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The transformative experiences of a scientist-professor with teacher candidate

Terry L.Hester Lashley
University of Tennessee

To the Graduate Council:

I am submitting herewith a dissertation written by Terry L.Hester Lashley entitled "The transformative experiences of a scientist-professor with teacher candidate." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Dr. Claudia T. Melear, Major Professor

We have read this dissertation and recommend its acceptance:

Dr. Mary Jane Connelly, Dr. Leslie G. Hickok, Dr. Kristen T. Rearden

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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Dr. Kristin T. Rearden, Assistant Professor

Acceptance for the Council:

Vice Provost & Dean of Graduate Studies

The Transformative Experiences of a Scientist-Professor with Teacher Candidates

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville

Terry L. Hester Lashley
December 2002

DEDICATION

This dissertation is dedicated to my family. I would not have completed this work without your support.

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I wish to thank all those who helped me in completing the Doctor of Philosophy in Education degree. I especially thank Dr. Claudia T. Melear who served as a wonderful role model to me and who encouraged me at all the right times. I sincerely thank Dr. Leslie G. Hickok for his important role in this dissertation. I appreciate his cooperation and willingness to give not only of his time, but also to share with me his candid thoughts regarding science education. Quite literally none of this work would have been possible without him. I thank Dr. Kristin T. Rearden for sharing her expertise and knowledge of qualitative research and, specifically, her assistance with the software program, HyperRESEARCH. I thank Dr. Mary Jane Connelly for her support and knowledge about educational change.

ABSTRACT

This case study documented the pedagogical and philosophical change experiences of a senior research scientist-professor at a large Research I University as he implemented an open inquiry immersion course with secondary science teacher candidates. The 4-semester hour graduate-level credit course (Botany 531) is titled "Knowing and Teaching Science: Just Do-It!" The students were 5th-year education students who possessed an undergraduate degree in the biological sciences. The premise for the course is that to teach science effectively, one must be able to DO science. Students were provided with extensive opportunities to design and carry out experiments and communicate the results both orally and in a written format. The focus of this dissertation was on changes in the pedagogical philosophy and practice of the scientist-professor as he taught this course over a 4-year period, 1997-2000.

The data used in this study include the scientist-professor's reflective journals (1997-2000), the students' journals (1997-2000), and interviews with the scientist-professor (2001-2002). HyperRESEARCH 2.03 software was used to code and analyze the reflective journals and transcribed interviews. Data were reviewed and then placed into original codes. The codes were then grouped into themes for analysis. Identified themes included (1) Reflective Practice, (2) Social Construction of Knowledge, (3) Legitimate Peripheral Participation, and (4) the Zone of Proximal Development.

There is clear evidence that the scientist-professor experienced transformative changes in his philosophy and practice over the 4-year period. This is shown by (1) differences in learning outcomes and expectations for Do-It! course students and traditional course students, (2) documentation of the scientist-professor's movement through the Concerns Based Adoption Model (CBAM) Stages of Concern, (3) increased collaboration and support from the college of education, (4) development and delivery of two other courses patterned after the Do-It! course, (5) interest and participation in education research, (6) presentation and participation in national and regional science education conferences, and (7) efforts to influence colleagues regarding teaching and learning. Furthermore, questioning strategies are an instructional strategy and dialogue is a component of all his university courses. Moreover, his professional research interest includes science pedagogy and he coauthors research articles with science educators.

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CHAPTER I

INTRODUCTION

Prior to, but especially on, October 4, 1957, world events shaped contemporary science policy and science education; these events would also affect my personal experiences with science and science education.

SPUTNIK I and II

> History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I. The world's first artificial satellite was about the size of a basketball, weighed only 183 pounds, and took about 98 minutes to orbit the Earth on its elliptical path. That launch ushered in new political, military, technological, and scientific developments. While the Sputnik launch was a single event, it marked the start of the space age and the U.S.-U.S.S.R space race.
>
> The Sputnik launch changed everything. As a technical achievement, Sputnik caught the world's attention and the American public off-guard. Its size was more impressive than Vanguard's intended 3.5-pound payload. In addition, the public feared that the Soviets' ability to launch satellites also translated into the capability to launch ballistic missiles that could carry nuclear weapons from Europe to the U.S.
>
> Then the Soviets struck again; on November 3, 1957, Sputnik II was launched, carrying a much heavier payload, including a dog named Laika. It was estimated that the satellite would circle for approximately 23 weeks, but Laika would only live for the first week, as was planned, because of limited oxygen and food onboard. (Harold K. Milks, 1958)

Personal Perspectives on Science Education

On October 4, 1957, I was 11 years old. I learned that Soviets had launched something called a satellite with an odd name, Sputnik I. The unusual name made it easy to remember; however, I remember more than the name of the satellite. This was an important event. There were to be several more Soviet launches within the next few months.

I also remember details of the launch of the dog, Laika, aboard Sputnik II. I listened to the recorded barks coming back from space and recall my concern for the fate of the famous little dog. Although the Russians said the satellite would orbit the earth for 5 to 6 months, we later learned that Laika had food and air for about one week. The possibilities of space travel, beyond Miss Pickerel Goes to Mars, Buck Rogers, and other comic book stories, became more real and personal.

Popular music, such as the instrumental “Telstar,” helped to promote a new interest in space. Comedians had monologues about space travel. Suddenly, I discovered that we were in a previously unknown (to me) “race for space.” America’s interest in “space science” was very high.

It wasn’t until my high school years that space science and science in general became important to me. Growing up in a very small rural community in Northern Minnesota, I was removed from high-technology businesses (high technology as a phrase was not known by me at that time), places of “big” science, and research universities. However during this same time, my high school science teacher, Mr. Drake, began spending his summers at Oak Ridge National Laboratory, in Oak Ridge, Tennessee, a distant and different place from Clearbrook, Minnesota.

During our science classes, Mr. Drake would tell wonderful stories about some of the science he had seen in Oak Ridge and that sparked my interest. His class was always interesting and I remember doing some science experiments during chemistry and physics classes. I decided then, I liked science. Mr. Drake also seemed to be really interested in his teaching of science, and he shared that interest with me. On several occasions, he talked with me about what I planned to do after high school. Mr. Drake suggested that I could probably do well in college science classes and that there were a lot of science careers I could consider. As it turned out my career choice wasn't made based upon my real interest, music. My boyfriend was going to pharmacy school in North Dakota, and pharmacy sounded like a reasonable career to me. So, that was my first college major. I also made this decision because I knew that pharmacy school required that I take quite a few mathematics and science courses. I liked (and did well in) mathematics and since Mr. Drake had made my science coursework interesting, taking more science, and, mathematics courses in college appealed to me. These high school events greatly influenced my college and career choices. It was not until some time later that I learned that Mr. Drake's personal science stories (and, perhaps, enthusiasm) were part of a science reform effort supported by the National Science Foundation (NSF). I learned much later that my local experiences were part of a much larger effort.

Science Education: Political, Historical, and Professional Perspectives

The science education literature is filled with references to major science events and science education reform efforts occurring over the last 50+ years. Increased interest in science and science education reform began during World War II when scientific advances, such as radar, penicillin, and the atomic bomb, were seen as important in bringing an end to World War II.

During the final months of World War II and at the request of President Franklin D. Roosevelt, Vannevar Bush, Director of the Office of Scientific Research and Development, prepared a report emphasizing the importance of science with regard to national security and as a "proper concern of the Government." Vannevar Bush was an appropriate choice to prepare this report. As a mathematician and engineer, credited with co-founding Raytheon Corporation, he reportedly was surpassed in professional identity at that time by only one person, Albert Einstein (Appendix 1.1). An underlying idea of the 1945 Bush report to the President is stated below:

> since health, well-being, and security are proper concerns of Government, scientific progress is, and must be, of vital interest to Government. Without scientific progress the national health would deteriorate; without scientific progress we could not hope for improvement in our standard of living or for an increased number of jobs for our citizens; and without scientific progress we could not have maintained our liberties against tyranny. (Bush, 1945, p. 2)

In Bush's report, Science—The Endless Frontier, (Bush, 1945) (more commonly known as the Bush Report) he recommended the creation of a National Research Foundation (NRF) to "initiate science policy in a new institutional arrangement, oversee all government scientific research and dispense grants to universities in support of basic science" (Bush, 1945, p.3). [The name NRF was later changed to the National Science Foundation (NSF).] Bush's idea for the NRF emphasized government policy in support of science, not science for government policy and was proposed as a "unique source of advice on science policy to the White House and Congress." However, Harold Smith, Director of the Bureau of the Budget (BoB), maintained that only the President and those directly responsible to the President should be given authority to disperse public funds and, further, called Bush's NRF proposal "arrogant and elitist" (Blanpied, 1998, p.).

During the extended discussions and arguments about the creation of the NRF, potential funding for the foundation was reduced when two other agencies were created and funded for defense purposes. The two new agencies were the Office of Naval Research and the Atomic Energy Commission. Fearing that the valuable ideas in Bush's plan would be discarded because of politics, several influential men, including representatives from the BoB; the Office of War Mobilization and Reconversion (OWMR); and, most important, John R. Steelman, OWMR Director, convinced President Truman to issue an executive order creating the President's Scientific Research Board (PSRB). The PSRB included many prominent figures, including Vannevar Bush. Bush, apparently for political reasons, chose not to be active in the PSRB work. The PSRB charge was "to review current and proposed research and development activities both within and outside of the federal government" (Blanpied, 1998). Furthermore, the

> board's chairman was to submit a report setting forth: (1) his findings with respect to the Federal research programs and his recommendations for providing coordination and improved efficiency therein; and (2) his findings with respect to non-Federal research and development activities and training facilities...to ensure that the scientific personnel, training and research facilities of the nation are used most effectively in the national interest. (Blanpied, February 1998, p. 10)

President Truman chose Steelman as the board's chairman.

Bush's plan, although prepared at the request of Franklin D. Roosevelt, was vetoed by President Harry Truman on August 6, 1947. Three weeks later, on August 27, Science and Public Policy: A Program for the Nation, was released. Often referred to as A Program for the Nation, the report was prepared by John R. Steelman, chair of the President's Scientific Research Board and the first White House aide to hold the title of

Assistant to the President. Steelman's report contained several volumes, two were particularly noteworthy and covered previously unexplored territory. Those volumes were Opinions of Scientists about Their Work and Opinions on Science Teaching (Steelman, 1947).

The NSF became a reality on May 10, 1950, when it was signed into law by President Harry S. Truman. (A timeline leading up to the creation of the NSF is found in Appendix 1.1.)

In the early NSF years, programs were focused in four specified divisions: medical research; mathematical, physical, and engineering sciences; biological sciences; and scientific personnel and education. The scientific personnel and education division had the responsibility of providing scholarships and graduate fellowships. In all cases, the NSF interest was basic research in the four major divisions.

Over the next 7 years, the NSF budget was increased, but not dramatically. Although Science—The Endless Frontier (Bush, 1945) suggested a first year budget of $33.5 million, the NSF received approximately one-tenth of that amount ($3.5 million) for fiscal year 1952. The reason given for the reduced funding was the cost of the Korean conflict. The budget did, however, increase to $134 million in 1959 and to $500 million in 1968. The success of Sputnik I was highly beneficial to the NSF budget appropriations.

Following the creation of the NSF, educational reform efforts have had at least three distinct peaks: (a) Sputnik I; (b) A Nation at Risk (National Commission on

Excellence in Education, 1983); and (c) the release of the publications Science for All Americans (1990), Benchmarks for Science Literacy (1993) and the National Science Education Standards (1996).

> Sputnik dramatically underscored the Soviet-American competition. While the satellite provided the first human reach beyond the planet, it symbolized in America the need for improving scientific education and basic research, needs already known to the scientific community. While that was the importance of Sputnik, equally important was the fact that the nation had already taken steps in the postwar period to build a scientific establishment (NSF) that could meet the challenge of this more visible scientific competition. That became the legacy of the NSF early years to Sputnik.
>
> Sputnik once again elevated the word "competition" in the language of government officials and the American public. Sputnik threatened the American national interest even more than the Soviet Union's breaking of America's atomic monopoly in 1949; indeed it rocked the very defense of the United States because Russia's ability to place a satellite into orbit meant that it could build rockets powerful enough to propel hydrogen bomb warheads atop intercontinental ballistic missiles. Perhaps more importantly, however, Sputnik forced a national self-appraisal that questioned American education, scientific, technical and industrial strength, and even the moral fiber of the nation. What had gone wrong, questioned the pundits as well as the man in the street. They saw the nation's tradition of being "Number One" facing its toughest competition, particularly in the areas of science and technology and in science education (Mazuzan, 1994, p. 9).

On April 12, 1961, the U. S. received another political and technological blow when a Russian cosmonaut, Yuri A. Gagarin, orbited the earth.

In May, 1961, the United States launched a manned rocket with Alan B. Shepard, Jr., aboard. However, the event paled in comparison to the Russian launch. The U.S. launch, a mere 15-minute suborbital flight totaling 300 miles, reached a height of only 116.5 miles. It was not until February 20, 1962, that the United States was able to match the Russian feat of putting a man into orbit around the earth with the successful flight of John H. Glenn, Jr.

These highly publicized events focused America's attention on our apparent subordinate position in science, mathematics, and technology. Moreover, the events triggered a national scrutiny of the entire education system, especially in the sciences.

> Sputnik raised questions about the ability of the nation's education system to compete. Congress responded with the National Defense Education Act of 1958. It emphasized science education and became a significant part of the country's science policy. The act provided a student loan program, aid to elementary and secondary school instruction in science, mathematics and foreign languages, and graduate student fellowships. While it was directed mostly at students rather than institutions, and was administered out of the United States Office of Education, the law had an important impact on federal support of science education. Both its fellowships and its institutional benefits followed geographic distribution patterns rather than the competitive elitist format typical of Foundation programs. Of even greater significance, however, the act opened the way for future legislation that redefined many of the relationships between the federal government and the education community (Mazuzan, 1994, p. 10).

There were also general concerns raised that the United States lacked not only science and technological expertise, but also that young people were not motivated to study science and were possibly being given less than adequate preparation in our public school systems. NSF would attempt to respond to this concern in the 1960s.

Although the NSF had "dabbled" in programs for college teachers as early as 1953, their work with high school teachers began with one science institute in 1954. Prior to 1957, and as a limited response to information that the Soviet's education system was possibly superior to the American education system, particularly in the hard sciences, the NSF increased its work in high schools. In fact, by the summer of 1957, the NSF was conducting science institutes in all but five states. Following the launch of Sputnik, the

NSF budget increased rapidly and an emphasis on better educating our youth in science (and mathematics) became a major focus for the NSF in the 1960s.

Numerous university-based programs were designed by scientists and university faculty with supposedly "teacher proof" curriculum and materials. These curriculum programs were created primarily by scientists and engineers for teachers. The programs were delivered in summer workshops and institutes, usually at universities. There were programs in physics, chemistry, biology, and mathematics. Although many of the programs were excellent, most did not survive implementation. The researcher believes this was due to unrealistic expectations of developers (a one-time fix), professional development methods, and time allotted for professional development. Of these programs, the Biological Sciences Curriculum Study (BSCS) is the most notable survivor.

A second and more contemporary moment in science education reform came with the release of A Nation at Risk: The Imperative for Educational Reform (1983). At the conclusion of this report, Americans were cautioned in war-like terminology about the mediocrity we have allowed to persist in our education system.

> If an unfriendly power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament (National Commission on Excellence in Education, 1983, p. 5).

