as she was mainly writing her dissertation. A young, white, unmarried female, she had earlier contact with the researcher from the Catholic church on campus and as such they were no strangers to each other. Moreover, she had served as one of the principal teaching assistants to Dr. G. during the conference of college science teaching at LSU and during his workshop with area teachers, which I attended, and also including assisting him during the teaching of the 1202 freshman chemistry course. She was always very helpful and available to the researcher. Usually, after mass on Sundays, she was very willing to engage in quite lengthy discussion about much of the other privileged information and behind-the-scenes talk in the Chemistry Department that were not readily accessible to the researcher.

Although from the midwest, she has come to like the area and intends to live here for quite some time after her graduation from LSU. She, too, had developed a keen interest in education as attested by her attendance at education seminars and conferences held at LSU.
Academic Setting

Louisiana State University

The information provided below is mostly a paraphrase and summary from a conglomerate of publications regularly offered by Louisiana State University.

Louisiana State University is the state's comprehensive research university with the main campus located in Baton Rouge. This comprehensiveness is recognized nationally by the Carnegie Commission as a Research I University -- one of 45 public and 25 private universities in the U.S.A. It has 250 buildings of uniform northern Italian renaissance style that serve as a unique and contemplative scene or setting for higher (university) education/learning. There are hundreds of century-old live oak trees among the main campus buildings as well as numerous gardens.

This is a large university. Physically the main campus sits on 650 acres of land. The university owns and conducts research on about 2,000 acres of land within the Baton Rouge city limits. It has a large student body, with the 1993-1994 academic Fall and Spring Semester registering student enrollment of around 27,000 students. This figure represents about 18 percent of all students in Louisiana enrolled in higher education.
There is almost an equal ratio of male to female students in the university, and their average age is 22.

Chemistry Department

The Chemistry Department is housed together with the Biochemistry Department in a six-floor building known as Choppin Hall on the university campus. It is a large building, in which there are many offices for faculty members and graduate students, with research laboratories having the state-of-the-art equipment/apparatus for various research activities in chemistry. Each faculty member usually has an assigned laboratory and a research team, which includes graduate students and senior undergraduate students and sometimes postdoctoral fellows. It is not uncommon for faculty members to team-up for research purposes. The department has very much an international outlook from the standpoint of graduate students and faculty, with a dominance of white males. There is only one African-American faculty member in the department.

This department has a separate four-story teaching building, known as Williams Hall, in which most of the chemistry classes are held. Also a chemistry library exists there. The classrooms are quite spacious and are equipped with screens for overhead projectors and with large chalkboards. Departmental seminars usually are held in Williams Hall.
The Courses and Classrooms

Chemistry 4571

Chemistry 4571 is one of the two chemistry courses at the core of this study. Chemistry 4571, known as Organo-Metallic Chemistry, is an advanced upper-level chemistry course designed and taught by Dr. G for the past seven years. It was designed primarily for chemistry graduate students and graduating chemistry seniors. In the earlier years, it was strictly chemistry majors taking the course, but as the years progressed, more and more senior-level undergraduate chemical engineering majors began taking the course. At the time of this research, there was a total of about 55 students enrolled in the course, with the chemical engineering majors outnumbering the chemistry majors by a ratio of three to two.

In previous years, the course was usually taught in a small classroom in the research building of the Chemistry Department, known as Choppin Hall, because only 15 or 20 students would be enrolled. At the time of this research, however, the course was moved for the first time to the teaching building of the department, known as Williams Hall, because of the large enrollment of students.

The classroom was situated on the second floor of Williams Hall, room 208. This is a very large and
uncluttered classroom, being equipped with an overhead projector, a screen and a large chalkboard spanning almost across the entire front wall of the room. The overhead projector, the large screen and chalkboard and a meter stick, which Professor G usually brings along to class, are constantly used throughout the classroom session by him. The classroom contained about 60 portable wooden desks, almost equalling the number of students in the class. Opposite the entrance doors of the classroom are large glass windows that span the entire length of the back wall. Although these windows were equipped with Venetian-type blinds, these blinds were usually open so as to allow for maximum outdoor lighting within the classroom. Since it was mostly through the winter and early spring months that this class was studied, the room was usually properly heated and was quite comfortable inside with adequate lighting.

When Dr. G began classes in the room, he would usually close the two entrance doors so as to avoid any distraction because there normally was some commotion in the hall as students waiting for their classes talked with each other.

It is noteworthy to mention that once students had formed their study groups of 2-4 students (See Appendix C), they usually sat proximal to each other in the same group, allowing for easy conferral on questions posed.
The class met on Tuesday and Thursday mornings in the spring of 1994, beginning usually at exactly ten minutes after nine and ending at ten thirty.

An expensive textbook (See Appendix F) was prescribed for the class, which Dr. G used only as a reference on reserve in the library.

Chemistry 1202

Chemistry 1202 is the other course at the core of this research. It is the introductory level chemistry course at LSU designed for science majors. There are many sections of this course and usually Dr. G teaches only one section of this course, in which there are enrolled about 200 or more students. Enrolled in this class were students who seemed to have varied mathematics and science backgrounds as well as varying cultural and experiential influences.

The course is taught in a very large classroom, designed as an auditorium, without any windows. There exist two screens for the use of an overhead projector, and usually Dr. G used both screens throughout his class sessions. There is also a large chalkboard covering almost the entire front wall of the room, and Dr. G usually writes on it daily. The room has a raised platform at its front for the professor to stand on. Dr. G brings a long meter stick (pointer) for use in the classroom.
This classroom for this course is situated on the first floor of the Chemistry Department teaching building known as Williams Hall in room 103. It is uncluttered with all the chairs being stationary. It was usually well-lighted and properly cooled during the fall months in which I studied the class. It is equipped with a laboratory-like table and a sink, quite appropriate for laboratory experiments and demonstrations. This classroom was insulated from outside noise and other distractions. The class met for an hour and 20 minutes on Tuesdays and Thursdays in the fall of 1994 and Mondays, Wednesdays and Fridays in the fall of 1992. An expensive text was prescribed for the course, but Dr. G never used the text. Instead, he made his own note package available to the students at a modest price of $10 (See Appendix E).

All students in the course voluntarily chose study group members of two to four students. Once the study groups were formed, the group members sat proximal to each other in class so as to allow for easy referral and working relations.

Data Sources/Collection

This study employed field methods that included long-term and intensive participant observations, interviews with key participants (the professor, students, and some graduate students of the professor), and the collection of artifacts (study guides, homeworks
and keys, past homeworks and keys, tests/exams and keys, past tests/exams and keys, class notes, teacher lecture notes, other hand-outs, grading scales, and profiles). Some of these and appropriate excerpts are included in Appendix D. Patton (1989) asserted that having multiple data sources is one of the principal and inherent traits of qualitative research. Although participant observation is the primary mode of data collection in this research, interviews and artifacts collection are crucial to the data base.

**Participant Observation**

During the entire Fall Semester of 1992 and Fall Semester of 1994, the researcher was fully immersed in the Chemistry 1202 classes every class day, with very focused observations of one hour or one hour and 20 minutes lessons respectively in each class. Also, during the Spring Semester of 1994, the researcher was fully immersed in the Chemistry 4571 class every day, with very focused observation of the one hour and 20 minutes lessons. Detailed descriptive information in field notes were taken of all the classroom activities and interactions as well as a time log of activities.

It must be emphasized that as the field notes were taken during these participant observations, no attempts were made to interfere in any way with the contents being taught, the materials being used or the manner of
presentation as I was purposefully unobtrusive as much as possible.

These field notes were discussed quite regularly with the chemistry professor throughout the semester for his comments and insights. Later when other key participants were determined, these field notes were also regularly discussed with them so that assertions consistent with the observations could be formulated. Through such constant discussion, subsequent observations were used to either refute, refine/revise, or accept the assertions being formulated throughout this study. Moreover, as a result of this extended participant observation, adequate rapport was also established between the researcher and the participants, which was in fact crucial in selecting some of the participants, the contents of the interviews and the kinds of artifacts for collection and analysis.

In the field notes, usually my personal experiences were written as memos to myself in the margins of the pages and the students' experiences were recounted, too. Also, there were detailed field notes from participant observation of the researchers at a two-day conference at LSU titled "Teaching Science at the College and University Level," in which the professor was a major discussant and speaker.
Based upon extensive and intensive participant observation, interviewing then became a necessary part of the data sources. As Patton (1989) has suggested, it is important to find out what people have to say because one cannot observe everything such as feelings, thoughts, and intentions. Patton (1989) further asserts, "Each time one asks and listens, the world will always be new and one will know how to enter into another person's experience" (p. 278). Interviewing then allows one to obtain descriptive data from the participants' verbal expressions.

Most of the interviews conducted with the participants were informal conversational interviews, quite unstructured and open-ended. These verbal responses obtained during interviews were usually recorded verbatim as much as possible in handwritten notes. By using conversational and unstructured interviews, it was assumed that the participants freely and frankly disclosed and discussed their feelings about any issues and ideas emerging during the interviews.

Artifact Collection

Many artifacts were collected throughout this study. The professor gave the students many papers from all sources as long as they related to the confines of the courses. Also, he was very generous with copies to the
students at no extra cost to them. Sometimes, even when the researcher and students needed to make extra copies and make copies of other things needed for their own purposes, the professor volunteered to make copies available. All these artifacts are auxiliary sources for interpretation of the data. These artifacts include homework, class notes, tests/exams, other hand-outs, the course syllabus and grading profile. The insights gleaned from this strand of data assisted in guiding the researcher's elicitation of some narrative material for the study.

Data Analysis

Among the constituents of the data collected for this case study were artifacts, interviews, and detailed field notes from participant observations of the professor's organo-metallic chemistry class (Chemistry 4571) throughout the entire spring semester of 1994, and his Chemistry 1202 classes in two fall semesters. Also included are detailed field notes from participant observations of a two-day conference titled "Teaching Science at the College and University Levels" (January 28-29, 1994), which was sponsored by the Louisiana Academy of Sciences with Professor G serving as the major discussant/commentator during the sessions as chairman of the "Chemistry Education Group" at the conference and a speaker about "The Development of Statewide Reform of
Chemistry Curricula for Universities." Excerpts of the Conference's session titles are included in Appendix B.

All these data were assembled and organized logically as the actual analysis occurred. In continued analysis of the data, a constant comparative method, as suggested by Glaser and Strauss (1967), was used. This strategy involved the daily reading and rereading of all the data until emerging patterns and categories were recognized, based upon the researcher's frequent consultations and referral to the overall research questions guiding this study so that the analysis of the data could be focussed.