A Nation at Risk (National Commission on Excellence in Education, 1983) noted five basic subjects as being critical: English, mathematics, science, social studies, and computer science. Politicians quickly responded to the report, and the United States. coined the slogan "America 2000," setting a goal that, by the year 2000, we would once again be First in the World (especially in mathematics and science). With the change from the Republican Bush administration to the Democratic Clinton administration, there was a name change to "Goals 2000"; the basic objectives were the same. An overall increase in standards and rigor at all levels was recommended. At the core of this effort was economic competitiveness and national security.

It is interesting to note that both of these significant moments are driven mainly by politics and tied closely to world situations. Furthermore, in each case, the economic and political well-being of the United States was placed upon our educational system and schools.

Soon after A Nation at Risk was released, the American Association for the Advancement of Science (AAAS) published their seminal work Science for All Americans (American Association for the Advancement of Science, 1990). Science for All Americans clearly identified the science literacy level envisioned for a scientifically literate society. Shortly thereafter, in 1993, Benchmarks for Science Literacy (BSL) (American Association for the Advancement of Science, 1990) was released. BSL provided a guide enabling educators to structure curriculum to reach the desired literacy levels by the end of 12th grade. Using this work the National Science Teachers Association in collaboration with the National Research Council (NRC) published the National Science Education Standards (National Research Council, 1996) further defining what students should know and be able to do in science after 12 years in school.

Despite the interest and emphasis on educational reform first in the 1960s and then again in 1983 after the release of A Nation at Risk, according to the Fifteen Years and Still A Nation at Risk Summit held April 3, 1998, we are still at risk. The Fifteen Years After A Nation at Risk report (Appendix 1.2) showed declines in several areas. In the general findings, category the report states that

- American 12th-grade students continued to score poorly in mathematics and science,
- General literacy skills remained very low,
- Literacy levels of 1521 year olds dropped between 1983-1992,
- SAT scores, although higher in 1995, were still 70 points lower than in 1963,
- Seventeen-year-olds' scores on the National Assessment of Educational Progress showed a slight increase in 1982, but were lower than tested in 1969,
- Remedial courses were offered in 80% of all public 4-year institutions and were needed by almost 30% of entering freshmen
- U. S. manufacturers maintained that 40% of all 17-year-olds lacked the math skills and 60% lacked the reading skills to hold down a job in their company,
- On the most recent U.S. physics and advanced mathematics tests students scored last in the advanced portion of the Third International Mathematics and Science Study assessment.

The findings were similar in the specific areas of content; student and curriculum expectations; academically focused time in school; and quality, professionalism and compensation of teaching staff.

THE CONTINUING PROBLEM

For most of my life I have observed or participated in science education reform activities and events. This personal perspective on reform comes from my past experiences as a science teacher and science education program administrator, and my current life as director of science and mathematics reform projects. Most of my experiences were with the most dominant mode of "reform" which is, in my view, to modify the veteran teaching force through inservice programs or institutes. As the literature will validate, this type of reform effort has been repeated for almost 50 years. Although there have been highs and lows in appropriations, the basic plan has remained constant: to reform veteran teachers, implement a teacher-proof curriculum, or both, solving the science education crisis "du jour." And, of course, the reformers must make sure the reform is done after school, on Saturdays, or during the summer break. Reformers must also make sure to complete the reform task in 3 to 5 years, the typical grant-funding cycle.

This situation does not warrant humor. The reality should be obvious to the reader. In order for K-12 classroom teachers, (actually K-16+ teachers) to teach differently, with what we espouse to be exemplary teaching practices, the teachers must be prepared differently. This change in preparation must occur in science-content classes, not just science methods-classes.

This dissertation presents a scientist-professor who has made significant changes in his professional teaching practices.

STATEMENT OF THE PURPOSE

The purpose of this study is to better understand and document the instructional, professional, and other relevant changes experienced by a senior-level scientist-professor of Botany as he delivered graduate-level science content through a full-inquiry method consistent with AAAS Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and National Science Education Standards (National Research Council, 1996). This single case study is a holistic, in-depth investigation of the changes/transformative experiences of the scientist-professor over the four-year period.

DEFINITION OF TERMS

Bloom's Taxonomy: A six-level description of learning outcomes. The intellectual outcomes (from simplest to most complex) are knowledge, comprehension, application, analysis, synthesis, and evaluation.

Concerns Based Adoption Model (CBAM): The CBAM is a conceptual framework that describes, explains, and predicts probable teacher behaviors in the change process.

Dialogue: Nancy Love (Love, 2002) says this a process where groups can create "shared meaning through respectful sharing and listening" (Love, p. 44). Using dialogue, individuals or groups can "build their capacity to inquire and learn together" (Love, p.44).

Legitimate Peripheral Participation (LPP): This learning theory focuses on the social nature of learning. It is based upon interactions between a master and newcomers with learning occurring within a situated context.

Reflective practice: Reflective practice is a mode that integrates or links thought and action with reflection. It involves thinking about and critically analyzing one's actions with the goal of improving one's professional practice. "Engaging in reflective practice requires individuals to assume the perspective of an external observer in order to identify the assumptions and feelings underlying their practice and then to speculate about how these assumptions and feelings affect practice" (Kottkamp 1990; Osterman, 1990; Peters, 1991).

Recursive loop in the Zone of Proximal Development (ZPD): A graphical representation created by Tharp & Gallimore (1988) illustrating how individuals build knowledge and capacity when assisted through the change process by more capable others.

Social Constructivism: This learning theory states that learners must construct personal knowledge of concepts and that such intellectual development best occurs within a community of learners rather than in individual isolation.

Three-point test cross: A traditional way of mapping chromosomes by doing test crosses and looking at the cross-over frequencies between different characteristics that are linked in some fashion. This is a traditional problem-solving activity in many genetics classes.

Transformative: In this context, transformative is operationally defined as the "thoroughgoing changes in deeply held beliefs, knowledge, and habits of practice" (Thompson & Zeuli, 1997).

Zone of proximal development (ZPD): The difference between what a learner can do independently and what can be accomplished cognitively with scaffolding from more knowledgeable others (Vygotsky, 1978). According to Lave and Wenger (1991) there are three interpretations of ZPD. The interpretation utilized in this work states that

> Under the societal interpretation of the concept of the zone of proximal development researchers tend to concentrate on processes of social transformation. They share our interest in extending the study of learning beyond the context of pedagogical structuring, including the social world in the analysis, and taking into account in a central way the conflictual nature of social practice. We place more emphasis on connecting issues of sociocultural transformation with the changing relations between newcomers and old-timers in the context of a changing shared practice. (p. 49)

STATEMENT OF THE PROBLEM

Many, perhaps most, science teachers begin their teaching careers in almost immediate need of professional development to enable them to provide instruction consistent with the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and the National Science Education Standards (National Research Council, 1996). It is a logical conclusion that this problem is related to teacher preparation practices, especially in the science content areas. Large, lecture hall presentation of science content is inconsistent with best practices as defined in the standards.

McDermott and DeWater (2000) identified one issue critical to the university preparation of K-12 teachers:

> In the United States, precollege teachers are educated in the same universities and colleges as the general population. In most institutions, two independent administrative units are involved: a college or school of education that offers courses on the psychological, social, and cultural aspects of teaching, and a college of arts and sciences (or equivalent) that provides instruction in various disciplines. Whereas the preparation of K-12 teachers may be central to faculty in education, such a function is often considered peripheral to the mission of a science department. Most faculty in the sciences take the position that responsibility for the professional development of teachers resides solely within colleges of education. This point of view ignores the fact that almost all the instruction that precollege teachers receive in the sciences takes place in science departments. If the current national effort toward reform in K-12 science education is to succeed, science faculty must take an active role in the preparation of teachers in their disciplines. (p. 241-242)

This research study will address the problem as stated above, especially as it relates to science instruction through inquiry.

The National Science Education Standards (National Research Council, 1996) document calls upon teachers to engage students in inquiry activities. Specifically, the Standards state that:

> Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data . . . (p. 105).

However, as reported, little is done at the university level, particularly in science-content courses, to prepare teachers for this type of instruction.

In my personal experiences with science-content courses, teacher preparation, and science education in general, there does appear to be a disconnect between theory and practice (what preservice teachers are told to do and what they actually see being done by their own science instructors). Also, as stated by McDermott and DeWater (2000), there may be a disconnect regarding the responsibility for teacher preparation, particularly in science content, even though both groups of instructors have a vested interest in graduates. Preservice teachers often are told how they should teach science and are provided with the research underlying the reason it should be taught in this manner, but the majority of the time they do not see these practices modeled in their preparation program, especially in the science-content courses.

If the purpose of science courses, at all levels, is to create a scientifically literate society, deliver science content, and develop conceptual understanding, then teachers of science, at all levels, need to have this experience during their university preparation. And, for this to happen, college and university science faculty must be involved and engaged in the science reform initiatives.

The Boyer Report (1998) states that most university faculty utilize a very traditional model of teaching and learning. Content is delivered in a teacher lecture/student note-taking format. As the National Science Education Standards (National Research Council, 1996) reports this is not best practice. To achieve change to a more standards-based practice, what needs to happen? How can this change be accomplished and what occurs when a senior research scientist-professor decides to make these changes? What experiences does the instructor have? How are the changes perceived by the students? In the reality of the give and take in instructional time and the additional time made for classroom discussions, what must be sacrificed? What might be gained? Could other scientists and professors of college science utilize this information to improve their own instructional practice and pedagogy?

ASSUMPTIONS

The following assumptions are made for this study:

1. All scientist-professor and participant/student journals are candid reports of issues, concerns, and occurrences in The Knowing and Teaching Science: Just Do-It class.
2. The scientist-professor's interview questions and sessions provide adequate opportunities for elaboration and clarification.
3. Science inquiry as an instructional method is desired in teaching and learning.

LIMITATIONS

1. The student population is different each year, 1997 through 2000.
2. The student cohort number varies yearly.
3. Graduate student assistants are different each year, 1997 through 2000.

DELIMITATIONS

1. Although the scientist-professor now teaches other classes in a science inquiry method, only data from The Knowing and Teaching Science: Just Do-It Class are used in this case study.
2. Assessment of the science content and pedagogy learned by the participants/students through this method of instruction will not be performed, although those data are presented, in part, elsewhere (Hickok, L. G. Warne, T. R., Baxter, S. L. & Melear, C. T., 1998.).

3. The focus of this study is on the scientist-professor; therefore, no student interviews have been conducted.
4. Follow-up with participant teachers for the purpose of examining transfer of pedagogical skills and content is not included in this study; however, this is part of other studies (Brown, S., 2002 & Lunsford, B.E., 2002).
5. This study is limited to work conducted in The Knowing and Teaching Science: Just Do-It Class between 1997 and 2000.
6. The scientist-professor's interviews were conducted in 2001-2002.
7. All quotations have been minimally edited for clarity.

CHAPTER II

REVIEW OF THE LITERATURE

The literature reviewed is presented under the following headings:

(1) Theoretical Framework

(2) The Change Process

(3) Science Inquiry

(4) Highlights in K-16 Science Education Reform

(5) Summary of the Literature

The purpose of this study was not to verify or dismiss a hypothesis or process. Rather, the purpose was to address the emergent themes of the case study and examine the relationship(s) to the established research. The literature reviewed for this study included: (1) the Theoretical Framework which focused on the facilitation of learning through multi-directional, cross-cultural collaborations. The facilitation of learning was studied from the perspective of the scientist-professor, science educator and, to a lesser degree, the students. (2) The Change Process literature which contributed to an understanding of the changes documented in the journal and interview data. (3) Science Inquiry, as a content and a pedagogy, which helped to establish an operational definition for a better understanding of inquiry in this case study research. (4) The selected Highlights in K-16 Science Education Reform was provided in a chronological format to illustrate the evolution of research on science education reform.

THEORETICAL FRAMEWORK

The following information on Social Constructivism, Vygotsky's Zone of Proximal Development, Lave & Wenger's Legitimate Peripheral Participation and Reflective Practice was used as theoretical frameworks to examine the scientist-professor reflective journals, student reflective journals and transcribed scientist-professor interviews.

Vygotsky's Zone of Proximal Development

Vygotsky (1978) reported that learning can be facilitated by an adult or capable peer who provides experience just beyond an individual's current capability, and helps him/her work toward achieving a new level of performance. Such help (scaffolding for learning) can slowly be withdrawn until the student can manage without assistance. Vygotsky called this operating within the zone of proximal development (ZPD).

According to Appleton (1997), Vygotsky's work has contributed to several other theories within the realm of social constructivism. One idea is that a "students' cognitive development is mediated by the social and cultural context" (Appleton, 1997, p. 50) in which learning takes place. This "cognitive development occurs through social interaction with adults, teachers, and peers and the use of language" (Appleton, 1997, p. 51). Learning is also facilitated by interaction with the associated cultural tools and symbols.

Lave and Wenger (1991) assert there are three interpretations of ZPD. The most literal interpretation is "characterized as the distance between problem-solving abilities exhibited by a learner working alone or collaborating with more experienced people" (p. 48). The first interpretation is sometimes called the "scaffolding" interpretation. The second interpretation is a more "cultural" one. In this interpretation, the distance is defined as that "between the cultural knowledge provided by the sociohistorical context…and the everyday experience of individuals" (p. 48). The third interpretation is a societal one. In this interpretation the distance is referenced in terms of "connecting issues of sociocultural transformation with the changing relations between newcomers and old-timers in the context of a changing shared practice" (p. 49).

Windschitl (2001) has written about knowledge construction that operates *between* groups of learners and thus somewhat expands the notion of ZPD within social constructivism to include groups of students. This expansion has been conceptualized as "constructive group interaction" by Hatano and Inagaki (1991). Constructive group interaction is defined as "the collective invention of knowledge that none of the group's members has acquired or is likely to produce independently" (p. 333). Classroom discourse (Lemke, 1990; Kamen et al, 1997; Roth, 1995) studies elaborate on interactions in classrooms and how discourse contributes to the construction of science knowledge. As individuals are introduced to the "culture" by more skilled members, knowledge and understanding are constructed through talk and work on shared problems or tasks (Driver et al, 1994).

Social Constructivism

The social context of learning is much more important than previously thought. Social constructivists assert that learners must construct personal knowledge of concepts and that such intellectual development best occurs within a community of learners rather than in individual isolation. They report that knowledge is not constructed individually;

that it is co-constructed through dialogue (Beeth & Hewson, 1999; Shepardson, 1999; Crawford, 2000; Keys & Bryan, 2001).

Emerging from social constructivism are several ideas of note: (1) A student's cognitive development is mediated by the social and cultural context and cognitive development cannot be separated from the social or cultural contest. The emphasis is on cognitive development within a social context, including the social context, instead of on developing cognitive schemes and structures, (2) Cognitive development occurs through social interactions with all others including adults, teachers, peers, etc. and through the language, (3) Cultural issues may influence and direct cognitive development, (4) Learning can be facilitated through operation within the ZPD and through scaffolding (structured assistance), (5) Study should be meaningful rather than in small components, and (6) Learning should be relevant and useful.

Another key idea in sociocultural research in science education is the relationship between language and science education (Lemke, 2001). This idea emphasizes the importance of the construction of a common language between teachers as a basis for meaningful reform (Keys & Bryan, 2001). A common, comprehensible language allows the teachers, students, and researchers seeking to work together on reform to develop mutual understanding.