Substantial codes that described pieces of the data were assigned to the emergent categories, and as the data collection progressed, the strength of the categories was confirmed or rejected based upon new data collected. It must be mentioned that although the codes may be the actual terms used by the participants in some cases, codes did not necessarily arise solely from the data. Instead, their use was influenced by the researcher's perspective and background. In the selection of items to be attached to a particular code, the researcher's inherent understanding of the world and prior background/upbringing definitely impacted the selection (Bogdan and Bilken, 1992).
As the analysis continued, a search for discrepant or negative incidents across all the data sources shaped the final categories. Before concluding the analysis, two of the participants, Mrs. M and Mr. E, were asked to read the category definitions and findings of the study as a part of the member or validity check. During the coding of the data, integrative memos attached to the codes helped determine the categories. Hutchinson (1990) has argued that such an analysis is ideally suited to form initial descriptions and explanations of complicated situations such as classroom activities/interaction.

In the final stage of the data analysis, a descriptive discussion of the findings of this case study is presented together with some theoretical interpretation. Data excerpts from field notes, participant observation, records of interviews, and artifacts collected are included in order to illustrate the professor's overall instructional strategies and his student/academic interactions and activities that are worthy of attention and analysis by other chemistry professors, science teachers, and other educators.
CHAPTER 4
FINDINGS AND DISCUSSION

Introduction

Usually, qualitative case studies take on the traditional form of narrative report. However, in his seminal work on case studies, Yin (1989) remarked:

The case study evidence does not need to be presented in the traditional narrative form. An alternative format for presenting the same evidence is to write the narrative in question-and-answer form. A series of questions can be posed, with the answer taking on some reasonable length. . . each answer can contain all the relevant information. (p. 135)

Also, concerning the writing up of qualitative studies, Hammersley and Atkinson (1983) argued that:

All qualitative field research seems distinct in the degree to which its practitioners lack a public, shared and codified conception of just how what they do is done and how what they report should be formulated. (p. 214)

Based upon these notions, I have decided that each research question be addressed separately in compliance with the question-and-answer format proposed by Yin (1989), since I feel more comfortable and competent using such a format. Using this question-and-answer format, this chapter has been apportioned accordingly to reflect and respond to each research question with the inclusion of some discussion of the relevant findings that are pertinent and specific to each research question posed.
It must also be asserted that most of the interviews conducted for this study were the conversational type, which are prone in many instances to the impossibility of capturing verbatim the participants' exact words. Thus, some of the remarks of participants included in this section are sometimes paraphrased or summarized in manners to resemble as closely as possible their exact statements in correct grammatical form.

Hallmarks of Current Instructional Practices

What are the hallmarks of Dr. G's instructional strategies and overall interaction with students and the general academic environment?

Indeed, this is a very critical question directed at the core of this inquiry. In responding to this question, certain salient features appearing quite unique and specific to this professor must at the outset be identified and categorized. They include the following:

a) Cooperative group work and "talking science" in study groups of 3-4 persons, with each group having a name according to the chemical elements and group members being expected to work together in and outside of class;

b) Multiple sources of student assessments and evaluation involving tests, final exams, homework, group responses and activities and personal circumstances;

c) Acute sensitivity and requisite reaction to the individual needs/situations of students intended to take into
account the specific circumstances/needs of the various types of students from both traditional and nontraditional backgrounds including women and other under-represented minority groups in science; d) The frequency of references to the human efforts and society’s influence in chemistry; this involved the use of lots of history and philosophy of chemistry coupled with anecdotes of some of his personal real-life experiences as a chemist and those of other chemists together with appropriate and interesting historical vignettes and other kinds of stories whenever possible and necessary; e) The integration of lecturing, demonstrations, modeling and other mind-capturing and appropriate activities as viable and daily routine classroom options; f) Personal qualities such as joviality, conviviality, congeniality, openness, frankness, distinctly audible voice, vigorous body movements and gesticulation coupled with an overall vibrancy and enthusiasm for both chemistry research and teaching as a profession; g) Obsession with the practicality of chemistry concepts and their everyday utilization for the professional lives and activities of students. These categories enumerated and identified above will now be further elucidated.

A) Cooperative groupings. Cooperative group work was a key technique used by Dr. G since he viewed this as being
essential for any meaningful teaching/learning to occur in chemistry. Moreover, he believed that by the use of such groups, "the students become attached to and can relate more to the chemistry content that they are studying". On the very first class day in both of his courses focused on in this study, the students were informed:

Break-up into voluntary study groups of 2-3 students choosing group members of your own preferences. Working in study groups provides maximum benefits to you because of the sharing of ideas which takes place. Moreover, each study group should select the name of one of the elements for its identification. Remember, however, that you are not locked into study groups and please feel free to change your group if for some reason things are not working well among you and the other group members.

This emphasis on study groups definitely impacted the students, and they readily formed working groups. Soon, the students began to recognize the study groups as being essential to their success in the course. When the first set of homework was handed-in, numerous comments were heard from the various groups in the Chem 4571 class, such as:

Mr. B: "It was very easy for our group to get together and we worked for about 3 hours together on the homework. Then we sought Dr. G's help with the harder problems during his open office hours. He did help us a lot and all in all, I consider the homework very fair reflecting what all we have covered so far in class even though we did spend a lot of time working on it. We all in my group had good scores which were all "A's."

Mrs. M: "I consider the homework very fair although we spend lots of time working on it because
after each of us worked on it individually for about 2 hours; we then got together for about another hour sharing our ideas on the more difficult problems. It paid off because we two did very well on the homework."

From these quotes, it was evident that students had no qualms about the cooperative groups and viewed them very positively.

Yet still, there existed other benefits for cooperative group members. Since each group was asked questions on a routine basis during class sessions, the group members as a whole could acquire bonus points for correct responses. These bonus points were supplemental sources used for decisions regarding the final letter grade in the course. Also, by being placed in groups, group members felt obliged to each other to be present daily in class and to sit together taking a kind of shared responsibility for each other, especially since it was not uncommon for group members to be called up front to the blackboard to solve a problem. Accordingly, from the Chem 1202 class Mr. E remarked "group questions forces one to attend classes and pay serious attention to what is going on in class; and also once he starts asking group questions it is just like the light bulb is turned on as everyone just knows that their group could well be the next." Mr. E further remarked "I find all good because no other classes I have ever had incorporated such group questionings." All of the whole outcomes and
other issues pertinent to this cooperative grouping are quite consistent with the findings of Johnson and Johnson (1988) that cooperative grouping promotes interpersonal relationships and critical thinking skills, surely increasing learning outcomes among students; and they are also congruent with ideas advanced by the BSCS (1993) calling for the need to use multiple instructional techniques in science classrooms. Moreover, since this group work and questioning technique fully engaged the students in "talking science" among themselves in and outside of classrooms, the ideas of Lemke (1990) about "talking science" are quite relevant.

An essential feature of the questioning involved the skillful use and manipulation of wait-time. Dr. G always provided the groups ample wait-time in order to allow them and somewhat force them to manifest some response. His wait-time expertise was sometimes professed by him decomposing questions into stepwise simple constituents. Other times he provided sufficient hints and other lead-ins so that the group in the spotlight could at least be able to verbalize something and not act like "dummies sitting on a brick wall," as he put it. On one occasion when the Vanadium group in the Chem 1202 class claimed not to have the faintest idea concerning a question, another group was called upon. When that group responded, Dr. G then rephrased the same question and
again called upon the Vanadium group, and this time they just had to say something. There seemed to be just no way to escape from his questions.

In fact, Dr. G from time to time emphatically said, "I encouraged group discussion and answer; so always say something because you lose nothing by saying something in this class even if you say something totally off the wall or out of the way." He further stressed "I want everyone to get an A in this course and so all this is intended to help you and not to penalize you; and I do believe that everyone can get an A in this course." As a consequence, such questioning was indeed an integral component of daily classroom activities. It must be mentioned that this questioning was a two way street with Dr. G entertaining lots of questions from the students. He encouraged students to ask lots of questions and express their concerns in the following words, "Stop me anytime you don’t understand something and ask as many questions as you want to; also don’t hesitate to come and talk to me because I am usually accessible in my office or somewhere nearby."

B) Multiple sources of assessment and evaluation. Assessment and evaluation of students were on-going processes for Dr. G beginning on day one of his classes. He used diverse assessment strategies constantly throughout the courses including graded homework.
assignments, tests in class, a final exam, group responses and activities in class and the students particular personal circumstances so as to accommodate the various kinds of background of students (See Appendix E and Appendix F).

He accomplished these assessments in many ways. In fact for the in-class tests and final exams, students always were provided ample time to work on and complete them. Dr. G usually informed the students, "For an hour and twenty minutes class period, I usually prepare an exam which can be completed in an hour's time and for the two hours final exam period I use one that can be completed in about an hour and a half." This was actually the case because in fieldnotes of observations from one of the first in-class tests, the following excerpts were recorded:

The test started at 9:10 AM and by 10:10 AM one student had finished and turned in his paper. By 10:15 AM another batch of students had finished leaving only about one half of the students still working on the test. By 10:30, only about ten students remained working on the test as the bulk of the students had already handed in their papers. Dr. G then announced an additional 10 more minutes for the students still working on their test; but he eventually remained in class until 10:45 AM when all the students turned in their work.

It is this sort of latitude which was so pervasive throughout his assessment strategies. Dr. G didn't like to unduly pressurize students in any way. Even concerning homework, many times he postponed the deadline
for handing them in when students presented valid excuses for delays or perhaps when he himself just was convinced that they needed more time.

He repeatedly told students not to be hesitant in coming to see him about any graded materials and as he put it "I am always more than willing to give extra points or credit to you all if the need exists." As another gesture, the students were offered the choice of whether to be graded only on their tests and exams or to include the other materials too. As expected, they opted for the more inclusive package. It is noteworthy to mention that sometimes after tests in both classes, Dr. G usually offered a bonus 10 points to all the students' grades whenever he recognized that a test contained some unfair questions from materials that had not been thoroughly covered in class,

In continued references to his tests and exams it is important to note that Dr. G highlighted to students what he expected them to know and provided clear hints about the questions to be asked on tests and exams. As such he constantly stressed quite frequently, "Understanding the homework will enable you to do well on the tests and the exam, so don't even think about failing this course because everyone can and will do well here." Another vivid incident worth mentioning here in connection with student assessment involved a young lady who had just
fractured her leg a few days before a test in the 1202 class. Hopping on crutches, she was still attending classes, and so on the day just before the second test, she approached Dr. G and humbly requested him to allow her to take her test a few days later since she was suffering from severe pain in her leg, making it difficult for her to study and concentrate. Quite surprisingly, he immediately replied, "It is okay for you to just totally skip this test because I can easily grade you based upon the numerous other activities of assessment developed for this course." Suddenly a big smile appeared on this young lady's face which was obviously an indication of huge relief from the burden of taking a test with an aching and fractured limb.

Dr. G also exhibited concern and awareness about students' obligations in other courses during his overall processes of assessment. At the very outset of the Chem 1202 course he expressed, "It is my desire to have all the homework and tests sufficiently spaced-out so as to not overcrowd you all, and not overlap too much with your work in other courses." In a discussion one day just before a test he stated, "I am concerned about jamming tests together especially administering the test during the mid-term week when you all have so many other tests to study for." In fact, from time-to-time, students usually voted on which specific class day they preferred
to take their test. As all deadlines were usually extended the following excerpts from fieldnotes from Chem 4571 are informative:

The third homework was originally due on the Tuesday right after the Easter break; but he postponed the deadline by another week knowing that students would just be returning from Easter vacation... students were also asked when they wanted to have their second test whether Tuesday or Thursday, and they decided on a Thursday (April 21st) for the test.