Lave and Wenger's Situated Learning: Legitimate Peripheral Participation

Lave and Wenger (1991) report "learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community" (p. 29). From this perspective, learning focuses on the learner rather than the teacher and the learning is situated in a *learning curriculum*. "It (a learning curriculum) is not something that can be considered in isolation, manipulated in arbitrary didactic terms, or analyzed apart from the social relations that shape legitimate peripheral participation" (p. 97). In a learning community participants interact "at multiple levels" (p. 98) and in many ways. Motivation for learning is intrinsic and comes from learners seeking to become full participants in the process such as thinking like a scientist, operating within the culture of the scientist. And as, Roth (Roth & Tobin, 2001) points out, "experiences with Legitimate Peripheral Practice (Lave & Wenger, 1991) in knowledge and knowledge-building communities appear to me more appropriate ways of looking at the young people whom we introduce to the business of teaching" (p. 108).

Reflective Practice

Reflective practice allows an individual to integrate and link thoughts and action with the purpose for improving professional practice (Kottkamp, 1990; Osterman, 1990; Peters, 1991). In educational settings, the work of Schon (1983, 1988) is often cited. Schon asserts that a person must be aware of their professional theories or ideas before their practice can be changed (Schon, 1983).

THE CHANGE PROCESS

The study of educational change is also historically linked to Sputnik. Following Sputnik, in an attempt to improve science understanding and experience for American students, new curriculum materials were developed and delivered to teachers in the early sixties with little, if any, professional development of teachers on the materials themselves (Shymansky, Kyle & Alport, 1983). The initial focus was on content. Later in the seventies, programs were offered to train teachers in the use of the materials.

However, evaluation of the projects failed to identify specific successes in the new inquiry-oriented curriculum projects. However, Bybee (1997) believes overall student performance was higher with the use of some of the new curriculum materials. Researchers report that curriculum programs were regularly discarded in favor of "another one." At this time, researchers began to examine the implementation process of the new pedagogies and curriculum projects. Subsequently, dealing with and supporting, educational change became a research focus.

According to Hord, et al, (1987), there are a number of known lessons about the complexity of educational change. They are:

1. Change takes time. Often a change in a teaching practice may take several years to implement.

2. Individual and organizational support during the change process will be different over time.

3. Change needs to be clearly defined, opportunities for collaboration must be available and administrative support must be readily available.

4. Change is usually resisted.

5. Continuous improvement requires ongoing goal setting, implementation efforts, ongoing assessment and adjustments.

6. Change is complex.

The Stages of Concern (Appendix 2.1) from the Concerns-Based Adoption Model (CBAM) is proposed as relevant to this research on multiple levels. Support systems will be examined in the following groups: between the scientist-professor and the science educator, between the scientist-professor and the students, and between the students themselves. By using the CBAM Model and associated questionnaires and instrumentation, teachers receive ongoing support for their concerns. Fullan (1993) suggests that teachers need to learn to change productively and move toward teaching for understanding. This view of change is consistent with the research presented in this dissertation.

SCIENCE INQUIRY

Inquiry as Proposed in Theory

The research about science inquiry or inquiry-type science is plentiful with the origins in the early sixties and the NSF-supported curriculum projects. However, there is general disagreement and confusion over what inquiry involves. There are conversations about guided inquiry, directed inquiry, challenge inquiry, open inquiry, "hands-on" as inquiry, etc. Moreover, these terms are often used interchangeably by teachers, science educators, and professional developers without clarification of the meanings.

The National Science Foundation's The Challenge and Promise of K-8 Science Education Reform (NSF, 1997) offers one of the better insights/perspectives on inquiry.

> Inquiry-based teaching is a challenge. Contrary to the claims of some critics, it is not a relinquishing of the teacher's role, nor is it simply messing about with materials. It is highly structured teaching--but structured to allow students to behave in a most fundamental human way, to be inquisitive. It requires a teacher who is knowledgeable about scientific content and pedagogy, significant blocks of dedicated classroom time, a system that supports the teacher's own learning, and high-quality materials and curriculum. In schools where attempts to implement inquiry-based science education have failed, it is often because one or more of these essential elements are missing (p. 8).

The foundational documents Science for All Americans, Benchmarks for Science Literacy (Appendix 2.2) and the National Science Education Standards (Appendix 2.3) have perspectives on scientific inquiry that are similar, but also subtly different. Benchmarks for Science Literacy (BSL) asserts that inquiry is a process while the

National Science Education Standards (NSES) asserts that inquiry is content as well as process. Therefore, Benchmarks for Science Literacy (BSL) emphasizes students doing scientific inquiry, whereas the National Science Education Standards (NSES) emphasize inquiry as both a process to be done by students and a concept (content) to be understood and recognized by students.

According to the Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (2000, p. 143), "support for inquiry-based teaching and learning must encompass several different elements:

- Understanding what is meant by inquiry-based teaching and learning and knowing the advantages documented for inquiry by research;
- Understanding the change process that occurs when teachers are learning to teach through inquiry and students are learning to learn through inquiry so that all of their concerns can be anticipated and support can be tailored to meet their evolving needs; and
- Providing a coordinated support system that maximizes the staff's opportunity to grown and succeed in teaching through inquiry" (NRC, 2000).

Anderson (2001) reports that the National Science Education Standards (NRC, 1996) uses the term inquiry in three main contexts. They are:

1. scientific inquiry

    ...refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (NRC, p. 23)

2. inquiry learning

    ...(is) something that students do, not something that is done to them (NRC, p. 2),

    ...encompasses a range of activities (NRC, p. 33),

…has multiple stages including "oral and written discourse, (NRC, p.36) and

3. inquiry teaching

…is expected to be prominent in science teaching (NRC, p. 2),

…does not imply that all teachers should pursue a single approach to teaching science (NRC, p. 2)

…refers to the activities of students in which they develop knowledge and understandings of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, p. 23)

Inquiry as Perceived in Practice

Roth and Roychoudhury (1993) report that "discovery and inquiry methods in science teaching" were "abandoned by teachers because of the difficulties they perceived in the classroom" (p. 237). Cited problems included "inquiry-based courses are difficult to manage, cause confusion in students, are too difficult for low and average ability students, and have uncertain learning outcomes" (p. 237).

Wiske (1994) reported that the pedagogy of inquiry required a "fundamental re-negotiation of intellectual authority" which "violates deep-seated, usually unrecognized assumptions and routines concerning the nature of knowledge and the roles of teachers and students" (p. 21). Moreover in an inquiry classroom, the teacher must be open to change and willing to "violate the paradigm that sanctifies knowledge as something the teacher possesses at the beginning, which students acquire during the course, and then demonstrate their own private possession on a test" (p. 21). Roth (1993) refers to his own "renegotiation" as a part of student's individual and collaborative construction of knowledge and meaning and forming consensus.

The research of Stepans, Saigo and Ebert (1995) emphasizes the importance of time to implement inquiry. Time constraints are problematic for a number of reasons. For example, Stepans, Saigo, and Ebert report "A critical consideration for inquiry instruction is time. Conceptual change takes time" (p. 44). Furthermore, inquiry learning often requires "repeated experiences" with a variety of materials, supplies and scenarios (p. 44) which again adds time as a critical construct for implementation. Additionally, individual and group construction of knowledge takes time. Moreover, the creation of and teacher support for inquiry-driven "teaching-learning contexts" also adds time. However, these contexts are necessary to provide learners with the opportunity to interact with science materials and each other (Roth, 1993) and in integrated contexts (Zubrowski, 1982). Also, because of teacher accountability issues, time for inquiry must also be weighed against time to prepare for standardized assessments that may not be aligned with inquiry instruction (Glasson & Lalik, 1993).

In 1996 a study by Haney, Czerniak & Lumpe (1996) was designed to determine the factors necessary for teachers to implement four strands in science education reform: inquiry, knowledge, conditions, and applications. Surveys were mailed 800 randomly teachers. The final sample included teachers from grades 2, 5, 8 and 11. The study confirmed that teacher attitudes and beliefs about the specific reform strand are critical and that the greatest motivation to implement science inquiry is high quality staff development, adequate funding, and appropriate curriculum.

Appropriateness of Inquiry Methods

Inquiry is reportedly an effective method to: develop the use of science process skills for designing investigations (NRC, 1996; Crawford, 2000; NRC, 2000); develop the ability to ask/refine appropriate investigable questions (NRC, 1996; Institute for Inquiry, 1998; Beeth & Hewson, 1999; Shepardson, 1999; Crawford, 2000; NCR, 2000); assist students to identify and operationalize variables (Institute for Inquiry, 1998; NRC, 2000); plan and complete long-terms projects (Roth, 1995; Crawford, 2000); facilitate problem solving skills; and develop communication and thinking skills (Roth, 1993; Crawford, 2000; NRC, 2000).

Inquiry may be less appropriate for learning that falls into the category of "facts and procedures." For example inquiry may be not be the best instructional method for student preparation for standardized tests (NRC, 200; van Zee, et al, 2001), preparation for classroom assessments such as short answer/multiple choice questions (van Zee, et al, 2001), or for effective speed of transmission on student acquisition of information (van Zee, 2001). Additionally, inquiry does not align well with recitation activities like IRE (Initiation, Response and Evaluation) also called triadic dialogue by Lemke (1990) or some specific science content/declarative concepts (Beeth & Hewson, 1999; NRC, 1996; NRC, 2000; AAAS, 2000).

The Salish I & II studies indicate that modified teacher training programs, including a Research Experience (RE), may change teaching practices. Also, it is proposed that through an RE, teachers may move along the continuum from traditional to constructivist/inquiry delivery of science instruction in K-12 classrooms (Melear et al, 2000). However, according to the Boyer Report: Reinventing Undergraduate Education (1998), little is done at the university level for any undergraduate student with regard to inquiry opportunities. The report states that the traditional lecture format of instruction persists in Research I Universities and it was "created for a time when books were scarce and costly" (p. 10). The report goes on to say that the lecture format has persisted because it "is familiar, easy, and required no imagination" (p. 11).

HIGHLIGHTS IN K-16 SCIENCE EDUCATION REFORM

A chronological review of the science education literature (1965-2001) shows many attempts to examine and, ultimately, improve the way science is taught. Science education was studied through direct observations of classroom practices; examination of pre-service, in-service, and teacher preparation programs; surveys of teachers' attitudes and perceptions toward science; questions about the possible predisposition to science teaching by certain types of individuals; and the identification of external obstacles to effective science education. Questions posed by researchers include:

1. What's going on in the classroom relative to science education?
2. What is good science education?
3. What are the characteristics of a good science teacher?
4. Are some teachers predisposed to be good science teachers?
5. Can university science education programs turn out teachers that are good science teachers?
6. What is needed for quality science education programs?
7. What changes are needed in pre-service as well as in-service programs?
8. Does a teacher's perceptions and attitudes toward science influence what goes on in the classroom?

Throughout the research period reviewed, there was strong interest in teacher attitude toward science as factor in successful science education practices. In the more recent literature, changes in science teacher preparation are evidenced. Over this same time period, the science education reform interests of federal agencies, such as the National Science Foundation underwent major shifts in focus. The efforts were shifted from individual projects which dealt with science education components to (2) systemic reforms which dealt with all the parts of school change to (3) comprehensive reform through partnerships with K-16+ schools, businesses and non-profit organizations, which involved the full educational system including teacher preparation programs.

For the purpose of providing a more historical context of science education reform, the review of the literature is presented chronologically.

The 1960s

In the 1960s, considerable science education research concentrated on finding out what was going on in science classrooms. Representative samples of research during this period follow.

Using a stratified two-stage survey, Blackwood (1965) looked at procedures, policies, practices, and conditions affecting science teaching in public elementary schools. Blackwood reported that 8% of teachers say they do not teach science at all. Teachers in the other 92% reported that science is integrated with social studies. This integration practice was a policy for some teachers (3.6%) and only done when appropriate by others (50.4%). Almost one quarter of the teachers (24.8%) thought science should be taught as a separate subject, however, 16.3% had no policy at all for science instruction or integration. Teachers in the Blackwood student reported the primary resource for science content was a textbook (78.1 - 90.7%).

Soy (1967) used a questionnaire to investigate 529 State College of Iowa elementary education majors' consideration of science as a specialty subject field. Soy believed that elementary education majors' consideration of science as a specialty subject field correlated with attitudes toward science. Furthermore, Soy speculated that children's learning in science increased as the teachers' attitude toward science increased.

Soy's results identified the following percentages for selected subject fields: Art (8.1%), Foreign Language (4.0%), Language Arts (40%), Mathematics (9.8%), Science (7.1%) and Social Science (31.3%). For those elementary teachers choosing science as a subject field, Soy noted: (1) Teachers report the influence of a talented high school instructor as important, (2) the more background in science, the greater chance that a teacher will choose science as a major field, and (3) those who choose science were more likely to come from a farm background.

The top three reasons elementary teachers did not choose science as a primary field of study in their undergraduate program were: (1) lack of interest in science, (2) difficulty of science courses, and (3) lack of high school science background (p. 512). From these results, Soy concluded that prospective elementary science majors: (1) need encouragement from counselors, (2) successful experiences with educators, and (3) increased feelings of content competency in a broader range of subject areas, especially in science and mathematics (p. 516).

Schwirian (1969) questioned why NSF science curriculum projects were unsuccessful. Schwirian believed that the teacher's attitude toward science was very important to the success of any curriculum project and presented eight hypotheses which she investigated using the Schwirian Science Support Scale, an attitude measurement instrument. Although Schwirian did not use her data to examine the relationships between science attitudes and teaching effectiveness, she indicated this is a promising area for research.

Wilson and Renner (1969) looked at the significant difference in "essential science experiences" (observations, measurement, experiments, interpretation of data, and prediction) between two groups of teachers. One teacher group received training in the Science Curriculum Improvement Study (SCIS), the other teacher group did not receive any instruction in SCIS methods and materials, or any other "new" approaches to elementary science instruction. An area of interest for Wilson and Renner was the type of student questions asked by SCIS and non-SCIS trained teachers; they were particularly interested in those questions which may give the student a chance to develop "rational powers" and improve the ability to think--specifically the use of higher order questions such as analytical questions. Wilson and Renner used the terms "inquiry" and "discovery" as they described new approaches in instruction and looked for these practices through multiple, direct classroom observations. The essential science experiences (data) were tabulated by observers who also used Bloom's Taxonomy was used as a reference check for categorizing the types of questions asked: Recognition, Recall, Demonstration of Skill, Comprehension, Analysis, and Synthesis.

The results were that the non-SCIS teachers used more recall/recognition questions and provided only limited opportunities for students to participate in the essential science experiences. SCIS-trained teachers asked higher order questions involving analysis and synthesis and provided twice as many essential science experiences as non-SCIS trained teachers. Instruction by SCIS teachers showed more skill-type questions, indicating they believed science is more like a skill subject rather than a body of knowledge (facts) to be memorized. SCIS teachers asked a total of 49% more questions. Wilson and Renner offered a subjective comment that the SCIS-trained teachers seem more excited and enthusiastic about science teaching.

Pempek and Blick (1969) focused on teacher attitudes and behaviors in light of the 1960's emphasis on dissemination and publication of science curriculum projects. They indicated there was little independent evaluation of the massive science education efforts other than "teacher acceptance seems to determine the success of any curriculum." Because Pempek and Blick believed that 20-50% of all students might be affected by the projects at some time during their schooling, they suggested more evaluation was needed.

Three major curriculum programs were part of the Pempek and Blick study: Elementary School Science (ESS), Science, A Process Approach (SAPA), and Science Curriculum Improvement Study (SCIS). The data instruments used were the Pempek Teacher Behavior Checklist, which measured teacher behavior as viewed by students, and the Pempek Teacher Attitude Scale, which measured teacher attitude toward science, science teaching and scientists. Results from the experimental group showed a significant difference in positive attitudes toward science (pre-test/post-test); the control group did not show this difference. They found attitudes of teachers with the weakest science background have the most change, teachers with a stronger science background have the least change, and self-contained science classroom teachers showed the most change as compared to teachers working in a departmentalized setting.

The 1970s

Perkes (1971) looked at the Elementary Science Study (ESS) program through a study of two groups of ESS-trained teachers during the teacher's first contractual year.

Both groups were given different instructions: one group was required to follow the pedagogical format of the curriculum project and the other group did not have that requirement imposed on their instructional style. Consequently, the participating teachers who were not required to follow the pedagogical format were allowed total control over their science instructional practices. This enabled Perkes to examine if teachers would continue to use the ESS pedagogy even if it was not required.

Comparison of the mean frequency scores on selected teaching behaviors showed that the content presented in science methods classes (which were supposed to teach "how to teach") did not transfer to the classroom. In reality, teachers taught the way they were taught. Similarly, this investigation showed that if the desired teaching behaviors important in new inquiry-based curriculum were to be realized, the teacher must follow the pedagogical directives of the program.

Bybee (1971, 1974) wrote about children's and youth's perceptions regarding effective science elementary and secondary teachers. In the secondary science education study, Bybee reported that all groups of students rate adequacy of relations with students in class and enthusiasm in working with students as the top characteristics of effective science teachers. In the elementary science education study, Bybee looked at the broad categories of teaching interactions: (1) teacher knowledge and organization of subject matter, (2) adequacy of personal relations with students in science class, (3) adequacy of plans and procedures in science class, (4) teacher enthusiasm in working with science students, and (5) techniques or methods of teaching elementary science.

The elementary survey was completed by forty-three elementary students, thirty-eight pre-service teachers with no teaching experience, twenty pre-service teachers with teaching experience, forty-three elementary in-service teachers from urban and suburban areas and thirty-three in-service teachers from rural areas. The results of the survey provided an extensive list of characteristics of the ideal elementary science teacher categorized by the five major teaching interactions. The number one and two ranked characteristics reported for the ideal elementary science teacher (for all survey groups) was (1) Adequacy of Relations with Students and (2) Enthusiasm in Working with Students. Bybee believed the elementary survey uncovered a "complex set of behaviors related to interpersonal relationships" and may be a very necessary component of elementary science teacher education.

Battaglini, Sr., Pirkl, and Horner (1975) looked at the reform of the College of Saint Teresa science program for elementary education majors. The College of Saint Teresa program (1969-1970) stressed involving pre-service teachers in quality, inquiry-approach science instruction rather than the traditional lecture-style courses. The focus was on sharing the richness of science as well as creating and sustaining curiosity about science. Later in the same year, Taylor and Armstrong (1975) looked at individual personality factors in pre-service teachers which were possible indicators of a positive attitude toward activity centered versus textbook centered instruction. Using an instrument called the Predicted Role Measure and a SCIS motion picture with the Catell's 16 Personality Factor Inventory, Taylor and Armstrong concluded they could predict which pre-service teachers were more likely to teach inquiry or hands-on science.

Barufaldi, Huntsberger, and Lazarowitz (1976) looked at 146 pre-service teachers' attitudes before and after completion of an elementary science methods course using a modified form of the Inquiry Science Teaching Strategies (ISTS) instrument. The results showed that there was a more favorable attitude after completion of the subject methods course. The authors indicated that in future research they will try to isolate the most significant factors contributing to attitude change.

Also in 1976, Nimmer investigated how elementary teachers learn to use their science curricula. Using a questionnaire mailed to 700 elementary teachers in South Dakota, Nebraska, Minnesota and Iowa, Nimmer discovered that most teachers (58.3%) learned the curriculum as they use it; he further stated that if teachers were well-prepared, this may be adequate. Results also showed that 68% of teachers who used NSF-supported curricula often learned how to use it in a workshop setting while teachers who used non-NSF supported curricula usually learned how to use it as they teach it (54.1%).

In 1977, James P. Barufaldi, Lowell J. Bethel and William G. Lamb published another study on the effects of a science methods course. The authors used a non-randomized, equivalent control group, pre/post design with three treatment groups. The instrument used was the View of Science (Hillis, 1975). The philosophical view studied was that of viewing science as tentative and scientific knowledge as uncertain--this philosophy is considered important to the objective of inquiry teaching. The authors believed this view affects a student's view of science.

It was concluded that a science methods course emphasizing inquiry-based teaching strategies and using a "hands-on" approach does promote the desired philosophical view. Using the ISTS instrument, Lazarowitz, Barufaldi, and Huntsberger (1978) continued along this line of research by comparing the attitudes of secondary science student teachers and elementary science education majors toward the inquiry approach to science teaching. Questions included: (1) Are secondary science student teachers (SSST) and elementary science education majors (ESEM) changing their attitudes toward inquiry at the end of the methods courses? (2) Is there a relationship between demographic and background variables of SSST and ESEM and their attitudes toward inquiry.

The study, which included 44 SSST and 98 ESEM using pre/post ISTS instruments, showed that both secondary and elementary teachers' attitudes toward inquiry were significantly improved after an appropriate methods course, but the improvement was related to different variables. Elementary science education majors' attitudes were closely related to their educational coursework, while secondary science student teachers' attitudes were closely related to their science background.

DeRose, Lockard, and Paldy (1979) reported that the classroom teacher is the key to an effective science program. They also note that elementary science was still a significant problem area and improved science teacher preparation, both pre-service and in-service, was an important concern.

Fitch and Fisher (1979) posed several questions related to the "state of the art in science education in Illinois schools." Some of their questions were:

1. What is the predominant elementary school science curriculum?
2. Is the curriculum textbook-based or it is a "hands-on alphabet" program?
3. Are teachers prepared to teach the courses being taught?
4. What are teacher's concerns about science instruction?
5. How much science is taught?
6. What sources of assistance are available?

With these questions in mind, the purpose of their research was to identify: (1) Time spent teaching science, (2) Elementary school science curricular programs in use, (3) Obstacles to science teaching, and (4) Sources of assistance for improving science education

Finding inadequate instruments to answer their questions, a questionnaire was developed by the Illinois Science Education Cooperative. In the area of time spent teaching science in grades K-6, there was a range of 58.5 minutes per week to 205 minutes per week, respectively. The curriculum used in most schools was textbook-based (72.5%). Some schools were using NSF-supported programs (27.5%) such as ESS, SCIS and SAPA I and II. The most commonly reported obstacle to the teaching of science was the teachers' lack of science background; second to that was inadequate facilities; third was lack of materials, equipment and supplies. Teachers participating in this study identified sources of assistance as being school or district based, followed by publishers and universities, and other schools. Another area reported was the per pupil expenditure for science instruction, which ranged from zero to $3.00/student for a three year period.

The 1980s

In 1980, Rowe reported on the status of science education. In this article she shared the following statistics:

- Time spent on science is down to 17 minutes per week in grades K-3 and 28 minutes per week in grades 4-6.
- Physical science knowledge has declined for 9-13 year olds.
- Teachers report science (and social studies) are not very important and create problems for teachers.

- Expenditures for science equipment and materials is minimal.
- Teachers say science is increasingly complex and too difficult for students.
- Teachers also report that although younger students are interested in science, they lose interest over time.

In this "heads-up" article, Mary Budd Rowe appealed to teachers to help protect and nurture quality science education programs.

Morrisey (1981) claimed that more attention should be paid to those individuals who are going to teach elementary school. He said that prospective teachers background characteristics and attitudes toward science and science teaching should be investigated as a screening process and stated this is no different a demand than made in the cognitive domain.

In 1982, Franz and Enochs looked at the preparation of elementary science teachers and examined certification requirements across the United States. They reported that only twelve states required more than six semester hours of science, and seventeen states required greater than zero but less than or equal to six hours. The remaining twenty-one states did not require any science for certification. In this particular time period, there was a "Back to Basics" movement where reading, writing, and mathematics were the emphasized subjects.

In 1983, Yager reported that according to the 1977 NAEP Third Assessment of Science, elementary students had more positive attitudes toward science because elementary teachers were more open to experimentation and discovery, and consequently sought more answers (with their students) than their secondary counterparts.

Teters, Gabel, and Geary (1984) shared the results of their survey to 252 teachers administered in one hundred K-6 schools. The survey results indicated that life science topics were more commonly taught, a hands-on approach was more commonly used in lower grades, a text-book approach was more popular in grades 4-6, and most instruction took place in large groups. When the teachers were asked what could be improved, the most common response was to provide science kits and teacher guides.

Koballa, and Crawley (1985) looked at reasons for negative attitudes toward science and asked if attitudes toward science could be improved. The authors suggested that a "teacher's attitude toward science is reflected in the time the teacher spends teaching science and the manner in which it is taught" (p. 228).

Schoeneberger and Russell (1986) provided case study information about four elementary teachers in two Canadian School Systems--Seaward and Trillium. Both case studies concluded that the state of science teaching was influenced by our culture's sense that it is relatively unimportant for children of elementary school age to study science. The authors state that elementary science is seen as being one of long-standing lack of emphasis, where science was seen as a "little frill" (p. 520).

The 1990s and beyond

Enochs and Riggs (1990) administered the Science Teaching Efficacy Belief Instrument (STEBI A) to 212 preservice elementary teachers. The gender distribution in this group was 184 females and 27 males This instrument was modified from an in-service orientation to a STEBI B, pre-service orientation. The study reported two main reasons why elementary teachers avoid teaching science: (1) self-perceived lack of ability and (2) negative external variables. Enoch and Riggs assert the results from this study could be used to positively attend to the belief systems of the teachers themselves as part of their teacher preparation program.

Shapley and Luttrell (1992) examined how hands-on science instruction might become the predominant method of delivery in a large metropolitan school district. The effectiveness of a mentor/colleague delivery system was tested using a pretest/posttest survey. Shapley and Luttrell noted the belief of other researchers (and themselves) that it is teachers who can create and maintain change within schools. Also noted was the need for teachers to be involved in creating the knowledge to achieve change, rather than top-down mandates. The need to improve teacher attitude toward science was shown as very important, however, it was not the only criterion needed to improve science instruction.

The basic premise of the Shapley and Luttrell study was that in order to facilitate and support change teachers, principals, and central office administrators must agree on and be involved with the change. Twenty-eight mentor teachers were nominated by 14 principals and all nominated teachers agreed to participate. Phase two of this study involved mentor teacher training and preparation of 72 grade-level, hands-on science lessons. These lessons were shared with other teachers by the mentor teachers. In order to receive copies of the hands-on science activity books, teachers agreed to attend 20 hours of grade-level, in-service training (conducted on Saturdays). The teachers were now called "colleague teachers." Subsequently, the colleague teachers delivered the prepared lessons to their students in an inquiry-based format. Over 200 teachers participated in the program but the data analysis was completed for only 96 teachers due to teacher attrition in the program. The evaluation instrument was a two-part survey. Part one of the survey looked at beliefs about teaching science and understanding the nature of science. An analysis of part one showed that positive changes occurred--meaning there were statistically significant improvement in the teachers' beliefs about teaching science and their understanding of science in the desired manner. Subset question analysis showed that after the program teachers: (a) felt better prepared to teach science content, (b) more at ease about being able to say they "did not know all the answers," (c) did not increase time spent on science, but did increase "hands-on" science instruction (this increase was over 100% for student-conducted investigations), and (d) spent more time on teacher demonstrations. Overall the instructional time spent on student investigations/teachers demonstrations increased from 34% to 62% of the total time spent on science.

In 1992, Tippins and Koballa, Jr. reported that the science taught in the 1990's will be determined by the design and quality of elementary science instructional frameworks.

Tippins and Koballa, Jr. also commented that for teacher educators these results point to the need to change teacher behavior by attending to the belief systems of teachers themselves--through the use of field experiences, peer teaching, and self-evaluation of microteaching.

The Finson, Beaver, and Hall (1992) research was conducted by science education faculty at Western Illinois University working in collaboration with the local Educational Service Center (ESC) in rural Illinois. The purpose of the project was to prepare mentor teachers and teacher teams to deliver quality math/science education programs to elementary (K-8) teachers in 40 school districts located in fifteen rural counties in west-central Illinois.

The targeted teacher groups were considered "hard to reach" because of their reluctance or inability to travel to regional and state science/mathematics conferences and staff development programs. The study involved 224 teachers in the 40 districts. The goals of the project were very extensive involving the acquisition of high quality materials, curriculum, professional development and teacher support networks.

Mentor teachers were utilized in this study. There were very specific selection criteria and training was regionalized into four geographic clusters. Mentors were trained first, then they returned to their schools and worked with their teacher teams who ultimately delivered the new curriculum ideas and activities to their students. Principals were encouraged to attend special sessions to keep administrators up-to-date on program activities. However, the principals' involvement was limited with only 65% of the principals participating and at the last principal session, only 15% of the principals attended.

An evaluation of the program was done using a 30-item pretest-posttest attitude and practices survey called the Assessment of Attitudes and Practices (AAP). The Science Teaching Self-Efficacy Belief Instrument (STEBI), which looked at the teacher's confidence for teaching science, was also administered in a pretest-posttest format to all teachers. An analysis of the data from both surveys showed: (1) improved attitude toward science, (2) improved science practices, (3) improved teacher confidence, and (4) (on the negative side) teachers did not change much in their expectations that student learning could be improved through the use of new program materials.

Barman and Shedd (1992) examined the design, implementation, and evaluation of a model K-6 teacher in-service program funded by the Indiana Commission for Higher

Education. The stated program goals were: (1) to "help teachers develop a rationale for teaching activity-oriented science," (2) introduce teachers "to the learning cycle teaching approach (exploration, concept introduction and concept application)," and (3) provide teachers "with a practical strategy for incorporating the approach in existing science materials."

Eighteen K-6 teachers from a central Indiana school district participated in the evaluation of this academic year in-service program. The evaluation looked at (a) participant attitude toward teaching science, (b) impact of the in-service program on the participants' science teaching, and (c) at the conclusion, participants' overall reaction to the program. Evaluation data was collected by interviews, classroom observations and review of lesson plan design. In phase one of the evaluation, prior to participation, teachers were asked to describe their expectations for the in-service program, their attitude toward science instruction and what place science had in their daily instructional plan. Also, participants were asked to prepare and submit a third-grade science lesson plan which was analyzed by the in-service program staff. Additionally, a random sample of classroom observations was conducted.

During the next phase of the evaluation, which was conducted during the middle and at the end of the program, participants were asked to develop two additional third-grade lesson plans. These lesson plans were statistically analyzed for differences between the newly prepared lessons and the lessons prepared prior to participation in the program. Also, post-program classroom observations were conducted in the previously visited classrooms.

Initial Interview questions were:

1. What expectations do you have of the program?

2. What would be the ideal science in-service workshop for you?

3. How do you feel about teaching science?

4. When is science taught in your classroom?

Responses yielded the following information:

1. Feelings of not being well-trained to teach science,

2. Teachers had a high interest and need for good hands-on science activities,

3. Teacher attitude about science determined when science was taught. Most teachers ranked science third or fourth after reading and mathematics but often it was taught as the last subject of the day,

4. Participants felt they did not have adequate equipment, financial support or time to prepare hands-on science,

5. Participants also reported that the teaching day did not have enough time to teach science.

After the program the same evaluation processes were conducted-participant interviews, lesson plan analysis, and classroom observations.