He (Dr. G) further informed the class that he would prefer that the class also reach a consensus for the time and date of final exam; but perhaps since many of the students were undergraduates this was somewhat impossible. Thus, they may be forced to stick to the university schedule for the exam which he didn't quite approve of. He also discussed possible dates for up to two help sessions for students before the second test; but since the students all seemed to have conflicting schedules and could not decide on several dates he proposed, it was then decided that individual class members come for private help sessions as they so desire before the test.

These assessment strategies are also congruent with the ideals of BSCS (1993) calling for the need of science instructors to use multiple and varied assessment strategies/methods to assess the diverse student populations in science classrooms. The BSCS (1993) again further recommends that "assessment should be an on-going process that begins with the determination of information and skills students bring to the classroom and continues with documentation of their progress throughout the course" (Page xiii). This is precisely what Dr. G seemed to be doing in his courses, and students apparently benefitted from such activities. The varied methods of
assessment and evaluation were indeed essential for any successful teaching/learning of chemistry and certainly Dr. G performed quite adeptly here. For example, in the 1202 class there were usually more than a dozen perfect scores for each test and the final letter grades for the course were mostly A's and B's with very few C's and D's. C) Keen sensitivity and requisite responsiveness to students' individual situations. One could not avoid the recognition of the impending impact on students that Dr. G's caring attitude exerted. Throughout the entire semester during his courses, he often reminded students in these words, "Always come and see me with whatever problem you encounter whether chemistry related or otherwise." In similar manner, Dr. G was always more than willing to entertain students' ideas and their other topics of interests, and quite often would mention them to some extent in class. It was common to hear him say to students, "Stop me anytime you are in doubt about anything".

Usually on any day after a class session, students crowded around his desk where a variety of issues were discussed with them as long as they were willing to continue. Students' needs always appeared paramount to him. In light of this, it is noteworthy to mention that in Chem 4571, which had about 60 students enrolled, he announced to the class at the beginning of the semester
that due to financial constraints, he was unable to print enough copies of class materials for all members of the group and it would become the responsibility of each group to make copies for all the group members. Soon however, he changed his policy when students voiced concerns about inconveniences and financial burden to them and announced, "From now on I will make more than enough copies of class materials available to each student." Such was the modus operandi for him throughout the semester as he constantly adjusted and revised things in order to cope with the requests of the class. On the very first day of this 4571 class he discouraged the students from purchasing the prescribed textbook for the course which he described as "this is a very bulky and expensive text too packed with lots of information and costing $55.00 which you as struggling students do not need to purchase unless you want it as a graduate reference book for inorganic chemistry; and yet still I will make two copies available on reserve in the chemistry library, which makes purchasing it completely unnecessary.". In the 1202 class, the copies of the notes were made available to the students at a modest price of only $10.00. This class had enrolled in it more than 200 students, and though he could not make copies of notes available for all of them, he still discouraged them from purchasing the textbook, which cost more than $40.00.
Such concern was reflective in Dr. G's instructional styles, his use of multiple sources of assessments and in almost all that he did relating to students and the broader, academic environments. Many of these have already been identified earlier. Nurturing and caring definitely cannot be overemphasized in any teaching/learning situations because students are human beings just like anybody else and they too have individual needs both in and outside of the classroom which should not be overlooked.

D) The use of history and philosophy of science. A major feature of Dr. G's work involved the abundance of references to the human effort and endeavors in chemistry as well as the present human experiences in chemistry, including those of himself and other adjacent and accessible chemists. Also, society's impact and contributions in chemistry and an overall insightful interjection of history and philosophy of chemistry throughout his teaching were outstanding. Good (1991), Matthews (1994), Wandersee (1990,1992), and others have called for the increased use of history and philosophy of science in science classrooms at all levels to enhance science content teaching/learning. This was skillfully displayed in Dr. G's classroom. Every class day, there were multiple references to the human agent and factors/efforts underlying specific chemical reactions
and other discoveries and concepts in chemistry. In fact the research work of local chemists was interwoven a whole lot into many of the Chem 4571 course topics. In a discussion about ferrocene, a very important compound used in industry, the names of fellow chemists and other research team members here at LSU were disclosed and their successes at working and synthesizing the ferrocene complexes were highlighted and appraised.

In other discussions about carbene, Fisher’s efforts in Germany working with carbene which eventually earned him the Nobel prize was highlighted in the discourse. In yet another classroom session, he elaborated on the differences between the German and American chemists in their naming of chemical compounds/complexes. A particularly interesting class session involved the topic of hydroformylation catalysis when a discussion concerning the efforts of Germany during World War II ensued. The following excerpts of field notes are appropriately informative:

The Germans had no oil, but they had plenty of coal and they needed oil to produce gasoline so as to run their war and war machines at the time. As a consequence, they perfected a method to produce gasoline and kerosene from coal by running hydrogen over coal in reaction chambers H₂+CO—>(CH₂)ₓ + H₂O. As such without importing oil from anywhere else, the Germans were successfully able to maintain and execute the war for many years—this is one example of a case where chemistry can be used in a negative way against people.

The entire class was somewhat spellbound with this little
historical vignette. One could visibly notice the glare in the students' eyes as well as the elation and excitement on their faces.

Dr. G was just loaded with many such interesting stories which he readily presented to the students. In a session on the topic of "banana bonds" which was linked to the work of Linus Pauling, one of the great American chemists of our century, Dr. G remarked "I know Linus Pauling personally and have met and talked with him at many conferences". In further discourse on the topic of ferrocene, Dr. G intimated to the class that "Wilkingson had originally discovered the same compound while in England but he later moved to France where I (Dr. G) had the opportunity to work with him in France when I was a post-doc... It was Wilkingson in France and Fischer in Germany who together won the Nobel prize for chemistry in 1972 for their work with ferrocene compound and complexes." In yet still other references to the human efforts in chemistry, once the rhenium-rhenium bond was the focus of a class session when it was revealed to the class that "It was the Russians who had originally discovered the bond but my major professor in graduate school, Professor Cotton worked further with it and is this year publishing his 1000th paper in inorganic chemistry". Comments, stories, and anecdotes such as these dramatically increased the attention level and
engagement of the students. Concerning this same topic of the rhenium-rhenium complexes, Dr. G further explained the works of a fellow chemist at Tulane University who had just recently presented an interesting paper at the meeting of the American Chemical Society. Although these stories were told mainly in the Chem 4571 class, most of them were also told in the Chem 1202 class with fewer details, of course.

E) The integration of lecturing, demonstrations, modeling, and other mind-capturing activities. The BSCS (1993) and other documents have called for the use of a variety of teaching strategies in order to accommodate the many students' learning styles and provide opportunities to help different students construct their understanding. These documents further stress the need for instructors to move beyond the lecture format only with the addition of laboratory demonstration and other investigative experiences. Dr. G utilized all of these in his classrooms and demonstrations were incorporated daily in classroom interactions. When one of his graduate students (assistants) substituted for him on one of those days that he had to be out of town for a professional meeting, the Chem 4571 class lasted for only about one hour, and then the students were dismissed. When an inquiry was made to the graduate student Mr. T concerning the early dismissal, Mr. T remarked "Dr. G has lots of
fill-ins from real-life and other demos which I am unable to provide; but I have covered the main areas of the notes that he expected me to finish. Dr. G's use of demonstrations and other techniques was so common that class time was always fully occupied.

On one occasion when there was a graduate seminar in the chemistry department on metal carbenes, which coincided very well with the same topic focused on during a class session at the time, the entire class was encouraged to attend the seminar. Furthermore, for the last one third of the Chem 4571 class sessions from April 5 to May 5, the topic was catalytic reactions, both homogeneous and heterogeneous catalysis. Lots of molecular modeling was shown to the class during this period as there was also considerable emphasis on the current uses of these processes in industries for the production of specific products and by-products for human consumption and other services. In another instance in the Chem 1202 class, he invoked a discussion about just how nutra-sweet, being about 200 times sweeter than ordinary sugar, was produced and other ideas relating to the difference in the taste of diet Coke and regular Coke. This scenario was so lively with the bulk of the input coming from the students in the form of questions, other pertinent examples, and responses. During such times, there evolved lots of interest among the students.
Dr. G just seemed to have an immense reservoir of examples and stories that he could easily draw upon to highlight the topics in class. One day when again discussing the topic of hydroformylation, many practical examples and very interesting information and stories were told to the class. In one such instance he revealed to the Chem 1202 students, "Exxon built the first hydroformylation plant here in Baton Rouge in 1947, which was the first such plant ever built in the USA and the world as a whole". He further discussed very briefly current research papers treating the subject matter.

Throughout class periods each day, he never just lectured. He lectured, used the overhead projector, wrote on the chalkboard, asked group questions, entertained feedback and other comments from students. All these were integrated continuously throughout the classroom sessions. He openly informed students, "The overhead projector is only an outline, but I am stressing thinking skills, so listen and concentrate without trying to scribble everything down." Lots of color graphics were used in his transparencies and he usually brought some molecular models to use in class. All this is quite congruent with the findings of Clermont et al. (1994) that experienced chemical demonstrators have high pedagogical content knowledge and an extensive reservoir of knowledge and other reasoning and teaching skills to
maximize the student learning of abstract and difficult chemistry concepts. Dr. G always reminded students "I do not bind students to textbook information due to the changing nature of chemistry; and so I do give lots of practical chemistry examples that come to my mind." (See Appendix H). Indeed Dr. G's combination of varied instructional formats as viable and routine classroom options day-to-day distinguished him as a college chemistry professor who did not see the teaching/learning as centered primarily around him. Instead, the students were drawn more into the process, and he manipulated the learning environment in multiple ways to facilitate meaningful learning in chemistry.

F) Personal qualities such as joviality, conviviality and congeniality, frankness, and so on. There were many suitable characteristics and qualities portrayed by Dr. G which were contributory factors to his success in the academic environment. Even though many of these have already been alluded to in earlier pages, it is still deemed necessary to reiterate and elaborate some of them at this juncture. His openness, frankness, distinctly audible voice, vigorous and constant bodily movements and gesticulation in class coupled with his ever present energetics and overall enthusiasm for research in chemistry and chemistry teaching as a profession, all profoundly impacted his interactions with students and
others. As Hewitt and Seymour (1991) reported, the personal traits of professors were considered a major factor by college students in their efforts to learn science. Moreover, since many scientists and science professors have been portrayed in textbooks and other media as being weird, uninteresting, unsociable and forever working nerds, it is noteworthy and quite exciting for students to encounter a real-life scientist whose personality is non-reflective of these negative stereotypes and assertions attributed to scientists.