Final interview questions included:

1. Describe the in-service program. What did you like and dislike about it?

2. How do you feel about the learning cycle approach to teaching science?

3. What changes have you made in your teaching as a result of participation in the service program?

Responses yielded the following information:

1. Overwhelmingly, participants liked the program.

2. Teachers agreed with the philosophy of letting children "discover" their learning.

3. Participants enjoyed learning about children's cognitive development.

4. Some felt the program could have been shorter, but couldn't suggest anything to delete from the program to make it shorter.

5. The learning cycle instruction was useful and said it could be applied in their teaching (not just in science teaching).

6. Some teachers commented on the amount of change required.

7. Regarding specific change in their own teaching
   (a) more involved with student exploration
   (b) more involved with science lessons
   (c) more activity-focused rather than textbook-focused instruction

During classroom observations it was found there was a more equitable emphasis on content and concept development than in earlier observations. Students were seen providing multiple answers or solutions in problem solving activities. Teacher-student interactions were improved and there was more emphasis on student exploration during science activities. A statistical analysis of the pre-post program lesson plans showed significant differences in the design of the lessons.

The authors emphasized that participants were volunteers and approximately one-third had attended an in-service on critical thinking. Both elements could have influenced the evaluation data and program outcomes.

Shymansky (1992) examined the basic problems with traditional science teacher education programs and discussed the advantages to a constructivist approach to science teacher education. Shymansky's opening sentence presents a common education joke told between 1960-70--when many teacher education programs had professors teaching in a style not consistent with the reform programs and *lecturing* about *inquiry learning*. Shymansky stated that these methods were confusing to teachers. Some specific problems reported included the following: programs tended to focus on methods and tricks favoring immediate results, rather than the intellectual aspects of being a teacher; courses were fragmented and had shallow instruction; and content integration and appropriate pedagogy were lacking.

The author recommended that teacher education programs include instruction through the use of constructivist learning models and stated need for teachers to be able to restructure conceptual frameworks as any learner does. Shymansky stated that, if there is any merit to constructivist learning models, teachers need to experience knowledge construction in order to change their own practices.

Barrow and Sawanakunanont (1994) studied a group of K-6 elementary teachers one year after an extensive science in-service training program. Teachers self-reported science teaching frequency and strategies by submitting teacher logs and lesson plans for a four week period. The authors wanted to determine program sustainability after one year.

Fifty-two randomly sampled elementary teachers participated in the NSF-funded K-6 Science and Mathematics (KSAM). KSAM goals included increasing elementary students instruction in quality hands-on, process-based science and promoting positive attitudes in science and mathematics. KSAM sought to accomplish these goals through teacher in-service training and materials development in four areas: life science, physical science, earth science, and mathematics. The evaluation that followed immediately after the program showed positive, significant effects on both attitude and teaching methodologies.

One year later, thirty of the fifty-two participants agreed to participate in another four-week study using a daily log adapted from the Weiss' 1987 instrument. Twenty-one of the teachers completed this study. The results indicated that all teachers taught science frequently, using one or more of the in-service strategies previously used during the initial project. The median science instruction time was 11-15 hours, mode was 6-10 hours. However, six of the teachers taught science for more than 20 hours. The average number of days for science instruction in a four-week period was 16. During this time it was found that teachers used the following methods of instruction: hands-on (9 times), discussion (13 times), field trips (0), audiovisual (3), lecture (6), and testing (3). Barrow and Sawanakumanont concluded that KSAM had a significant effect on science instruction.

No pre-in-service data regarding science instruction teaching and methodology was given for this group of teachers. Also, out of the 52 participants, only 30 participants chose to be part of the follow-up study, and the other 22 participants indicated they were not teaching science at the time. No follow-up on the significance of this large number of non-science teaching participants was given. The authors indicate there is a need for more studies on long-term impact of teacher in-service programs and the elements of successful programs.

In 1995, Lopez and Tuomi found that science instruction is a lower priority for most elementary teachers. Elementary teachers reported that reading, writing, and arithmetic are the top priorities. It is also reported that standardized tests focus primarily on these three subjects.

The Haney and Lumpe (1995) article pointed to classroom teachers as the focus of school restructuring. The current science education reform efforts reviewed were Project 2061 (American Association for the Advancement of Science, 1989) and the

National Science Education Standards (National Research Council, 1996). The authors cite numerous references which identify teachers as the most important element in the reform efforts. Haney and Lumpe (1995) documented the importance of teacher beliefs and evidence of the perceived need for professional development as reported in surveys by classroom teachers.

Teachers lack teaching expertise in areas associated with science education reform. Reported science teaching methods included textbook-type instruction, group work, field trips, and demonstrations to a lesser degree. Other teachers reported they did not do lab activities and did not emphasize inquiry and problem solving. In most cases K-8 teachers stated they did not have a good background in science content.

In another needs assessment survey conducted by Haney and Lumpe (1995), the teachers reported a need for teacher leaders who were given release time and compensation for their extra work. Elementary teachers re-emphasized the need for more science content knowledge and hands-on activities.

Stohr-Hunt (1996) examined the relationship between the amount of time students spent experiencing hands-on science and standardized science achievement scores. The study involved 24,599 eighth grade students from 815 public and 237 private schools. Using a 25 item multiple-choice cognitive test developed by the Educational Testing Service (ETS), science knowledge and scientific reasoning ability (p. 104) were examined. The test looked at three types of knowledge: recall, comprehension and higher level comprehension. Stohr-Hunt defined higher level comprehension as all levels of Bloom's taxonomy above comprehension. The student scores were matched to a teacher questionnaire reporting the frequency of hands-on science experiences. Stohr-Hunt reported that students who experienced hands-on science instruction frequently, defined as daily or once a week, had statistically higher scores on science achievement than students who experienced hands-on science instruction infrequently, defined as once a month, less than once a month or never.

The author reported two limitations of this study: (1) an assumption of ANOVA was violated when teacher questionnaire data was matched to student scores and (2) the nature of the teacher data is self-report. And an important question posed through this research—"Is a paper and pencil science achievement test an appropriate measure of performance for hands-on science instruction?"

However, a positive correlation between hands-on science/inquiry science and science achievement was not always reported by other researchers. For example, although Wideen (1975) did find a positive correlation when he compared SAPA-instructed students to traditional/textbook-instructed students, one year later in a similar comparison study conducted by Davis, et.al. (1976), no difference was found in SAPA and traditional/textbook student scores. In another study done by Vanek and Montean (1977) ESS was compared to textbook instruction, the differences in science achievement were found to be not statistically significant. In a study comparing Intermediate Science Curriculum Study (ISCS) and textbook instruction, Atash and Dawson (1986) found that ISCS students scored significantly lower than students in the traditional science program.

In 1997, Briscoe and Peters noted that several methods show promise for improving the delivery of elementary science. These methods include changes in university courses, more involvement of pre-service teachers, improved in-service and professional development opportunities for practicing teachers, and specific support mechanisms for teacher support such as lead teachers.

The research of Eiriksson (1997) and Moore & Watson (1999) indicates that science educators are concerned that elementary pre-service teachers have anxiety about science as a subject and are reluctant to take science content courses. Both studies report this may be related to previous negative formal schooling experiences which most probably begins in elementary school. Jarrett (1999) supports this notion as he quotes Hawkins (1990) stating "the effect of poor science preparation in school" causes a "loop in history by which some children grow to be teachers, taught science little and poorly, they teach little and poorly" (Hawkins in Jarrett, 1999, p. 49). Jarrett further states that the results of a 1993 survey of elementary teachers shows while 76% of elementary teachers felt competent to teach reading/language arts, only 28% felt competent to teach science. And although 99% of the elementary teachers felt that hands-on/inquiry-driven activities should be an important part of science instruction, 25% of the teachers indicated that they were not well-prepared to use a "textbook as a resource." The textbook was the "primary instructional tool" (Jarrett, 1999, p. 49).

Tosun (2000) reports that "...simple transmission of more science content through a traditional lecture method is probably not 'the answer' nor is it the primary factor that determines the success of a (science) teacher" (p. 29). Tosun goes on to say that although science content knowledge has a questionable role in science teaching beliefs, self-efficacy about science teaching can be positively impacted through a pedagogical change in teacher preparation practices influencing teacher attitudes and beliefs toward science (p. 30).

In recent research by Roth & Tobin (2001), coteaching as a model for science teacher preparation is explored and has the potential for addressing attitude, content and pedagogy challenges. "Coteaching" teams a beginning teacher, cooperating teacher and university faculty. The coteaching idea addresses the theory-practice gap that is discussed in Keys & Bryan (2001). The premise is that through coteaching, problems associated with connecting theory and practice can be addressed in a "professional discourse community." For example, if a student knows that the expected role for science teachers in inquiry instruction is as a "facilitator" it is appropriate for new teachers and teacher candidates to learn about that role as part of the teacher preparation program. Coteaching allows for this to happen as the team works together in a school setting to deliver instruction. A noted bonus in coteaching is that university supervisors grow in their own "praxis and understanding of their teaching" (Roth & Tobin, 2001, p. 3).

SUMMARY OF THE LITERATURE

The literature cited here establishes a framework for this case study. First, Vygotsky's Zone of Proximal Development, Social Constructivism, and Lave & Wenger's Legitimate Peripheral Participation were described. These studies support teaching and learning and cross-cultural exchanges while emphasizing knowledge construction of individuals and groups. The validity of this framework was documented through multiple research studies.

Another body of literature central to this case study was that of the change process. The issues involved in educational change are shown to be predictable and often occur in stages. Furthermore, positive progression through the change process can be facilitated by others and has been systematized in the CBAM. Because science inquiry was the primary intervention in this case study, the understanding of it as content and pedagogy was critical. Science inquiry was operationally defined for this study through multiple research sources as well as explicitly defined by the American Association for the Advancement of Science: Project 2061 Benchmarks for Science Literacy publication and the National Research Council's National Science Education Standards. Finally, the historical perspective on science education reform was presented to illustrate the decades of extensive efforts made to change the way science is taught. It is believed that to fully understand current efforts in science education, the reader must be aware of the social, political, and educational motives of this movement.

CHAPTER III

RESEARCH DESIGN AND PROCEDURES

This chapter is organized into four sections:

1. Overall design.
2. The Knowing and Teaching Science: Just Do-It! course.
3. Sources of data.
4. Data analysis procedures.

OVERALL DESIGN

This study is qualitative research, specifically, a single case study with holistic design. The rationale for this single case is that the principal subject is a unique case. He is a senior research scientist-professor at a Research I University who is implementing science education reform with teacher candidates in a graduate level botany course. A qualitative research design was chosen because it provided a mechanism for an in-depth examination of complex and interrelated activities over a long period of time. This research provides a descriptive analysis of the processes and events, including all of the complex classroom interactions in the Knowing and Teaching Science: Just Do-It! course over a four-year period.

The challenges of this research paralleled those described in Marshall and Rossman (1995). The challenges were to (1) develop a conceptual framework...that is thorough and concise, (2) plan a design that is systematic and manageable, yet flexible, and (3) integrate these into a coherent document...(p. 5-6). A case study design was chosen because of "the desire to document individualized client outcomes..." (Patton, 1980, p. 64). Specifically, the researcher seeks to document the transformative experiences of the scientist-professor over the four-year period through an examination of a set of complex interactions. Also examined are the effects of these changes on the coursework and students. A model explored for these transformative experiences is an adaptation of a graphical representation of the Zone of Proximal Development with an X-axis of time and a Y-axis of capacity. This model provides a mechanism to visualize the stages of capacity development and presents a recursive loop for cycling back through the change process at progressively higher functional levels (Appendix 3.1). Text excerpts from the scientist-professor's journals indicate this cyclical process.

> For the Do-It course I probably spent more time after each period sort of mentally assessing and reflecting what had happened. That probably is preparatory for the next class. So it is sort of a reverse order preparation.
>
> I have some ideas about something that would work even better. I'm always trying to...I've never taught the Genetics and Society course in the same way. It has been modified quite substantially each year and I think this year it finally worked quite well so I may not make too many changes this time. But with the Do-It course, there's always some thought about how to do it better. I think it is logical. (Dr. Temple's Interview, 5/17/02)

An additional facet in this study and occurring over the same time period is the implementation of an intervention integral to the change process. The intervention, science inquiry, in this case study is well documented in the journals and interviews and is described in the research literature, however, no clear set of outcomes related to inquiry is being evaluated. Student outcomes are reported elsewhere and are the subject of other dissertations.

As reported by Yin (1994), case study methodology is appropriately used to: (1) explain complex causal links in real-life interventions, (2) describe the real-life context in which the intervention has occurred, (3) describe the intervention itself or (4) explore those situations in which the intervention being evaluated has no clear set of outcomes. This research clearly addresses items 1, 2, and 3. Item 1 is addressed relative to the political/historical nature of science education reform and social constructivism within the Teaching and Knowing Science: Just Do-It course. Item 2 is addressed within the social constructivist framework as related to Vygotsky's Zone of Proximal Development (societal interpretation) (Vygotsky, 1978) and Lave and Wenger's Legitimate Peripheral Participation (Lave & Wenger, 1991). Item 3 is addressed through the political/socio-historical perspective on science education reform since World War II.

Other characteristics of qualitative research utilized in this dissertation include the following: Qualitative research (1) is naturalistic, (2) draws upon multiple methods that respect the humanity of participants in the study, (3) is emergent and evolving, and 4) is interpretive. Furthermore this researcher is sensitive to her own role in the research as well as her personal biography and how this may shape the study. Therefore, the underlying methodology is an inductive design. . . " in that the researcher attempts to make sense of the situation without imposing preexisting expectations on the research setting" (Patton, p. 40).

Because of the extensive amount of data available for study the researcher chose to select three dominant themes that emerged from coding and analysis of the journals and interviews. These themes are (1) facilitating learning through dialogue, (2) becoming a reflective practitioner and (3) an emphasis on learning as opposed to teaching through interactions with and observations of students.

THE COURSE

The four-credit graduate course, Knowing and Teaching Science: Just Do-It! class, Botany 441/442 (531), was offered for the first time in the fall of 1997. Course syllabi from 1997 through 2000 are found in Appendix 3.2. There are scientist-professor transcript excerpts in Chapter IV which provide details on the course beginning with initial conversations between the Science Educator (College of Education) and himself (Botany Department).

The basic premise for the course design was that "in order to effectively teach science, one must be able to DO science!" Therefore, course design included an open inquiry science immersion experience for all students. Elements of the course intent taken from a compendium of syllabi are described below:

1. Students will have the opportunity to conduct hands-on investigative-based research with a unique "tool" that provides interest, flexibility, and speed in the laboratory setting.
2. Students will have ample opportunities to design and conduct experiments.
3. Students will have the opportunity to present scientific data.
4. Transfer to the classroom of the skills and processes learned in this course are a principal outcome.

SOURCES OF DATA

Because the University of Tennessee (UT) requires the submission of an Institutional Review Board (UT-IRB) Form B whenever using human subjects, all required UT-IRB submissions were submitted for the full term of the research project, 1997-2000, and have been updated though 2002. The data used in this study are described below.

Scientist-professor's Reflective Journals

The scientist-professor's reflective journals are a daily record of the events and interactions in the classroom. Furthermore, the journals provide a detailed record of the scientist-professor's thoughts about individual students, change process issues, and outside-of-classroom student discussions. The journals were prepared regularly, usually daily, by the scientist-professor using IBM via Voice, Version 8, a voice recognition software program. The IBM Via Voice software enabled the scientist-professor to make direct voice entries into his computer which were directly converted to text documents.

Students' Reflective Journals

The students reflective journals are individual daily records of the events and interactions in the Teaching and Knowing Science: Just Do-It class over the time period 1997-2000. Journal submissions were a requirement of the course and are a record of classroom events, questions, concerns and overall impressions. Some of the journal entries were prompted by questions asked by the Teaching and Knowing Science: Just Do-It Science Educator, to encourage the journaling process and solicit specific information. Other journal entries are purely "reflective" in nature. The course syllabi for 1997-2000 (Appendix 3.2) informed students prior to beginning the class that their journals would be collected and utilized for educational research purposes.

Initially, the student journals were handwritten submitted to the Teaching and Knowing Science: Just Do-It Science Educator who had the handwritten journals transferred to text files and then verified by each student for accuracy. Later, the students submitted their own computer-generated journals, thereby eliminating transcription.

Scientist-professor's Interviews

The scientist-professor interviews were conducted by the researcher. The interviews were designed to provide the scientist-professor an opportunity for additional reflection and commentary on his journals and on the student reported classroom events. A total of four interviews were conducted: September 7, 2001; December 12, 2001; January 7, 2002; and May 17, 2002. Two interview methods were used. Focused interviews solicited specific comments on the archival journals while open-ended interviews were used to gain additional insights on overall events and impressions. During the May, 2002, focused interview, stages of the change process as described in the Concerns Based Adoption Model (CBAM) were explored by the researcher and scientist-professor. During the same interview, specific perspectives of the scientist-professor on science inquiry were documented. On two separate occasions, additional conversations, not in interview format, were held to prepare for presentations at the Association for the Education of Teachers of Science (AETS) conference and the National Association for Research in Science Teaching (NARST) conference. These conversations often clarified and enhanced previous transcribed interviews, however, they are not reported as interview data and were not coded with HyperRESEARCH software.

The three types of data are used to provide a multiperspectival view of The Knowing and Teaching Science: Just Do-It course, specifically as it relates to the scientist-professor's personal, professional and instructional experiences, and changes over the research period.

DATA ANALYSIS PROCEDURES

The data was studied in regard to the major theories supporting the transformative changes of the scientist-professor: Social Constructivism, Zone of Proximal Development and Legitimate Peripheral Participation. A design scheme for data analysis is found in Appendix 3.3. Extensive data collection enabled triangulation to ensure the ethical validity of the research results; however, the amount of material collected between 1997-2000 and available for this research also posed the problem of volume of written text. Manually coding data is time intensive and awkward usually involving excised passages from transcripts, note cards or post-it notes and physically arranging and re-arranging the data several times. Consequently, this researcher chose to utilize technology through a software program designed to code qualitative research, HyperRESEARCH 2.03.

HyperRESEARCH 2.03 software, a product of ResearchWare, Inc., was used to code and analyze the reflective journals of the scientist-professor, the student's reflective Journals and the transcribed interviews. HyperRESEARCH software was developed by Dr. Sharlene Hesse-Biber, T. Scott Kinder and Paul Dupuis to assist in the analysis of qualitative data. The product was introduced in 1991.

The HyperRESEARCH 2.03 software provided a technology tool for reviewing, categorizing, tabulating, and recombining of the archival and interview information to prepare a rich descriptive case study. HyperRESEARCH 2.03 was chosen for data analysis because of the following features: (1) the ability to code and retrieve data, (2) assign custom codes, (3) analyze data at any time during the coding process, (4) assign multiple codes to a single source, (5) assign a single code to multiple sources and (6) add annotations to the source material. HyperRESEARCH 2.03 also allows researchers to systematically present data in an orderly and logical manner for examinations similar to statistical analysis and easily group codes according to theme.

Stages of analysis

The scientist and student journals and interviews were analyzed in the same manner by a single researcher.

1. All journals entries and interviews were studied in a hard copy format prior to the HyperRESEARCH coding process.

2. Each journal entry and interview was converted from Microsoft® Word 2000 to text files and saved into a dissertation documents text files folder by specific document type and date.

3. The researcher then reviewed each text file chronologically and established a system of codes for the text. There were no pre-established codes used as all codes were generated by the researcher.

4. An annotation feature of the HyperRESEARCH 2.03 software program enabled the researcher to establish operational definitions for each code. This annotation provided consistency in the coding process.

5. Following the coding process, the files were saved in a coded text files folder.

6. Then individual reports were generated for each journal entry and interview using the HyperRESEARCH 2.03 software. Each generated report was organized by the established codes. A sample page of a generated report is found in Appendix 3.4

7. In the next phase of analysis, emergent themes were established based upon the frequency of the documented codes. Some re-grouping of codes was done in a second (verification) reading of the journals and interviews.

8. Descriptive quotes from the journals and interviews were provided to support the codes and themes being analyzed.

9. All the codes established during the coding process were not used for final analysis. Some of the initial codes were regrouped in themes and, subsequently, only four codes are addressed in this dissertation.

10. A final discussion relates the emergent themes to the research reported in and underlying this dissertation.

11. An interpretive summary follows the discussion of the relationships between the themes and research.

CHAPTER IV

RESEARCH FINDINGS

ORGANIZATION OF THE CHAPTER

This chapter is organized into six sections:

1. The background information includes the academic preparation and career information on the principal subject of the case study, a brief description of the 1997-2000 student cohorts and a course description for the Knowing and Teaching Science: Just Do-It!
2. An overview of the codes used in this case study with descriptions.
3. A thematic and chronological presentation of the data 1997-2002. Data are presented in two forms. Years one through four (1997-2000) data are provided in the scientist-professor's Journals and, to a lesser degree, the student journals. Years five and six (2001-2002) data are from personal interviews with the scientist-professor.
4. Summary of the dominant themes.
5. Analysis of the relationship of the research to the emergent themes.
6. Summary of the findings.

BACKGROUND INFORMATION

Academic Preparation and Career Information on the Subject of the Case Study

The *principal subject* in this case study is a senior research scientist-professor who holds a Bachelor of Arts in Biology from Murray State University (Kentucky), a Master of Science in Botany from Ohio University (Athens) and a Doctor of Philosophy in Botany from the University of Massachusetts (Amherst). He is currently a Senior Professor of Botany at the University of Tennessee and has been at the University since 1979. The scientist-professor's credentials include numerous publications, research grants, a U. S. Patent and an Invention (C-Fern™). His vita lists his principal research areas as plant genetics and development, teaching materials development and science pedagogy. Communication with the scientist-professor confirmed that science pedagogy as a research interest was added in 1996. Since that time, he has participated in numerous national educational conferences. Conferences attended by the scientist-professor (as a participant and a presenter) included the Association for the Education of Teachers of Science (AETS), National Association for Research in Science Teaching (NARST), National Science Teachers Association (NSTA) and regional science education programs through the Appalachian Rural Systemic Initiative (ARSI), West Virginia Science Teachers Conference (WVSTA) and Tennessee Science Teachers Association (TSTA). The scientist-professor's vita is found in Appendix 4.1.

Student Cohort Information

Nearly all of the 1997-2000 participating students were fifth-year students who held an undergraduate degree in a biological science. The Botany 531, Knowing and

Teaching Science: Just Do It! class was designed for this classification of students. The total number of students in the cohort over the research study period was thirty-eight.

Course Description

Botany 531 is a four-credit course offered through a collaborative effort of the Botany Department and the College of Education. The course intent is based upon the premise that "in order to effectively teach science, one must be able to DO science." It is proposed that doing science should be inquiry-driven and that science inquiry would be enhanced and improved for pre-college students if their teachers have first-hand experience with inquiry during their teacher preparation program. Therefore, the course provides the opportunity for students to participate in a full inquiry with a living organism, the C-Fern™. Students engage in research, design and conduct experiments with the living organism, and have the opportunity to experiment with other materials much like a research scientist does.

Some of the course expectations include (1) presenting a scientific journal article, (2) presenting research on the 'unknown' material used in the class, (3) writing a research paper, (4) presenting a grade 7-12 inquiry-based lesson, (5) maintaining a laboratory notebook and a reflective journal, and (6) actively participating over the semester. The class schedule is flexible with students having almost unlimited access to their laboratory and materials over the semester. Course syllabi for 1997-2000 are found in Appendix 3.2.

OVERVIEW OF THE CODES WITH DESCRIPTORS

Figure 4.1 on page 69 was created with Inspiration Version 6 software and graphically displays the 1997-2000 data codes.

The master code list included references made by the scientist-professor that were initially coded with original code names and recorded on a master code list. In subsequent readings, the initial codes were refined and combined to make a total of four codes that were used in the final analysis of this case study. It should be noted that because of the course design, reflective practice pervades this study and was encouraged by journal writing. However, reflective practice was not specifically taught as a method nor was it an anticipated outcome of instruction.

As previously noted in the research design section, the coding process was done through the use of HyperRESEARCH 2.03 software and did not begin with pre-established codes. The codes were original descriptions that were established through multiple readings of the journals and interview transcripts.

The HyperRESEARCH 2.03 software has an annotation function for consistent coding by multiple readers (coders). Because the researcher was the only person coding the journals and interviews, the annotation feature was used to assure consistent coding over multiple readings. The four codes established through re-reading and re-grouping were: (1) facilitating student learning, (2) reflective practice, (3) educational research references, and (4) observation of students as related to learning.

Overview of the Major Thematic Codes with Descriptors

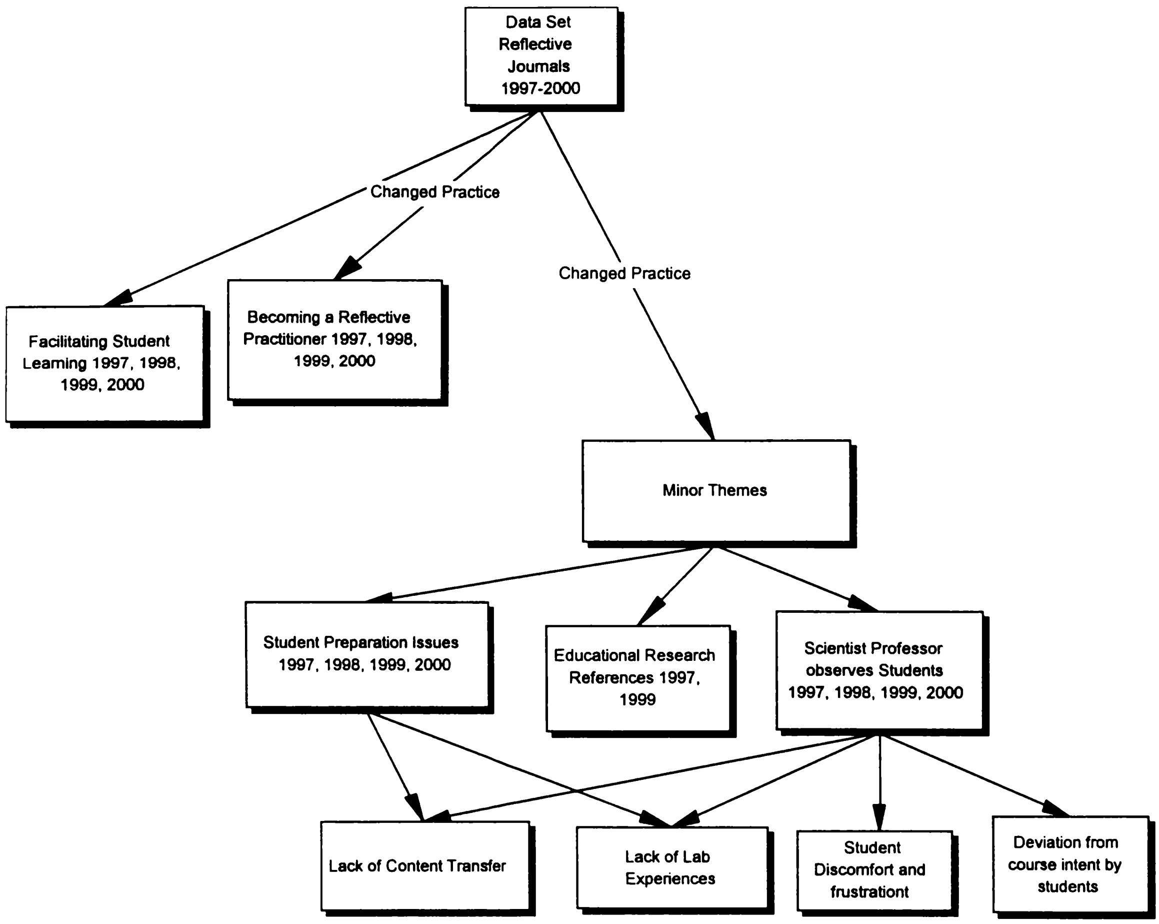


Figure 4.1. Overview of the Major Thematic Codes

Facilitating Student Learning

Facilitating student learning refers to the journal entries and interviews that exhibit specific characteristics of socially constructed meaning. References include descriptions of conversations with students that assisted the student(s) in constructing their own knowledge through dialogue, as opposed to knowledge delivery by monologue/lecture.

This code also refers to the journal entries and interviews that exhibit specific characteristics of an emphasis on student learning versus teaching and lecturing. Characteristics of this code are consistent with the National Science Education Standards (National Research Council, 1996) and changing emphasis areas where there is less emphasis on knowing scientific facts and information and more emphasis on the depth of understanding of scientific concepts and developing abilities of inquiry. Some specific examples of learning by inquiry are provided in Appendix 2.2.

Becoming a Reflective Practitioner (asking instructional self-questions)

Becoming a reflective practitioner refers to the journal entries and interviews that exhibit characteristics of reflective practice often with the scientist-professor asking instructional self-questions. This type of reflection dominates the scientist-professor's journals and interviews and overlaps with all of the other themes. Moreover, reflective practice in this study demonstrates an integration of the scientist-professor's thoughts and actions for the purpose of improving professional practice.

The nature of this study provided significant opportunity for reflection and was, in fact, encouraged through the preparation of journals. However, reflective practice methods used by the scientist-professor emerged as a dominant theme when the journal entries and interview transcripts were coded. The researcher had not considered this body of research in the original preparation of Chapter II and, thus, the associated research literature was added late in the dissertation process.

Scientist-professor Observes Student Behaviors as Related to Learning

This code refers to the journal entries and interviews in which the scientist-professor comments on his personal observations of students. The observations are recorded with a perspective on student learning and are instructionally relevant for the scientist-professor. This code is applied to references where the scientist-professor comments on the lack of student content knowledge transfer or deficits in laboratory experiences and techniques. For example, this code would be applied to journal entries and interviews that specifically address the issue of a student's failing to make what the scientist-professor believes are logical connections to previously acquired knowledge and new situations.

As these students are fifth year students possessing an undergraduate degree in one of the biological sciences, most of the references here are related to the student's science content preparation and laboratory techniques (and abilities) from their undergraduate program.

Educational Research References

The educational research references code refers to the journal entries and interviews in which the scientist-professor writes or speaks about educational research and reform issues such as science inquiry as a pedagogy, constructivism as a way of learning, etc., with regard to his professional practice and student learning.

THEMATIC AND CHRONOLOGICAL PRESENTATION OF DATA

The journal and interview data are organized by themes and presented chronologically. The scientist-professor's reflections on the introduction and overview of the course are provided in the first section. Student impressions of the course structure and requirements are also provided in that same section. The next four sections are the major themes: Facilitating Student Learning, Becoming a Reflective Practitioner, Observation of Student Behaviors as Related to Learning and Educational Research References.