Dr. G possessed the complete embodiment of all the positive imaging needed in chemistry and science. It was recounted in fieldnotes that Dr. G never stood in any one spot while in class, but he constantly moved around the room and spoke in a very audible voice. More than once he informed students "I am quite willing to entertain your ideas and topics of interests; and so don't hesitate to bring them up whether in class or outside of class". Moreover, Dr. G exhibited enthusiasm for chemistry in many ways. In one instance, during the Mardi Gras weekend, he told the students "I am going to be working in my laboratory all throughout the holiday except for Sunday and so any student who needs help for anything, please feel free to stop by". This was told to students to let them know that although during the regular school time he spent much time with the teaching and students,
he still valued research and had to always find time to do his own research work.

Dr. G was just so informal and willing to chat just about anytime. Usually when there were hand-outs to be distributed, he personally hand delivered them to late comers and other students who were absent from class once they entered class. Even when students forgot to pick-up or failed to obtain certain class materials, he reminded them to recover the class materials. All these actions were geared towards helping the students in whatever way he could. He was frank and always open to students. Concerning the tests for his classes, he often told students, "I do not ask tricky questions on exams, no formula memorizing, no trivial question; only the key concepts that are emphasized and stressed in class and on previous homework and exams as the homework and exams now are closely related to the previous ones from former classes which you have."

Still in regard to homework and tests, it was noted that after grading every homework item and exam, Dr. G commended the class about their strengths; and he also pinpointed their weaknesses. He then thoroughly addressed these faults until convinced that the class was ready to move on to other topics. Once after a test in the Chem 1202 class, Dr. G said, "I am very pleased with the exam because the class did very well averaging about
82, a B with a bunch of people making A." All these traits were combined with a remarkable sense of humor which was usually relaxing to everyone. In regard to his sense of humor, one day he commented to the students in the 1202 class, "I am the shortest in the department but perhaps the loudest". At another time in the Chem 4571 class, in reference to the accuracy of a concept proposed by Dick Schrock, a chemist at MIT (Massachusetts Institute of Technology) with which he (Dr. G) was not too comfortable, he remarked "Dick Schrock is at MIT and I am here at LSU, so I guess we may just have to accept his view". Comments like these evoked spontaneous laughter among students which was necessary at certain moments to divert the seriousness of class engagement in chemistry content.

Just by being around Dr. G, one noticed chemistry being alive and not a dull and abstract science as has been widely depicted. The very amiable personal traits of Dr. G registered a kind of indelible imprint on the minds of students and everyone coming in contact with him. Students don't want to feel downgraded and isolated by professors/teachers in classroom situations as is often the case in college chemistry classrooms.

G) Obsession with the application of chemical concepts to the everyday lives of students. All the classroom interactions of Dr. G were packed with the practical
aspects of chemistry as have been already highlighted. One was overwhelmed by the exuberance of real-life incidences that were so skillfully interwoven into his courses (See Appendices H and I). One day in the 4571 class when the topic of the medication I-bu-propylene was drawn into the limelight, useful information about the R and S forms of this compound was provided, with students being sensitized to the fact that the R-form of this compound is extremely liver damaging while the S-form is the useful medication so common nowadays. The students were then provided a bit more detail when Dr. G remarked, "Through the research of chemists, pharmaceutical companies have now perfected a mechanism to yield 90% of the useful S-form even though the normal reaction process favors a higher yield of the poisonous R-form." As a consequence of such interesting disclosure in class, a very lively and highly engaging exchange of ideas ensued in class.

It was indeed instances such as these that permitted the students to become a part of the contents being studied and to situate themselves right at the heart of the contents. This obsession with practicality registered as being crucially significant for many students. Mr. B disclosed, "Every day in class I am looking forward to more such graphic examples from real-life situations". Similar comments were often made by
various students from both the Chem 4571 and Chem 1202 classes throughout the semester. By making explicit references to everyday practical situations, students were encouraged to take more personal responsibility for making sense of the chemistry concepts. This is in consonance with the notions advanced by Basili and Sanford (1991) that teachers must emphatically communicate to students that science should make sense; and provide to students the opportunity to see science concepts as being capable of solving real-life problems, thereby illustrating its utility and bridging the apparent gap between "school" and "real" knowledge. Dr. G certainly achieved this through his inclusion of pragmatic scenarios in a dynamic fashion.

All this was expertly intertwined into the overall instructional strategies and interactions by Dr. G in order to establish and manage a good teaching/learning environment for chemistry in college. In such an environment, students and teachers became active co-partners striving to achieve excellence in chemistry education.

Prior Experiences and Incidences Influencing Current Practice

How and why did Dr. G become concerned and interested in the works and ideas of science education scholars and other scholars such as Sheila Tobias who are preoccupied with science educational issues.
In reference to this question, certain preliminary insights from Dr. G's life profile must be articulated. Dr. G revealed that immediately upon completing his doctoral degree in chemistry in 1979, he obtained an over-seas appointment in France where he worked for two years from 1979-1981 as a postdoctoral fellow. He cherished this experience and opportunity, saying, "While in France, I really acquired an international outlook on education." It seemed that such an international outlook and perspective allowed him to realize first-hand how well other countries' students, especially European students, were succeeding and performing in science even though he never verbalized it as such. However, he usually presented an overhead transparency to the high school teachers that he worked with and to this freshman class showing the dismal comparison of scores for USA students in math and science with those of students in other top industrialized countries of the world.

There were yet still other significant scenarios from Dr. G's personal life as a student in college that became contributory factors in his later quest for excellence in chemistry teaching. As an undergraduate he said, "I did lousy on exams because I was a slow thinker and graduated in the lower half of the class... I always liked to take time off to reason out things for myself and as such never regarded exams as an accurate
measurement of my abilities." Even though such incidences had major impact on him, when Dr. G began teaching, he remembered that he was just like other regular college chemistry professors. He covered abstract contents very fast in lectures with a heavy reliance on prescribed textbooks and used in-class exams as the primary medium for student assessment. However, Dr. G remarked that he later began feeling that he just had to do something different because, as he put it, "Students were never getting it and were failing all the time, and also the students were complaining about not doing well. . and so even though I started out teaching very fast, I began reflecting on my own life as a student and tried to change in order to accommodate the students' needs more and more."

Moreover, the decade of the eighties experienced renewed and invigorated efforts from the National Science Foundation and many other sectors in America for improved science education and this coincided very well with the beginning of Dr. G's teaching career as a university professor. All the popular newspapers, magazines and television stations were frequently highlighting numerous stories, articles, commentaries and documentaries depicting the dismal state of science education in the USA while simultaneously clamoring for positive actions. Being a very prolific reader, Dr G noticed and became
attuned to all the public outcry being directed at his profession that he cherished. Concerning this, he disclosed, "When I read and came across pertinent things, I began photocopying and clipping away things for my own file...and since I read Sheila Tobias' work my main concern now is making chemistry relevant to students."

It must be mentioned that during a visit with Dr. G one day in his office, he displayed an entire cabinet stacked with numerous articles and other printed materials which he had carefully copied, preserved, and arranged systematically so as to permit easy access. In fact, he was willing to share his materials and loan some of them; as a consequence, such a gesture eventually permitted some of the materials to become invaluable components of this report. A specific case involved a discussion with him concerning a certain article in science education during which time my desire to eventually look-up and photocopy the article became obvious; and then he suddenly remembered, "I have it in my office; so come right along with me and I will make a copy of it for you."

Indeed, it was surprising to learn that such a renowned and very busy chemist possessed so many reading materials on science education. He later remarked in responding to a question about how is it that he had acquired so much stuff in education, "I just copy things
as I see them when reading; and store them because I know that they relate to my profession as chemist and a college chemistry professor". It was even more impressive to note that despite the fact that Dr. G's office is inundated with a tremendous volume of reading materials, he knew exactly where to access the science educational papers upon request.

So then, from the above information and other data provided thus far, it is evident that incidences from Dr. G's life experiences as an undergraduate and as a postdoctoral fellow in France, coupled with keen sensitivity to his students' outcry and their poor academic performance provided the signals and wake-up calls for Dr. G's interest in the science educational arena. He has now convinced himself that chemistry is understandable to students and has real implications for their everyday life which can be vividly presented in the classroom. As a consequence, Dr. G does everything possible to make chemistry interesting to students.

**Factors Promoting Instructional Innovations**

How and why did Professor G become willing to tryout new ideas from science educational researchers/reformers in his college chemistry classes?

For about five years now Dr. G has been initiating new ideas in his 1202 freshman chemistry class, his 4571 upper level undergraduate and graduate organometallic
chemistry course, his other courses, and his weekly
seminar-like interaction with his graduate students and
postdocs coupled with his interactions with area high
school chemistry teachers. It appears that the single
most compelling impetus of such initiatives has been
attributed to the outpouring of so much positive feedback
from teachers, parents, students and some of his other
departmental colleagues. In his teaching and
interactions with students, Dr. G strived to foster a
positive atmosphere of warmth, openness, and
encouragement while simultaneously stimulating a sense of
wonder and curiosity in students through learning
activities loaded with exciting and relevant tasks. As a
result of such innovations in his classrooms, and
recognizing the positive feedback from students, Dr. G
was requested at least twice to present a seminar to the
faculty and graduate students of the entire chemistry and
biochemistry departments. During one of the seminars
which I attended, Dr. G presented some noteworthy
comments from some of the students of the 1202 class when
he originally introduced the new techniques. The
following constitute some excerpts of such comments which
are deemed relevant to Dr. G's insistence in trying out
new ideas in the classroom.
A. "I have hated chemistry in the past. 1201 chemistry was a burden and I felt that I learned nothing. However, Dr. G made chemistry interesting and now I feel differently about the subject."

B. "This is the first time that I've taken a chemistry course at LSU that I've completely understood. The graded homework is a wonderful idea and it insures complete understanding of the course. The notes enabled me to listen to the lecture instead of scrambling to copy notes".

C. "I hated chemistry with a passion and I scraped by with a C in 1201. However I have a very good chance of getting an A in Dr. G's class because he goes out of his way to find examples that the average student can understand. The study guides and his overheads help so much. He is very concerned about his students learning concepts and not just spitting out numbers we've had to memorize. He is always available to talk to and help the students, and he treats them fairly and doesn't talk down to them. He also has 2-3 study sessions at night before every test. This was also very helpful."

Similar comments were heard from students in all his classes observed.

Indeed with such comments and positive feedback, it is no wonder that Dr. G gathered enough courage to continue the innovations. Similar remarks were still filtering in to Dr. G during the period of this study, and he noted, "Recently another student remarked that when he took chem 1201 it was really all about how well he could use his calculator."

In addition to such direct feedback from students, the input from nonstudents and the general academic community had been quite fantastic. Parents, relative and friends of students who had courses with Dr. G usually met him and reported about the enthusiasm with
which the students discussed his courses. He once remarked, "Mothers and fathers sometimes meet me in public and openly express their appreciation to me for how much enthusiasm in chemistry I seem to have inspired in their sons and daughters."