Data are provided through selected and representative quotes from the journals of the scientist-professor and the students for the period 1997-2000. The scientist-professor's year 2000 journal entries are limited because he did not maintain regular journal entries due to the lower number of students in the Do-It! class and an increased workload. Data for the time period 2001-2002 is limited to transcribed interviews with the Scientist Professor.

Referenced Journal Entries and Interviews are provided in a consolidated format as Appendix 4.2.

Introduction and Course Overview

The Teaching (and Knowing) Science: Just Do It! course was first offered in the fall semester of 1997. Each year there was an introductory message from the scientist-professor, in which the course intent was shared and a scenario for inquiry studies was established. The first class consisted of seven students.

Introductory Message 1997

> In this first session I gave them a brief introduction of what the class was going to be about. And then the graduate student administered the testing portion to them. This took about one and one-half hours. After that they went back to the lab and we gave them more of an overview of what our intentions were. Then we let them loose. We gave them RN5 spores. The spores had been spiked with various types of "dirt" such as leaf debris, dead insect parts, dust, etc. We did this because the spores themselves were too clean to give much fungal contamination. This turned out to be a good move in that later on it made the students a little bit more broad minded and skeptical about exactly what they were dealing with. We used the concept of this being Sojourner dust from Mars, the recent Mars mission, which was sent back to earth to find out if it indeed, as suspected, was a living type of material. It's important at this point to emphasize to them that we don't necessarily want them to tell us WHAT the material is, but to tell us ABOUT it (Dr. Temple's Journal, 8/28/97).

Introductory Message 1998

> In today's class we had a total of 11 students enrolled. Dr. Taylor took them for approximately one hour for testing. After that, we introduced ourselves, the whole class, and then I briefly went into some aspects associated with the syllabus. I think everything was fairly well covered and I tried to make a special emphasis on the fact that it was a free form, collaborative type of experience and that we really wanted them to learn about how inquiry is done or how science is done and specifically gave them the idea that this was the kind of class type situation that one would hope would be in their classrooms in the future. Dr. Taylor helped things along by adding in very pertinent ideas or suggestions as we went through some of the introductory material...
>
> ...As opposed to last year, this class seemed to move along fairly well. There was not quite as much hesitancy and a feeling of 'what do we do now'. This may have been associated with a better introduction or it may be associated with the fact that the class has been offered before and some information was out and available about it. Also, Dr. Taylor may have given them more indication in her comments and obvious enthusiasm for the class. Nonetheless, it really did go out a little more smoothly and perhaps best said is that it seemed more comfortable for the students than

> last year. I did not get the idea that any of the students were excessively uncomfortable with the situation (Dr. Temple's Journal, 8/27/98).

Below are five student reflections about the course structure showing their initial frustration, challenges and concerns. One student also questions why this is the first time he has ever had this type of course opportunity in his four years of college.

> My initial thought about this class is that I am going to have to stretch my thinking capacity and go beyond the typical boundaries of a "normal" science class. Throughout school you are conditioned to perceive and think in a certain fashion about science. I believe it will take me a while to get a good grip on this class and, hopefully, I will challenge myself to do the best I possibly can in this class (Student: Eileen, 8/27/98).

> I expected him to begin...with "normal" teaching, taking up his prominent position in front, while the rest of his colleagues help him maybe to operate some equipment. ...he explained about the materials, and said "there is an unknown substance which you are required to find out about. Please go ahead." I thought he was joking...they gave no clues at all as to what we should do (Student: Kathy, 8/27/98).

> This is a very frustrating project for me because I don't know what to do. All I can think of is trying to grow it and see what it turns into. Perhaps if I had more lab experience in public school, I would be more prepared (Student: DeLaine, 8/27/98).

> I must admit that this class is going to be far more challenging than I first thought. One primary reason is that I was not expecting this format...I thought it would be a "How to teach labs class" structured similar to an education course...I am worried about how well I will do. This course has definitely hit upon my weak points and, therefore, I am positive it will help me later in my career (Student: Louise, 9/2/98).

> In all of my four years at UT for undergrad, only once was I, as part of a class, asked to design an experiment and that was in oceanography. We studied plankton and brainstormed on our goals, time constraints, weather conditions, available equipment and the relevance of our findings. Suddenly this seems really sad that only once in four years was I asked to come up with my own experiment (Student: Lucy, 8/27/98).

Introductory Message 1999

This was the third year of the Teaching (and Knowing) Science: Just Do It! class once again offered in the fall semester. This class had four students. The scientist-professor shared the following statement about the first class on August 27, 1999.

> Because of our lack of readiness with the testing portion, we have postponed the pretesting until next Tuesday. Consequently, for the first period I had all of the time available to talk to them and get them started. This seemed to work quite well. I spent perhaps 30 minutes going over the syllabus and talking about the philosophy of the course. I think they got the idea. I tried to be much more explicit than I had been in previous years. Then we talked about the unknown and now also set out some ground rules concerning outside sources of information. I indicated that since Dr. Summer. And I have in fact worked with the UNKNOWN for quite some time that they should not look under any web pages in biology that had our names on them. Also, I asked that they not look in any library research article sources that would contain our names. I indicated the point strongly that any other sources were fair game. I indicated that they would not necessarily need outside sources, but in the real research world outside sources are frequently consulted. So, I indicated that they could use textbooks or research articles and so on…
>
> …For the first time, this year I introduced what I called a culture pod. I indicated that this would substitute for what has frequently been requested, namely an incubator. So, by doing this I was quite assured of them using it but yet I didn't really tell them to use it. Consequently they ended up putting three dishes into the culture pod. The temperature inside should maintain itself at 4-6 degrees above room temperature. This should assure that there is very adequate growth of material, both spores and contaminants, by the second class on Tuesday (Dr. Temple's, Journal, 8/27/99).

A student responds to the first class.

> …this class is pretty exciting. I can't say I've ever been "just pushed over a cliff" the first day of class. All we know is that our unknown (which came in a little vial) is a living organism that was on the shuttle…
>
> …This is a hard concept for me. The end goal for me has always been to find out WHAT something is. That is why you look at its different

characteristics. In this class it seems that we could do an endless number of experiments—even after we know what it is. This should be interesting (Student: Lucy, Journal, 8/31/99).

Introductory Message 2000

This was the fourth year of the Teaching (and Knowing) Science: Just Do It! class once again offered in the fall semester. This year's class had six students, one of whom was a participant-observer. The scientist-professor shared the following thoughts about the introduction provided for this year's class.

> The TA administered their questionnaire during the first part of the class. She also scheduled videotaping sessions with them for 10 minutes each next Tuesday...
>
> After the TA administered her materials, I came into the class and went over the syllabus with them. I was careful to not talk too much about the process of science and how much this course would be different, because the TA's interview on Tuesday will touch on some of these issues. I did however give them a general overview of what the purpose of the course was in terms of giving them a genuine research experience than they normally would get in a laboratory type course. I brought in a cart full of materials and miscellaneous things, including some petri plates with agar and a pink growth pod. I briefly showed them the materials and said something about some things but made the point that these were some things that they may have some use for and that they should ask me for any additional supplies or materials that they need for the work that they're going to be doing. This seemed to go over pretty well. Then I presented 10 vials of the unknown to them. Two of the bottles were pre-sterilized and the others were not. I then emphasized that we wanted them to find out things about the unknown and I put it in the context of an unknown organism that had been found by an ecologist in a tropical rainforest. I told them that the National Science Foundation had provided the laboratory and funds that they were currently associated with to enable them to find out about the biology of this organism. I then left them.
>
> As I was leaving and talking with the Participant Observer and the TA in hallway I noticed that the students were holding the unknown up looking at it and having some limited conversation about it. I stuck my head in the door briefly and told them that the only absolute ground rule was that they could not search for information about the unknown using my name. They

> could, however, use any literature or textbook sources that they were interested in (Dr. Temple's Journal, 8/24/00).

One of the Do-It! '2000' class members shares her initial impressions about the introductory message from the scientist-professor.

> This class is very curious. I never really experienced anything like this before. Every other science class has been much more rigid, especially in the lab. Never was I given liberty to do most anything I want. (Student: Connie, 8/24/00)

Facilitating Student Learning

In 1997, there were twenty-five quotes related to facilitating student learning. This theme is demonstrated when the scientist-professor guides student discussions and participates in their construction of meaning without resorting to giving out the answer. The scientist-professor indicates that this type of change in teaching style is very difficult for him, especially in the first two years (1997-1998) of the course.

"Wait time" is particularly difficult for the scientist-professor and the Do-It! students as it is often longer than seconds or minutes. Wait time is occasionally several days. An example of this theme is provided below.

> *Facilitating student learning 1997*
>
> We have given them a very large amount of guidance and instruction through the feedback on their write-ups of an experiment and also during the journal club presentations. That should be enough. We need to sit it out and see how things develop from here. Maybe the best role we can play is one of encouraging students to actively pursue their planned experiments and to help them in time management...
>
> At our wrap up session, Kurt brought up some observations he had made and, in a nutshell, he seemed to be saying that we were on the verge of perhaps giving too much instruction to the students. I agree. We need to sit, watch, and observe and not get into a situation where we are telling the students how many replicates, what the controls are and so on. Dr.

> Summer seems to have a slightly higher tendency to do this than I do, although, we both are very tempted at this point to give more guidance and instruction to the students. We have given them a very large amount of guidance and instruction through the feedback on their write-ups of an experiment and also during the journal club presentations. That should be enough. We need to sit it out and see how things develop from here. Maybe the best role we can play is one of encouraging students to actively pursue their planned experiments and to help them in time management. That is, helping them get through all of the experiments that they would need to get through in a timely fashion. There is still time to allow them to set up an experiment that doesn't have a perfect design and analyze the results, and then hopefully, re-do the experiment with a better design. That was the original intention of the course and we don't want to lose that as our objective (Dr. Temple's Journal, 10/16/97).

Facilitating student learning 1998

In 1998, there were forty-one quotes related to facilitating student learning. Selected quotes about this theme are listed below. The first quote demonstrates the scientist-professor's reflections on his need to intervene to facilitate student learning.

> It is the first example this year and last year in which Dr. Summer and I both felt that we have to make a major correction in the way in which somebody was running an experiment. This is an excellent example of a situation where if we had not stepped in and just let them continue going their experimental results would be very questionable or invalid. It certainly would not have been conscionable to let them proceed without this correction. It will be interesting to see if any of their thoughts on this are recorded in their reflective journals (Dr. Temple's Journal, 9/29/98).

On the same date, the students report their impressions about experiencing this type of facilitated learning.

> We realized that we had not controlled all the variables as much as we had wanted to. The main problem was that after bleaching the unknown, we left it on top of our bench for 7-10 days before we used them. During this time, the same was exposed to light. So we essentially started off with all the samples exposed to light. We had not realized this! (Student: Kathy, 9/29/98).

> Dr. Temple talked about protocol today. He questioned our group about why they waited after sterilizing a sample before putting it on the Petri dish while the rest of us have sterilized a sample and immediately put (it) on our plate. He said that as a group we needed to do the same protocol... (Student: Nancy, 9/29/98).

> Dr. Temple and Dr. Summer indicated that our experiment was full of confounding variables...I'm not sure what everyone else is getting out of the course. I know that I personally go through periods of revelation and despair, but all in all I feel almost empowered by everything we've done thus far. I used to feel intimidated to even be in the building. I was trying to get certified (to teach) in biology and didn't have a clue about science. I was a huge hypocrite and felt everyone could sense it. Now I feel confident walking down the hall! I've made my own medium and I've put together a good (albeit, somewhat flawed) experiment. (Student: Nathan, 9/29/98).

Two other examples of facilitating student learning by the scientist-professor are listed below:

> Some mentioned the idea that if the lobes were bisexual then all they needed were themselves to reproduce and that would make sense if they were alone. So they were going well beyond the simple observational stage and actually making some interpretations based upon the biological contexts. I still have to push them into coming up with particular experiments to come to some sort of resolution about lobes versus grapes. The group...had an experiment going that fit into the discussion. They set up isolates, groups of five, and groups of 15. I asked that they analyze their data today and really think about. At the end of the day I looked at their results and the most striking thing was their failure to really use quantitative methods. Some of them had numbers but they did not put the numbers into any format such as averaging and graphing that would allow them to look at any sort of trend that was associated with the treatments. So, I encouraged them to do just that. To graph their data...this seems like another big leap for them to take. Very interesting! (Dr. Temple's Journal, 10/13/98).

> They got to the point of suggesting that there may be some sort of chemical signal that was controlling the formation of grapes. I talked with them about that idea for a short while, but they never fully came up with a method of testing for the presence of the chemical (a bioassay!). But I left them with the challenge. I felt that if I stayed around for much longer, I would give them too much information (Dr. Temple's Journal 10/20/98).

Facilitating student learning 1999

A common example of how the scientist-professor facilitates student learning is by asking questions. Students comment on this type of "questioning" instruction throughout the four-year period.

> I said things such as 'Is exchange made only after day six? How do you know when they do exchange something?' This finally convinced them that they would also set up experiments by separating spores (Dr. Temple's Journal, 9/9/99).

> I did not want to give them excessive help with their experiments but I did not want them to go off the deep. So I just hung around and listened. When I heard them talking about something that might be an experiment or that used a particular word or phrase that I thought could be used to develop a conversation, then I went to them, individual or group, and discussed it further mostly by asking questions (Dr. Temple's Journal, 9/28/99).

The following student comments emphasize their growth in understanding about science and the Do-It! course.

> At first we seemed to know nothing and now there is almost too much to comprehend. I'm more concerned about not having enough time to look at all the different specimens than anything. We have seen some very different things and have all had some neat experiment ideas. I don't know how we are going to test it all. You have all these new things, questions and ideas. I believe I need to slow down and try to focus on one thing and do a specific experiment on that one thing (Student: Lucy, 9/13/99).

However, as several students report, they are aware that Dr. Temple is there to guide them (facilitate their learning). One student hopes she can do this in her own classroom.

> It was really nice to have some guidance by Dr. Temple He reassured us that we weren't going on a wild goose chase, and said that he wouldn't let us get too far off track. That is exactly what I wanted to hear. He's not

> telling us the answer, he is just reassuring us that we are making progress (Student: Francisca, 9/15/99).

> I think it works well having Dr. Temple give us clues and ideas. He does not give us the answers but guides us to get our own answers. I hope that I will be able to do this with my students (Student: Nancy, 10/29/99).

> Slowly providing us with information has kept us paced in our progress. It is probably better than being spoon-fed all at once (Student: Nathan, 10/8/99).

And, toward the end of the semester, the following quote shows one student's increased confidence in her abilities to handle this type of course format.

> Our morale was absolutely boosted. We were a bit concerned that by the fourth day after inoculation, none of our unknown had germinated. We thought we had messed up during the bleaching process. However, Dr. Temple assured us that we needed to be focused and be alert to notice details (Student: Kathy, 11/12/99).

Facilitating student learning 2000

The following journal entry typifies a true facilitation of learning. The scientist-professor has established a community of learners who are engaged in knowledge construction. He describes spending most of his time in true facilitation activities.

> Just as in the last class, I spent most of this classroom session going up and down from my laboratory and assembling different things that they requested. It certainly kept me busy, and I did not have a lot of time to be in front of them. This bothered me, because I wanted to see more of what was going on with them. However, it also kept me out of the classroom and prevented me from leading them on too much at this critical time (Dr. Temple's Journal 9/19/00).