The steady increase in the enrollment in Chem 4571 was itself another dynamic indicator of the effectiveness of the measures instituted by Dr. G in his teaching, which he saw as a motivation. The class had grown from a mere 10-15 students in recent years to nearly sixty students at the time of this study. All this is quite delightful to Dr. G and he cheerfully commented, "Six, sixty, or six hundred, it does not matter to me because I still spend more time with my courses anyway; and it will only mean more time and more work grading tests, homework and the groups all of which I don't mind at all." All these developments were encouraging Dr. G to continue the novel ideas in his classes. Also, the fact that area high school chemistry teachers keep coming back year after year, usually using up their own time on Saturday for learning activities with Dr. G is also another factor impelling him to maintain such a trend. In reference to his work with the high school teachers, he once said, "I've been working with the high school teachers for three years and they seem to like what we are doing." Recognition and acceptance of his teaching
initiatives by other highly placed groups appeared to be another incentive for Dr. G’s efforts to implement novel ideas in the classroom. Besides his teaching awards, the delegation of such major responsibility as Chairman of the College Chemistry Curriculum Reform Committee by the Louisiana Academy of Science and its other affiliated organizations was a further testament of the high esteem accorded to the efforts of Dr. G from the local community and the general academic environment. (See Appendix B). With mounting support from such a broad spectrum and the realization of fruitful outcomes, he just couldn’t relent in his quest for excellence in chemistry teaching/learning.

Collaboration and Communication with Others

How and why is Dr. G sharing his ideas about teaching practices with other colleagues?

There has been so much criticism today directed toward college science professors, especially chemistry and physics professors. It has been found that the physical sciences are most especially not attractive to students any more, and this seems particularly true of chemistry, which is a central science serving as a "gatekeeper" to other scientific and engineering careers (Navarra et al., 1992). It has also been reported by the BSCS (1993) that many students take their last formal science course in college and that there is an increasing
enrollment in college science classrooms of women and nontraditional students such as Asians, African-Americans, Hispanics, and other historically underrepresented people in science. The BSCS(1993) has further noted that many teachers/professors are not keen on pedagogical approaches addressing the cultural alienation to science as well as the other specific needs of nontraditional students. In fact, Dr. G had emphasized that "98% of students taking freshman chemistry courses at LSU are not chemistry majors and as such professors need to cut back on pointless details" However, this seemed not to be the case as one of his graduate assistants, Mr. T, had observed, "So far maybe only 50% or less of the faculty in the department are like Dr. G or are trying out some of the ideas of Dr. G."

In efforts at exposing other faculty members to such innovation, Dr. G had willingly provided his complete set of Chem 1202 notes and teaching package to a few other colleagues in the department and some of them had quite a bit of success using them even though there still existed some problems. As he observed, "Women faculty members especially have problems with freshman students yacking but at the upper level they do fine." Dr. G felt that the lack of discipline of a few students, especially their unruly and intermittently distracting conversation with each other during class time, was a problem. He was
personally usually able to overcome this due to his agility as he constantly moved around the class throughout the class session and spoke with a loud and commanding voice. All this, he felt, was usually difficult for some to do in a large lecture room with 200 or more students. In other words, it must be said that he seemed to possess some classroom management skills which are not easily transferrable to all other professors, but yet can be acquired if some concerted efforts are exerted. Thus he still was willing to work with colleagues who wanted to improve their overall instructional strategies.

Another concrete effort of Dr. G in this regard involved the presentation of seminars to the department. Even though this has been alluded to already, other excerpts from the seminar become quite relevant at this juncture. In the following excerpts, he instructed his colleagues in some of the precise measures needed to be initiated.

- Graded homework worth 50% of grade
- Bonus homework and only 3 hourly exams instead of the usual 4 hourly exams
- Hybrid of multiple choice/essay exams
- No Scantron exams; only 10 questions per exam
- Complete set of answer handed out promptly for all homework and exams
- Provide a story line so that the students can know where we have been going and how it all fits together
- Relate key concepts to everyday life
- Use homework and exams to reinforce key concepts
- Do demonstration and integrate them closely into the concept you are trying to teach and drive
The issues outlined above are deemed fundamental in view of the fact they appeared to form the core of Dr. G's attempts at improving college chemistry teaching. In numerous interviews and conversations with students, they repeatedly referred to the lack of such incidences in their other science classrooms contributing to the difficulties they experienced in chemistry and other science courses.

The following comments from students highlighted their previous plight in other chemistry courses taken:

Mr. T: "When I took this same course two years ago with Dr. G, it was so interesting and not cut and dried as other professors here make their courses"  
Mrs. M: "I have had about five courses here so far in the department and those courses have been quite difficult for me; but this is the first test I have taken here so far that I didn't have to study (memorize) so hard because since I had carefully worked all the homework problems, I just went over them again. In fact the test was surely based on the homework and previous tests he gave us, and three of the questions came directly from one of the tests from three years ago that he distributed to the class... one of Dr. G's postdocs from China who helped to grade the test thinks that Dr. G is too easy because he gave points for every little thing that students do. But I disagree with the postdoc because I think it's okay for him (Dr. G) to be that way and do such things"  
Mr. B: "I regard the test as being very fair. Many of the questions reflect the homework and previous tests we had access to. Some of the questions were reworded questions from the previous tests of years back but overall I am satisfied with the course so far".  
Mr. E: "I am happy with the test. My score was very high especially so not being an aspiring
chemistry major... I never even knew that I could do so well".

These remarks from students who were taking or had previously taken courses with Dr. G made it somewhat important that other professors acquaint themselves with these innovative ideas. He had certainly exerted much effort to involve his departmental colleagues in the reform movement as the data provided indicate. Indeed it is quite commendable that his toil has not been fruitless as some of the faculty in the department are joining the bandwagon for excellence in chemistry teaching/learning. Dr. G revealed recently, "Most of the professors teaching the various sections of Chem 1202 are talking to each other more so nowadays about ways to improve the teaching of the course." As a consequence of such conversation, a kind of breakfast meeting between professors and their students taking the course was initiated in the fall of 1994. Thus, in the fall of 1994 Dr. G held on a routine basis a breakfast meeting at a designated place (local pastry shop) with a group of three or four students at a time on each classday morning around 7:30. This was intended to help the students and professors to get to know each other better and to feel comfortable around each other. It was also intended to impress upon students their human value to the class. Thus they were only encouraged to attend and not coerced in any way nor penalized at all for being absent from the meeting. From
further information gathered, the breakfast meeting did progress well, with the students chosen usually showing up for breakfast. Surely without communication and collaboration among some of the professors, such a seemingly positive gesture could not have been accomplished. Concerning this idea, Dr. G commented, "I'm always open to other people's ideas as I also tell them mine."

Concern and Efforts at Precollege and College Chemistry Teaching and Learning

How and why is Professor G concerned with chemistry teaching and learning in general?

From the literature that has appeared in recent years, some of which has been highlighted and specified in the literature review section of this report, the grade sheets of American students in science have not been rosy, especially regarding chemistry. For Louisiana in particular, the situation is even gloomier with students ranking among the lowest in the United States in chemistry achievement scores and among graduates as chemistry majors. Dr. G informed me that in previous years, there have usually been only about 30 chemistry undergraduate majors at LSU, although there is a slight increase right now. Moreover, it has been stated by Dr. G that the economy in Louisiana is heavily dependent on the chemical industries. Concerning this Dr. G disclosed, "There are 270 chemical plants in Louisiana and this is
in fact 25 percent of all chemical plants in the USA."
He further disclosed, "These chemical plants employ about
75,000 people directly with an additional 350,000 jobs
indirectly linked to these chemical plants." This is
indeed an enormous dependency of Louisiana's economy on
chemistry and chemical industries. As such, Dr. G was
convinced that people at all levels in Louisiana need to
know and be familiar with some chemical concepts because,
as he put it, "It is more likely that students in
Louisiana may be employed in a job in the future that is
somehow chemistry related or dependent whether or not
they are chemistry majors."

With such a view in mind, it was no surprise that
Dr. G had been working with area high school chemistry
teachers for over several years. His work with the area
teachers was especially useful since many of the
chemistry teachers reported that they were actually
teaching outside of their specialty areas due to the high
attrition rate of science teachers. Thus, in his
sessions with area teachers, he tried to bring chemistry
alive to the teachers by introducing them to numerous
simple demonstrations that the teachers can use in their
classrooms to captivate students' attention and sensitize
them to real-life and everyday situations involving
chemistry. The following excerpts of fieldnotes are
illustrative of this:
In his discussion of solution chemistry with the teachers, he informed them that they could simply find two pennies, one made before 1982 and another made after 1982. Then each of the two pennies were dropped in separate beakers containing concentrated HCL. In the beaker containing the penny before 1982, the reaction was very vigorous with the sudden dissolution of the penny producing a deep-blue solution while in the other beaker everything was very mild eventually producing a light-blue solution. Thereafter a very interestingly brainstorming discussion ensued pertaining to the differences involved here and some of the historical factors responsible for the reduction in the amount of copper in the pennies being made beginning in 1983. The teachers were then encouraged to repeat the same and similar activities with their students.

As this excerpt indicates, this is one way that Dr. G was concerned with chemistry teaching and learning in general as he worked with area teachers. An integral constituent of his sessions with teachers involved them visiting the computer room of the chemistry department where they encountered first-hand the most advanced state-of-the-art computer graphics in chemistry. There they were shown how to create different sizes and shapes of bonds, bond angles, bond lengths, molecules, and compounds after which they were allowed to work with the computer graphics for a while. This was a new and very exciting experience for the teachers. In later conversation with Dr. G he noted, "Seeing is believing and as such they will believe that chemistry actually works and they will be able to take back such information to their students who may become excited too about
chemistry". The session with the teachers ended with a visit to the newly constructed multimillion dollar facilities at the Center for Advanced Microstructure Devices (CAM-D), operated by LSU on the outskirts of Baton Rouge. This facility houses some of the most modern apparatus for scientific research and as such the teachers were able to see the real-world working environment of scientists. They all became enthusiastic and it was hoped that they would be able to impart such enthusiasm and related habits of mind to their students.

It is necessary to mention that during the session, snacks, coffee and other items for refreshment were provided, including a lunch. It appeared that the pecuniary rewards were of minimal concern to Dr. G when working with these teachers, and in regards to this he stated, "They're supposed to eventually remit some money to me through a grant to defray some of the expenses incurred but whether they do or not, I just don't care because I just want to help these teachers who need the help so badly". For the session with the area teachers, it is also noteworthy to mention that the chemicals used were from his personal laboratory and he was assisted by one of his graduate assistants, Miss C.

In his continuing efforts at chemistry learning/teaching in general, Dr. G maintained open office hours throughout the school year and usually
worked on weekends and holidays. Despite his very busy schedule, during the period of this study his untiring commitment to the College Chemistry Curriculum Reform Committee was an indication of his concern for chemistry teaching and learning in general. He devoted much of his personal resources and time to such activities and yet he was able to engage himself in authentic research activities in chemistry. One of his graduate students, Mr. T remarked, "We still get good grants from NSF and industries from the Texas and Baton Rouge areas." It appeared that a dedicated and competent corp of graduate students and post docs, some of whom were paid directly from funds obtained from industries that Dr. G had been doing research for, played a pivotal role and were crucial in all these activities. He once noted, "My group is a good group and they work very hard". One of his graduate students Miss C commented "He works us very hard when there are exams, homework, and other things to be graded as well as when he has other things to do; but we don't mind because he always shows concern for us in other important ways too." In fact during the conference on "College Science Teaching", Miss C. was with him throughout the conference videotaping and doing other necessary chores which he periodically assigned to her. His graduate students and other group members were indeed energetic and did seem to work very hard along with him.
during all his activities. All in all, Dr. G was concerned with chemistry learning and teaching generally and the data presented validate the manner in which he exhibited such concern, especially here in Louisiana. **Beliefs and Philosophy Regarding Chemistry**

Why and how is Dr. G interested in students knowing/learning chemistry?

This question essentially relates to the philosophy and beliefs of Dr. G concerning chemistry. He is convinced that chemistry is a central science and that chemistry is interesting, understandable, and has lots of real-life implications/applications. In documents obtained, the following figures used in his introductory comments during his sessions with the area teachers as well as on the first day of his 1202 class session illustrated this view.
Figure 1
Chemistry shown as a central science and linked to other sciences.
Figure 2
Core branches of chemistry linked to other engineering and scientific professions.
The above two graphic representations were self-explanatory and encapsulated the core of Dr. G's ideas pertaining to the paramount significance of students knowing and liking chemistry. Not to belabor the issues, but one easily recognizes from the figures that all the major sciences and their related engineering professions are directly linked to chemistry. As such, Dr. G visualized chemistry as being extremely interesting and relating to all aspects of human life in this modern world which is so dominated by the impact of science and technology. He succinctly summed up all of it in the following assertions:

Chemistry is fun and has real-life implications and applications everyday for all students and people today. So, there are certain basic chemistry concepts that are necessary facts which all informed citizens must be aware of, and all students need to know how chemistry impacts their lives. They need to be able to make informed decision based upon the understanding of certain key principles and concepts in chemistry. I believe that every student can learn some chemistry and it is my role and responsibility to facilitate their learning as much as possible because basic chemistry knowledge is important for all students.

Indeed these words revealed Dr. G's innermost thoughts and emotions about chemistry. He further emphasized another time to students in one of his class sessions, "Everyday in this class, I will provide many real-life examples of why the things we are teaching in this course are important to daily living in the modern world." (See Appendix H)
Wholeheartedly embracing such a holistic and central belief regarding chemistry knowledge, Dr. G indulged in numerous classroom activities intended to engender and foster in students knowledge of and appreciation for chemistry. Such goals seemed to be remarkably accomplished through diverse endeavors. For instance, he usually presented to the students on slides the pictures of many chemical refineries right here in Baton Rouge and other parts of Louisiana. Other slides with the pictures of bottles (both plastic and glass), clothing, cans, and so on, including various other common household and everyday items were presented to students. Usually mind-captivating highlights were a routine composite of slide presentations. In one such discussion relating to superconductors, students were informed that "25% of electricity produced is lost in the present wiring system due to the high resistances in the wires; but with the chemist now discovery of and later the establishment of the commercialization of the high temperature super conductor using liquid nitrogen at 77°K having essentially no resistances, electricity losses will be minimal." As this discourse progressed, the entire class became totally engulfed in a lively feedback and interaction.

There were also other such verbal exchanges deemed necessary for inclusion here. On one occasion, students
were alerted to the fact that "NMR (Nuclear Magnetic Resonance) developed in chemistry; but is now being more pervasively used in medicine as MRI (Magnetic Resonance Imaging) for the very early detection of cancer in people." It was later pointed out to students the significance of just how such a tool developed in chemistry had now been responsible for saving the lives of millions of Americans. From the classroom interactions, the students appeared to appreciate this discussion very much because with cancer being so rampant, its early detection is crucial in determining the probability for life or death of a cancer patient. The development of the so-called "miracle drug" ampicillin was also the focus of another such discourse. Also, at another juncture, the drug AZT, which is the only one presently believed to have some positive attenuating effect on AIDS patients, became the focus. Dr. G told students, "AZT, which is actually a 3-azo-3 deoxythymidine, had been a compound developed by chemists." The students were then provided more details concerning the chemistry of this medication. As expected, they all became quite interested in this topic because AIDS is another major killer disease, especially among young people, without a definite cure presently and perhaps not in the foreseeable future. Such topics
certainly evoked hearty interactions in the classroom, rekindling students' enthusiasm for chemistry learning.

In his continuing efforts with students regarding chemistry, Dr. G told students in class, "Everyone can get an A because you don't have to follow the textbook blindly; and I will always describe the scientific definitions in terms of the simplest physical analogy that one can relate to." A vivid case quite pertinent here involved the topic of positrons. Dr. G made explicit the notion that "Positrons are actually anti-matter that had been discovered by physical chemists and this gave rise to the development of PET (Positron Emission Tomography)." He further explained "this technique of analysis is essential in numerous branches of science nowadays." Students became just so baffled and overwhelmed about this whole notion of anti-matter which appeared somewhat controversial and inconceivable to them at first.

All the endeavors of Dr. G seemed to be consistent with his beliefs that chemistry is the central science and related to things around human beings daily in this modern world. He reiterated to students in no uncertain terms, "Students, you need to learn the fundamentals in chemistry in order for you to understand the practical things in life relating to chemistry." In a nutshell, it can be asserted that Dr. G has been portrayed as being
interested in students learning and liking chemistry, and as a consequence he surely engaged in a series of carefully designed strategies, orchestrated and tailored to intentionally and successfully nurture students' chemistry knowledge.
CHAPTER 5
CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

Conclusions

Science education scholars and the accompanying related literature coupled with other relevant documents have all identified certain characteristics and features of a good science teacher/professor. In class notes provided by Wandersee (1994), these characteristics and features were summarized and depicted in a manner to include the overall broad spectrum of traits, expectations, and outcomes of science teaching. In an outlined and very flexible framework, the following headings and phrases constitute such summary and depiction:

A) Under teaching styles/approach, an excellent teacher:
1) is enthusiastic about teaching students the subject matter;
2) treats students with respect and designs curriculum to meet the needs of all students regardless of the level of instruction;
3) relates the subject matter to the students’ lives;
4) sets an example of integrity in and outside
of the classroom and teaches students responsibility and high standards;
5) plans lesson well in advance and gives adequate time for each topic and integrates subjects;
6) teaches well organized concepts in a conceptually concise fashion;
7) stresses concept learning instead of rote memorization;
8) continually reassesses approaches, lectures and tests to insure fresh and relevant curriculum.

B) Under subject expertise/teaching techniques, an excellent teacher:

1) teaches students how to learn, analyze and think critically emphasizing good scientific methodology and problem solving skills;
2) prepares lessons that will enhance problem-solving abilities of students;
3) develops hands-on activities to illustrate concepts and uses a variety of approaches to assist the learning processes: lectures, discussion, laboratories, and other demonstrations, field trips, guests speakers, students presentations, films, slide shows, hand-outs, overhead projectors, blackboard
writing and questioning;
4) keeps up-to-date in the subject matter by being somewhat a student too all the time.

C) Under teaching environment, an excellent teacher:
1) creates an exciting classroom environment/atmosphere so as to enhance learning as much as possible;
2) acquires up-to-date and the state of the art equipment/apparatus for laboratory work;
3) involves oneself in committees/organizations geared towards the improvement of their institutions, department and oneself;
4) generates new and exciting ideas and show students discrepant events so as to stimulate and foster their critical thinking abilities;
5) encourages students to ask questions about the lesson and to give other feedback and input frequently;
6) maintains a safe and clean classroom and laboratory;
7) knows the essential for administering first-aid in case of emergency or accident.

D) Under professional development, an excellent teacher:
1) continually updates and upgrades his/her
knowledge base in numerous ways such as:

a) by reading the literature (e.g. journals like the American Biology Teacher, Science News, Scientific America, Science, Journal of the American Chemical Society, The Journal of College Science Teaching, Journal of Research in Science Teaching, Science Education, etc);
b) attending conferences, conventions, workshops and seminars as well as giving presentations at such forums whenever possible;
c) visiting and collaborating with local laboratories and industrial plants/facilities as much as possible.

2) becomes active in professional organizations and encourages colleagues to join as well;

3) seeks grants, and other financial/material support to purchase equipment, for organizing and attending meetings/conferences and for other special educational projects and purposes.

Although this outline and basic framework of the traits and features of good science teachers as well as the outcomes of good science teaching pertain in some instances more to specific levels within the precollege
levels, no level is exclusively exempt here. These characteristics relate appropriately to college level science teaching in general and specifically to chemistry teaching too.

In fact, it has been reported that higher education has few appropriate offerings and models for future precollege level teachers; and that science at all levels is generally taught as a foreign language without any excitement and discovery (AAAS, 1989; Hewitt & Seymour, 1991; Tobias, 1990). The literature review section of this report has already highlighted these issues, and so it would be redundant to further explicate them at this juncture. However, as a consequence of this inquiry, there were abundant data presented as evidence to support the claim that indeed Dr. G is a good embodiment of many of the outstanding traits of a good science teacher. This case study using ethnographic methodology exposed and documented the salient activities and interactions of Dr. G with students and the general academic environment. The data that have been inscribed attest that he devised numerous ways of connecting chemistry to the students' everyday lives ranging from food ingredients, household supplies, to medical break-throughs/controversies and other current science headline news such as nuclear accidents. Students became engaged and enthusiastic in their study of chemistry, and as consequence exhibited a
high level of involvement in the class sessions as these data illustrate.

Dr. G tailored his chemistry courses to relate to students' interests spanning from environmental issues, food ingredients or medical breakthroughs/controversies. Like many other college chemistry professors, Dr. G did possess a high level of subject content knowledge and indeed this is invaluable. However, he was found to be very capable of structuring both the external and internal learning environment of the students in his chemistry classrooms so as to facilitate their chemistry learning. It is within this arena that many college science professors exhibit deficiencies and ineptitude.

Dr. G apparently had acquired a high level of insight into the learning psychology of students, and he realized that the effectiveness of any learning is largely determined by the context in which the learning of content is presented. Consequently, he strived constantly to contextualize chemistry teaching/learning as effectively as possible even though this exerted a considerable demand on his lesson planning, his selection and preparation of media, as well as his personal sense of creativity and ingenuity. However, he complied very well here with all these and showed minimal problems in his interaction in the classroom. He achieved profound impact on his students and meaningful
chemistry learning was accomplished by the students in all his chemistry classrooms studied.

It was Dr. G’s dual efficiency and expertise in both subject matter knowledge and pedagogy known collectively as pedagogical content knowledge (PCK) and coined by Shulman (1986), that became so attractive and compelling to students. The students in Dr. G’s classrooms, from their numerous comments, did appear to perceive their classroom environment in a very positive manner. They were quite keen and impressed about the extent to which they (students) participated in and showed interest in the classroom activities, and their overall involvement in the course. Also they commended the high level of support, help, friendship, and interest displayed by Dr. G towards them. Additionally, many students spoke favorably about the order and organization in the classroom relating to the smooth running of classroom activities and the cordial behavior of students in class.

In brief then, it is noteworthy to observe that Dr. G’s class sessions were usually busy occasions for both him and the students since he possessed a very thorough and comprehensive knowledge of chemistry content, including also a wide range of teaching strategies that he could use seemingly without a great deal of difficulty. His expectations of all students’ achievements were high, consistent, and firm, as he
always encouraged students to take full responsibility for their own learning. While in class, he continually monitored the activities of all the students by moving around the class and manipulating group questioning and the entire social environment so as to obtain students' feedback, and he gave bonus points to students for engaging in all these. As he encouraged students quite frequently to actively engage in all their classwork both inside and outside of the classroom, he did not hesitate to give praise to the whole class, to particular cooperative group members, and to individual students whenever warranted. Moreover, Dr. G always provided clear explanations to students by using concrete examples to illustrate abstract concepts and frequently used analogies and examples from outside the confines of the classroom in order to facilitate their learning experiences.

Dr. G recognized that the students were the focus of teaching and learning, and as such it was his responsibility not to center the teaching/learning around himself. Instead he had to draw upon the resources of all the students in the class in many ways such as by soliciting information from them, making eye contact with them, getting to know their names, and encouraging them to think critically. By so doing, he definitely performed an excellent job as a facilitator of chemistry
learning; and indeed he can be regarded as an exemplary chemistry professor in college. This inquiry brought into the limelight his unique skills and talents in such a manner so that all his activities and interactions with students and the general academic environment would be instructive for college science teaching at all levels and content areas.

In his study of two exemplary high school biology teachers, Treagust (1991) reported that the use of small group discussion and the frequent use of laboratory demonstrations, as properly related to text and other classroom situations, were very effective in the biology classroom. Other issues highlighted in this study included (a) the teachers' expectations of high level of students' academic work, (b) the teachers involving all students in class activities, (c) the teachers informing students of tasks and other work well in advance, (d) the teachers expecting students to comprehend content materials, and (e) the teachers moving around the students and cooperative groups during classroom activities.

Although this was a high school situation, my study has demonstrated that in a college classroom these same traits and attitudes of teachers/professors definitely have similar possible impacts. This is in fact new knowledge related to college chemistry teaching since all
these similar traits and characteristics from the high school biology class were found to be parallel in the college chemistry classroom. Other similarly relevant findings targeted the precollege level, but the findings of this study pinpoint that they are also valid at the college level.

Furthermore, the findings of this study portraying Dr. G as an exemplary chemistry professor are quite consonant with the ideals of science education researchers/reformers that excellence in college science teaching is a key factor to the overall revamping of science teaching at the precollege level. Moreover, it has been emphasized that there exists a serious need for cooperation between teachers at all levels and scientists in all areas, be it in universities or industry, if science education is to fully attain the nourishment required. Since Dr. G had been quite active in this regard, there is certainly much to be gained by the science education community from this research.

Limitations

The theoretical foundations of naturalistic inquiry certainly provided its strength as well as the limitations, all of which have already been extensively deliberated in the methods section of this report. Since this inquiry was a case study employing naturalistic/qualitative methodology, it is important to
emphasize that the primary goals of this kind of research are description and understanding. This work was aimed toward an interpretation of a phenomenon, not necessarily an unbiased description of the phenomenon itself. As such, since the understanding and meaning-making achieved through naturalistic methodology are of a very contextual nature, one is unable to make predictions based on this study. Moreover, one cannot generalize the outcomes of this research to different settings and subjects/populations even though it is acknowledged that human behavior has certain commonalities which one can strive to describe and interpret as accurately as possible (Bogdan & Biklen, 1992; Lincoln & Guba, 1985).

Furthermore, Dillon et al., 1994 have reported that teachers' philosophies of science and science teaching are closely tied to the instruction and learning possibilities they provide for students. Consequently, there will always be differences in instructional approaches of teachers/professors which will always be influenced by or reflective of the personality of the individual and their teaching philosophy, content knowledge, and knowledge of students and teaching/classroom interactions (Shulman, 1987, Treagust, 1991). Considering all of these, it can be asserted that even though variability of teaching styles will exist as expected for teachers covering the identical
curriculum/material, and that one can teach in characteristically different ways, this case study illustrates certain significant features of good science teaching. What emerged as a matter of importance from the data is that teachers need to sustain not only enthusiasm, but also a high level of engagement and motivation for all students. They must furthermore encourage students to take responsibility for their own learning while focusing on understanding conceptual knowledge. The issue of teachers shaping/structuring the classroom organization, lesson contents and the overall learning experience in science so as to support the students through ways whereby the students are also valued in such a classroom climate was salient, too. It has been found that the effective use of pedagogical content knowledge (PCK) is one of the characteristics of experienced science teachers which distinguishes them from their less experienced colleagues (Shulman, 1987). As such, individuals who possess the necessary chemistry content knowledge and some preparation and awareness of pedagogical issues can use this pedagogical content knowledge and reasoning skills to maximize the students' learning of abstract and difficult chemistry concepts. These individuals can then become exemplary teachers/professors who are able to frame chemistry content knowledge for successful instruction.
Implications and Future Research

Despite the limitations inherent in this study, there surely exists the need for science education to continually and carefully document the teaching practices of exemplary college professors through more such case studies like this one so as to contribute to the furthering of the understanding of just how the variables of science content, instruction, and students' characteristics, interact to produce effective pedagogical content knowledge.

Beginning college science professors and those with longer service may need a firmer grounding in just how the various science concepts, teaching strategies, students' learning styles, and classroom management patterns, all interact to produce the highest possible learning outcomes with respect to specific science topics and skills. There exists a need for studies such as this case study and for other follow-up studies which examine and expose the factors that contribute to the experienced teachers' success and the growth of their pedagogical content knowledge or the factors that may hinder the same. These studies are quite appropriate as science educators/researchers continue to build upon the noteworthy exemplary teacher studies already implemented (Brickhouse and Bodner, 1992; Tobin and Frasier, 1987; Treagust, 1991). It is also deemed quite important that
university professors and administrators together with science educators, identify, implement, and support teacher education programs that foster the professional development of teachers and of college science professors with respect to pedagogical content knowledge and establish the accompanying reward system. There are yet many unanswered questions about the development of expertise in teaching; but it is only through case studies such as this inquiry and other similar studies that researchers will continue to explore and uncover valuable evidence concerning the development of expertise in teaching.

Implied in this study is also the need to investigate in detail the dynamics involved in the cooperative grouping activities used in the college chemistry classroom in order to better understand how such group work actually operates at the college level. The urgency for a kind of communication between successful college science professors and their other less successful counterparts in teaching appears to be emphasized as well as a kind of mentorship program for beginning teachers and less successful teachers at all levels. Also, this study raises the issue pertaining to a collaborative effort whereby it becomes necessary for greater contact among science teachers at the precollege level, science educators and scientists at the college
level so that precollege education can be provided the intellectual nourishment it needs. It is this enrichment/nourishment that Hurd (1986) reported to be lacking in science educational reforms/perspectives. The need for college students in science teacher preparatory programs to visit the classrooms of exemplary college science professors who would become a kind of role model for their own teaching was also revealed here as a result of this study.

Students usually spoke very favorably about Dr. G’s straightforward and succinct note packages used for his classes. Even though this issue was not fully and specifically demonstrated and articulated in this report, concerning the issue of his note package for both the Chem 1202 and the Chem 4571 courses, this study seems to convey certain implications for curriculum development. Regarding curriculum development, this study elucidated the necessity for textbook writers at all levels to understand and anticipate the needs of the various kinds of students they are developing texts for; and the specific locale/setting the text are to be used so as to reduced the level of difficulty in text comprehension and also be skillfully selective in focusing on important concepts.

This idea is in consonance with AAAS (1989) report that science texts contain too much information and too
many topics, and continually more and more topics are added as these texts are revised and updated. AAAS (1989) further decried this because as a consequence, too little time exists to teach most of the broad and high level content in the breadth and depth expected and demanded by the topics. The (AAAS) report further emphasized that the need to reduce texts so as to teach "less" but in more detail so that "less" actually becomes "more". That study (AAAS, 1989), furthermore, seems to be calling on teachers to be descriptive and practical as much as possible whereby they will not be so abstract to make chemistry and other science content scary and uninteresting to students. Thus, good teachers/professors are challenged to develop in students scientific attitudes, high level thinking skills as well as curiosity and creativity. The data gathered through naturalistic methodology of this case study definitely explicated salient information and issues deemed crucial in any efforts at successful chemistry teaching/learning.
REFERENCES/BIBLIOGRAPHY


Sunberg, M. D., Dini, M. L., & Lee, E. (1994). Decreasing course content improves students' comprehensions and


Wandersee, J. H. (June 1989). Communicating crisply: Using graphics to represent scientific knowledge. A paper presented at a seminar in the Department of Curriculum and Instruction, Louisiana State University, Baton Rouge, LA.


Yore, L. D. (1991, Dec. 10). What research says about—Science textbooks, science reading, teachers’ attitudes and beliefs and students’ metacognition. A paper presented at the faculty-graduate students seminar in the Department of Curriculum and Instruction, Louisiana State University, Baton Rouge, LA.

APPENDIX A

PROFESSOR G: LIFE PROFILE IN EXCERPTS

Birth Place and Date: Pennsylvania; May 1953
Marital Status: Married with two children (boys)
Education: B.S. Chemistry - University of Rochester, 1975
Undergraduate Research Topic - One Dimensional Organometallic Conductors
Ph.D Chemistry - Texas A & M University, 1979
Thesis Title - Electronic Structure of Metal-Metal Triple Bonds
Postdoctoral - Universite Louis Pasteur, Strasbourg, France, 1979-1981
Research Topic - Organo Metallic Cluster Chemistry

Professional History: 1989-Present
1986-1989
1981-1986
Associate Professor of Chemistry, LSU
Assistant Professor of Chemistry, LSU
Assistant Professor of Chemistry, St. Louis, Missouri

Honors/Awards: Member of the Editorial Board, Inorganic Chemistry, 1993-1996
LSU Student Government Association Teaching Award, 1993
Monsanto Young Faculty Research Award, 1982
CNRS Postdoctoral Fellowship, 1980
NATO Postdoctoral Fellowship, 1979

Consulting: Hoechst-Celanese Corp. (1990-Present); Hydroformylation Catalysis
Ethyl Chemical Co. (1990-Present); Molecular Modeling
ARCO Chemical Co. (1990-1993); Hydroformylation Catalysis

Research Interest: Synthesis, structure and reactivity of bimetallic transition metal compounds with particular emphasis
on hydroformylation catalysis; bimetallic cooperativity in Catalysis; asymmetric hydroformylation. Synthesis of novel poly-phosphine ligand system. Molecular Modelling in transition metal catalyst design

Professional Activities: Local Co-Host (fund raiser) for NSF Organometallic Workshop, New Orleans 1993
President TRIPOS/SYBYL
Molecular Modelling User’s Group, 1992
Organized TRIPOS Users’ Group Meeting, St. Louis, Mo., May 1992
Organized Symposium on Activation of small Molecules by Polynuclear Transition Metal Complexes at the Joint Southeastern/Southwestern Regional ACS Meeting, New Orleans, La., December 1990
Member, American Chemical Society, (ACS)
Member, American Association for the Advancement of Science (AAAS)
Member, Sigma Xi

Publications: Many in the Journal of the American Chemical Society (JACS) and Inorganic Chemistry dating back to 1977

Research Team: One Postdoc, five graduate students and a couple of undergraduate students

Courses Offered/Taught: Chem 1202, Chem 4571, (these are regularly taught); Chem 4431 Chem 7770, molecular modelling (these are sparingly taught)
APPENDIX B

EXCERPTS OF SESSION HEADLINES

From the Conference on "Teaching Science at the College and University Level" held January 28-29, 1994 on the Campus of Louisiana State University, Baton Rouge, Louisiana

Friday, January 28, 1994

12:30-2:00 PM
Luncheon Meeting
Discovery Curriculum: Faculty and Curriculum Development: A New Approach to Teaching Introductory Chemistry with Implications for other Disciplines
Keynote Speaker from College of Holy Cross, Worcester, Ma.
Comments: Dr. G

2:15-3:30
Breakaway Sessions A
Scientific Disciplines: Current Practices and Future Challenges
Chemistry
Moderator from Southern University
Discussion Leader: Dr. G

3:45-5:00 PM
Plenary Session
The Reform of Science Education In Louisiana
Development of Statewide Reform of Chemistry Curricula for Universities.
Dr. G, Chairperson

Saturday, January 29, 1994

9:45-11:15 AM
Breakaway Sessions B
Chemistry Education Group - Dr. G
APPENDIX C

ELEMENTAL NOMENCLATURE OF COOPERATIVE GROUPS

Nobium 2 students (2 males)
Copper 4 students (1 male & 3 females)
Gold 2 students (1 male & 1 female)
Magnesium 2 students
Silver 4 students (2 males & 2 females, all Asians)
Technicium 1 student (male)
Tungsten 3 students (3 males)
Scandium 3 students (2 females & 1 Male)
Zirconium 2 students
Tantalum 5 students
Chromium 4 students
Nickel 5 students
Platinum 3 students
Molybdenum 4 students (1 male & 3 females)
Iron 2 students
Zinc 2 students
Palladium 2 students
Cobalt 2 students
Vanadium 2 students
Titanium 3 students

About one-third of all the students in chem 4571 were females.

Cooperative groupings for Chem 1202 were too lengthy for inclusion.
APPENDIX D

SOME INCENTIVES PROVIDED TO STUDENTS

1) The two tests with answer keys for the tests when the courses were offered in previous years were given to the students.

2) All previous homework from the last three year with answer keys were made accessible to students.

3) Copies of exams and keys for the last 2 years were made available to the students.

4) Offered help sessions twice a day: morning hours 10-12 and evening hours 5-7 on Mondays and Tuesdays before the final exam and before each hourly exam in the courses.
APPENDIX E

EXCERPTS OF CHEM 1202 SYLLABUS, FALL 1992


Optional Supplement: Full Copies of all the notes used in class. Available at Kinko

Exams, Homework, Grading: There will be 3 fifty minutes (hour) exams and a Comprehensive final exam involving 1202 students from all the sections. The hourly exams are on Wednesday of the following dates: September 23rd, October 28th and December 2nd

The grading percentages are shown below:

- 3 hourly exams: 30% (300 points)
- 1 final exam: 20% (200 points)
- 10 Group Homework: (50%) (300 Points total at 50 points each)
- Bonus Homework: (10%) (100 points)

Instructor Evaluation and Class discussion:

Homework: There will be 10 graded homework assignments for this course. Students can work in study groups of three to four people. Each student in the study group however, must turn in their own handwritten copy of the assignment. Each study groups should hand in the names of students that will be involved in the study group on August 28. Each group will be assigned the name of an element from the periodic table. I will be asking questions in class to the study group. I therefore suggest that members of the same study group try to sit near one another in class. If I ask your group a question, you will be allowed a short period of time to discuss the question and answer it.

The grading scale for homework and exams is as follows: A = 100-87% B = 86-74% C = 73-61% D = 60-50% F = below 50%

Bonus Homework: There will be at least one bonus homework assignment. It will be a 2-3 page essay on some chemistry topic and will be worth 100 points (as much as an hourly exam). I will hand out some suggested topics for the bonus homework assignment during the first 2 weeks of class. It can be handed in anytime before December 2nd.
Office Hours: I have open office hours so feel free to stop by anytime except: lunch 12-1 PM especially Fridays, after 3:30 PM and right before the lecture. I will announce other times when I know for sure I will not be around. If my office door is closed, I am not around or extremely busy. I have answering machine service 24-hours around the clock so feel free to leave a message. I am more than willing to make specific appointment time to meet with you—even on evenings and weekdays. Help Sessions: There will be 2 help sessions immediately prior to each exam (on Monday and Tuesday). I will schedule at least one help session for late afternoon/early evening, I will answer questions about the lecture material and homework problems. Additional help sessions will be scheduled if demands warrants them.

Important Dates During the Semester:
August 31 Monday - Final date for adding course for credit and making section changes
September 7 Monday - Labor Day Holiday (no classes)
11 Friday - Final Date for Dropping Course without a "W"
October 12-16 Mid-semester Examination Period
20 Tue. Mid-semester grade due
26 Mon. Registration for Spring Semester Begins
November 6 Fri. Last drop day
26-27 Thanksgiving Holiday
30 Beginning of Dead Week
December 4 Friday Last day of classes
7-13 Final Exam Period

Then a list of chapters, title of topics and the sections and pages of the textbooks to be covered was attached to this syllabus which is unnecessary to be included.
APPENDIX F

EXCERPTS OF CHEM 4571 SYLLABUS, SPRING 1994

This is an advanced undergraduate, introductory graduate level course that covers the organometallic chemistry with emphasis on basic reaction types and the natural extensions to the very relevant areas of homogeneous catalysis. An outline of the course contents is shown below with each section taking up about one third of the course.

A. Ligand Systems and Electron Counting
B. Fundamental Reactions
C. Catalytic Processes
   etc. Future Industrial Trends

Optional Text: "Principles and Applications of Organotransition Metal Chemistry by Collman, Hegadus, Norton and Finke (University Science Books) approximate cost: $52

Study Groups: The class will form study groups of 2-4 students to work together on homework problems and answer questions in class.

Grading: Two 1 and 1/2 hr. Exams  300 points
(30%)
1 final Exam  300 points
(30%)
4 homework  400 points
(40%)
class participation  100 points
(bonus)
Instruction Evaluation  ?? points
(bonus)

Copies of lecture notes available to each study group
APPENDIX G

TIME LOG OF A TYPICAL CLASS SESSION

For about first 30 minutes of class time: Lots of writing on the blackboard explaining concepts as they are being shown from the overhead projector. Also during this same time period he entertained lots of question from the students.

For about the next 20 minutes of class time: Asked group questions to the various groups and called on some of the groups forward to the blackboard to solve problems. He gave groups enough time to respond to questions and also assisted them in their explanations.

Last 30 minutes: Lots of class discussion on the topic interspersed with concrete references and examples of real-life situations. The overhead projector was still being used as he talked very loudly and moved all around the class and wrote on the blackboard quite frequently when necessary while using lots of modeling.
### Appendix H

**Table of pH of Common Materials Extracted from Chem 1202, Fall 1992 Note Package**

<table>
<thead>
<tr>
<th>Substance</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mol HCL</td>
<td>0.0</td>
</tr>
<tr>
<td>Gastric Juice</td>
<td>1.4</td>
</tr>
<tr>
<td>Lemon Juice</td>
<td>2.1</td>
</tr>
<tr>
<td>Orange Juice</td>
<td>2.8</td>
</tr>
<tr>
<td>Wine</td>
<td>3.5</td>
</tr>
<tr>
<td>Black Coffee</td>
<td>5.0</td>
</tr>
<tr>
<td>Urine</td>
<td>6.0</td>
</tr>
<tr>
<td>Milk</td>
<td>6.9</td>
</tr>
<tr>
<td>Pure H2O</td>
<td>7.0</td>
</tr>
<tr>
<td>Blood</td>
<td>7.4</td>
</tr>
<tr>
<td>Baking Soda Solution</td>
<td>8.7</td>
</tr>
<tr>
<td>Ammonia</td>
<td>11.9</td>
</tr>
<tr>
<td>1 Mol NAOH</td>
<td>14.0</td>
</tr>
</tbody>
</table>
Hydroformylation is the second largest homogeneous catalytic reaction.

Over 12 billion pounds of aldehydes (alcohols) per year.

Commercial catalysts are complexes of Co or Rh.

Selectivity to linear (normal) and branched (iso) products.

\[
\begin{align*}
\text{H}_2\text{C}=&\text{CH}-\text{R} & \text{H}_2\text{C}=&\text{CH}_2-\text{CH}_2-\text{R} & \text{H}_2\text{C}=&\text{CH}-\text{R} \\
\text{Rh or Co} & \text{ Catalyst} & \text{linear} & \text{branched} & \text{Alddehydes}
\end{align*}
\]
VITA

Mr. Zehyoue is currently a full-time student in the Department of Curriculum and Instruction at Louisiana State University. His previous academic experience involved serving on the faculty of the University of Liberia on a part-time basis for a few years and also on the teaching faculty of various high schools in Liberia.

While working on a part-time basis in academia, Mr. Zehyoue worked for eleven years as a chemist/geochemist at the Ministry of Lands, Mines and Energy in Liberia. There he was the assistant-chief chemist/geochemist with responsibilities for the supervision of the laboratory staff and the routine analysis of soils, rocks and other requisite samples, including some research activities.

Mr. Zehyoue has written numerous newspaper articles on scientific issues in Liberia, and has attended seminars in and outside of Liberia.

He is receiving his Ph. D. in Education, Curriculum and Instruction with a minor in Chemistry Education. He previously had obtained a Master’s Degree in Chemistry from Marquette University and a Bachelor’s Degree in Chemistry from Cuttington University College in Liberia.
Candidate: Anthony Quilah Zehyoue Jr.

Major Field: Curriculum and Instruction

Title of Dissertation: The Chemist in the College Chemistry Classroom:
A Case Study of Excellence

Approved:

[Signatures]

Major Professor and Chairman
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:
April 10, 1995