The following journal entries describe students who are engaged in problem solving and in their own learning process. Frustration is a strong undertone in most of the student journal entries, but it is clear that several of the students value this learning experience.

We are all VERY frustrated and down about this now. We have no idea how to even begin answering these questions they are asking. After Dr. Temple left the lab, we were scanning a biology book and found a life-cycle of a fern and it looks very, very similar to what we are seeing in this unknown. We are going to keep this to ourselves for a while (Student: Connie, 9/19/00).

I have written twenty pages of observations, but I feel as if I have nothing concrete and I am missing something big. We brainstormed on ways to test the unknown to reach useful data. Also, Dr. Temple wants us to be designing more complex experiments (Student: Tanya, 9/19/00).

He said that I wasn't clear in some areas, and I agree with him. I'll talk to him to see how I can be a clearer thinker and presenter. We also had a chance to ask each other questions about the research work we reported on, by far the hardest coming from Dr. Temple Questions like "what is the control? Is the sample size sufficient?" Those are really basic questions but so tough to decipher at times (Student: Frank, 9/19/00).

Dr. Temple kept asking about what control and sample sizes were used in the articles. I believe this was to guide us to begin asking and formulating more "in-depth" questions and hypotheses (Student: Sam, 9/19/00).

In today's class I attempted to get things moving in terms of speeding up their progress in understanding what is going on by doing what I have done in the past: giving them an opportunity to write down five questions apiece. I did this at the beginning of class and then came back 20 minutes later and compiled the questions in my office. Subsequently, I returned to the classroom and discussed the questions. As in previous years, most of the questions were answered by asking the students what they knew about it. In most cases the knowledge is there, but it is not assembled or is perhaps withheld because of a hesitancy and saying something that 'might be wrong' (Dr. Temple's Journal, 10/3/00).

We got to give Dr. Temple five questions each this week and he promised to answer them. However, we actually answered most of them together, instead of him just feeding us. I think that I really just need assurance on some of my assumptions and ideas. I am really ready to start my experiment on Monday (Student: Connie, 10/3/00).

Dr. Temple opened the class by allowing each of us to ask five questions about the unknown. Once the questions were compiled, we answered each other's questions with a little prompting (Student: Sam, 10/3/00).

> Although I did not receive the results I expected, I didn't let myself become discouraged and I thought about what this told us. It felt very good to make such a discovery. I was proud of my critical thinking abilities in conversation with the others in lab as well. I feel as if we are starting to put important pieces together (Student: Tanya, 10/3/00).

> This is a challenging process...I sometimes wish that the answers could be fed to me, but I totally feel that this process will help me in the future. I still believe that all science teachers should go through a class similar to this class (Student: Frank, 10/3/00).

However, at the end of the semester, two students have positive feelings about their results and their learning.

> I've taken my final data and am ready to write my report. I can't believe the results I got! Totally opposite from the expected...I guess that's science for you. Yes, it has been frustrating at times and hard to live with, but I made it (Student: Connie, 12/7/00).

> We just finished our presentations. It is hard to believe that this semester is already over. I put more time into this course, especially at the beginning, than many of my other classes...the course was dissimilar to all previous courses and experiences. However, I learned a lot about scientific thinking, experimental design, and the nature of science (Student: Tanya, 12/7/00).

Becoming a Reflective Practitioner

A dominant theme throughout this case study is reflective practice. The examples presented here are reflections that specifically address self-questioning about improved instructional practice and student learning.

Reflective practice 1998

> What are we doing different this year? Is the difference between this year and last year purely dependent upon the types of students that are in the course? Or are we doing something significantly different? Are the students perhaps a little bit more prepared for the concept of the course because of what Dr. Taylor has indicated to them? Did the five minute interview help to ease them into the situation? Is the absence of a video camera important? Last year, when Dr. Summer and I walked into the

room there was generally a hush that came over all the students. According to the TA they had been arguing quite a bit or perhaps expressing discontent with the course among themselves but that certainly does not seem to be the case this year. So, what are we doing differently??? (Dr. Temple's Journal, 9/3/98).

Reflective practice 1999

It is time for minimal interaction with me. In fact, I often feel that I'm getting in the way and should not even be in the classroom (Dr. Temple's Journal 10/19/99).

So, it indicated to me that he did in fact have a good visual recollection of what the organisms look like, but he just was not confident in his own ability to put it down on paper-without going to a textbook as a support. This is very interesting and I think as much of a learning experience for me as it was for the student (Dr. Temple's Journal, 11/18/99).

Reflective practice 2000

In my previous life as a researcher/teacher I would definitely have classified this individual as being a student that was not capable in this subject area. Also, I would have doubts, very serious doubts, about his qualifications concerning teaching. In my "new life" as a scientist/educator I am trying to be a bit more reflective about just what the student is presenting to me. Although I am trying to be more reflective, I still find myself with very strong thoughts about the student's qualifications. But, I wonder if he really should be in the classroom, ever? So, I will continue to be patient and try to work with him and see how things develop (Dr. Temple's Journal, 10/3/00).

Again, as in previous semesters, it is very obvious that this type of experience or something similar to it is absolutely necessary for the students. I am not certain, given the results from this semester, that this particular course format is the solution to the problem. However, I feel that it is a better approach than most laboratory experiences that students get as undergraduate research participants. More fundamentals on experimental design, or original thinking, tying things together at the conceptual level, etc. etc. are absolutely needed and are typically not provided in the research laboratory setting - at least at this level. Of course, there are exceptions. (Dr. Temple's Journal, 12/13/00)

The observation of students for the purpose of facilitating learning is evidenced in the following quotes. These observations are grouped chronologically and also, where appropriate, by the subcategories as described on the Inspiration graphic on page 69.

Scientist-professor Observes Student Behaviors as Related to Learning

Observations in 1997

Because the scientist-professor is engaged with the student learning, observations of their behaviors are critical to this study. Here the scientist-professor observes student *deviation from the course intent.*

> It also became clear during the period that the students knew some information about C-Fern. Apparently, they had seen the C-Fern information on the Botany bulletin board. Melody went to the internet and pulled up the C-Fern webpage. She read some information on the introduction pages, but did not really get very much information. At any rate, the students did learn that it, the C-Fern, was an aquatic plant and obviously that it was a fern. I don't really think that they learned much more than that, however. An interesting point was that they attempted as a group to keep their knowledge of the C-Fern a secret. For some reason they did not want us to know that they, in fact, knew something from another source. We will try to bring this out next Tuesday in class. (Dr. Temple's Journal, 9/18/97).

Again, because the delivery of the course is not a lecture to be absorbed by the students, the scientist-professor observes student behaviors. In this instance, he refers to the *lack of content transfer* (application) in new situations. This is a common theme over the four-year period.

> We tried to push them some in terms of their understanding of what was going on. However, we were somewhat disappointed because it does not seem that they have a very firm grasp on things. It was interesting that there were two general biology books in the lab that they had brought in themselves. They, some of them, were consulting these books and were looking at fern life cycles. There were pictures of gametophytes and terminology, etc., but it was interesting that the students really didn't

> analyze what was in the book deeply and relate it to what they were seeing under the microscope. For instance, there was a photograph of a gametophyte with many archegonia. The students didn't look for comparable structures in their own living material. We're very perplexed about this?? (Dr. Temple's Journal, 10/2/97)

The students also notice their *lack of transferable knowledge*. Here, one student expresses her own concern over her lack of prior knowledge on content and lack of comparable educational experiences.

> Today we spent the majority of class in a "lab meeting" atmosphere. Melody and I volunteered to go first. I wish we wouldn't have. Dr. Summer and Dr. Temple really drilled us with questions. We didn't think our discussion would have to be so in depth. I don't know about Melody, but I felt really stupid. I'm pretty sure that she felt the same way. They were asking us to explain what we meant by growth and how we would explain it to Dr. _______ in Russia who couldn't speak English.
>
> In a way this is good but I think it would be better for a research oriented class rather than an education one. Maybe if I had more experience dealing with science from his angle, I would feel more comfortable. I also am having a hard time relating to how this all ties into teaching a high school level class. I don't remember ever learning in this way. (Student: Lucy, 10/2/97)

The scientist-professor reports and acknowledges student discomfort beginning early in the semester. In this journal entry, he is specifically addressing "wait time."

> There were some more very uncomfortable (for all of us!) silent periods during this class. They need some extra encouragement next class!! (Dr. Temple's Journal, 9/2/97)

On the same day, one of the students, Bill, feels lost and uncomfortable with the course structure.

> Some of the things have sprouted and I suspect that they are some type of plants. Anyway, sometimes I feel totally lost in this class. After so many years of structured classes, to be involved in this just makes me feel lost. I really don't know which way to go. I guess the main problem is initiation for all of us. It seems no one knows what to do and when someone comes

> up with an idea everybody likes it. I guess it is because no one has a clue. We accept ideas even though they may not be useful. At this point in time though, any idea is welcomed to start the class. (Student: Bill, 9/2/97)

Observations in 1998

Again, the scientist-professor refers to the lack of student *transfer of knowledge* in new situations. The following two journal entries indicate that the scientist-professor is learning about the content knowledge base of these students. All of the students have successfully completed four years of content training in the biological sciences (at this same university!).

> We tried to relate this to the concept of eggs and sperm but they didn't grab a hold of the idea and this sort of dropped away in the conversation. This was very curious. (Dr. Temple's Journal, 9/15/98)

> The notable things about anything that we might call a deficiency in them as a whole are the following: a hesitancy to come up with formal experimental designs, their failure to recognize the very simple but appropriate questions that they're asking, their hesitancy to initiate experiments with an adequate number of replicas and backup dishes. Also, they are generally not well versed, at least in a practical sense, in the idea defining how they were going to measure something, how they were going to represent (data), and essentially how they were going to generate data sets. (Dr. Temple's Journal, 9/15/98)

The scientist-professor observes student *deviation from the course intent.*

> The presentation by Ian was a shock! He began by handing out a relatively long paper that was basically a review of some of the literature that Dr. Summer and I have generated on C-Fern. This was a pure violation of the initial instructions…but he didn't seem to realize it. He also had intermixed with this some of his own "experiments," although they really aren't very much of experiments. He handed out this paper to everyone and as I was glancing through it decided that the best thing to do was to end his presentation. (Dr. Temple's Journal, 10/27/98).

The scientist-professor observes students as he checks for understanding.

> A variety of questions were asked and the responses were generally quite good. They have come to a partial and certainly incomplete understanding of the organism at this point, but it seemed that most of their observations were well taken. They are, in fact, making some very keen observations such as the organism does not appear to need a carbon source in the medium and, therefore, it seems to be photosynthetic. (Dr. Temple's Journal, 9/10/98)

Observations in 1999

The scientist-professor is aware that students are uncomfortable with their situation and concerned they are going in the wrong direction with their experiments.

> At this point, they still seem to be wary that they may be going off in false direction, and I wanted to be sure that they understood that I would not give them incorrect information nor would I let them go hopelessly down a dead end of an investigation. (Dr. Temple's Journal, 10/5/99)

Observations in 2000

This comment by the scientist-professor recognizes that the students have a lack of experimental design experience and limited laboratory work.

> Also, it is interesting (and not surprising) that the boys set up a single petri plate and a single pot of soil to do their "experiment." Let's hope that there are really dramatic changes in what they are doing by the time they get finished with the course and before they get into the classroom. (Dr. Temple's Journal 8/24/00)

And, once again, the scientist-professor acknowledges the lack of content knowledge of one of the students.

> I do not think Frank is equipped to teach in the classroom. He has serious deficiencies both in terms of content as well as in his conceptual understanding of the subject material at a basic level. Added to this, his complete lack of any ability to really ask questions and design effective experiments to answer them makes him highly deficient in terms of ever teaching in an inquiry based setting. For his final research paper on C-Fern, we went through approximately five drafts of the paper. In the final

> draft, I awarded him 10 of 20. It was very thin both grammatically as well as in its overall structure. Very, very frustrating! (Dr. Temple's Journal 12/13/00).

However, wherever appropriate, the scientist-professor also makes sure to encourage the students.

> So, I congratulated them on a series of good observations and encouraged them to be sure that they wrote things down. I also pointed out in our general conversations any instances where they suggested experiments and had at least a glimmer of some type of hypothesis. This seems to be quite necessary at this point. The students are not sophisticated enough or comfortable enough in their dealing with open-ended research to know when in fact they do have a particular hypothesis or when they have observations that should be noted (Dr. Temple's Journal 8/29/00).

Educational Research References

The scientist-professor refers to his knowledge of the education literature and, specifically, to constructivism as a teaching methodology.

References in 1997

> At the end of all other presentations, I offered to be a sort of secretary and to list the various terms that were discussed on the board. The following terms were included: germination, growth (size), developmental stage, control, treatment, quantitative, replicate, graph, observations, data, percent, design, presentation, hypothesis, gametophyte, sporophyte, sea horses, egg, sperm, fertilization, haploid, diploid, gametangia, hermaphrodite, males archegonia, fan, banana, environmental impact...they had, in fact, generated all the definitions and descriptions represented by these terms. So, I think this was a demonstration of the type of constructivist method that they talk about in the education literature. That is, having terminology, after the students have experienced the observations and definitions. (Dr. Temple's Journal, 10/2/97)

References in 1999

Scientific inquiry

> In the remaining portion of the class, I emphasized to them that they had been gathering much information and many observations that were very interesting and, therefore, they were at a point where they had to begin more formalized assembly of the data as well as questions. In other words, falling more along the guidelines of formalized scientific inquiry (Dr. Temple's Journal, 9/21/99).

Constructivism

> Their (the Do-It! students) familiarity with the organism at this point is really quite good. It is quite amazing to see the many different aspects that they are familiar with concerning differentiation, sperm release, and so on. However, they are quite unable about putting it all together and coming up with an accurate description of what they're seeing. It is especially interesting that this exercise is forcing them to draw on their past knowledge (sketchy as it may be at this time) and they're having to deal with things at the sub-cellular level, the cellular level, the organism level, and interactions between organisms and defining the conditions for experiments. So it is really quite a thorough exercise on experimental aspects of biology. (Dr. Temple's Journal, 9/14/99)

Interviews with the Scientist-Professor 2001-2002

The scientist-professor stopped keeping a reflective journal after 2000. As previously reported, this was due to an increased workload and the limited number of students in the 2000 Do-It! course. He is not keeping a reflective journal for the fall 2002 class. Interviews with the scientist-professor occurred in 2001-2002. There were additional conversations with the scientist-professor in 2001-2002 related to preparation for two science education conference presentations (AETS and NARST).

The themes of the interviews are consistent with those identified in the 1997-2000 journals. The two dominant themes from his journals in 1997-2000 in the 2001-2002 interviews continue: becoming a reflective practitioner and facilitating student learning.

Becoming a reflective practitioner

Becoming a reflective practitioner is clearly indicated in this interview quote from December 12, 2001. The scientist-professor struggles with the amount of content he covers with his students, however, he also realizes that if he wants to change his practice, there is a need for more than superficial changes.

> The biggest change that I am really still struggling with is the idea that content has to be necessarily limited. The type of approach that I have taken for many, many years in teaching a course like general genetics would be to have a schedule of "x" number of chapters, sometimes two (chapters) a lecture, and pushing student through that material as quickly as I could. Also, with a mind to try to explain it fully and actually teach them something. But, nonetheless, it was really a content driven type of approach. And I'm still struggling with that. But I am, probably on a scale of 1 to 10 if I was a 1 before; I am probably about a 6 now in terms of my conscious balancing of content versus other things like understanding and dialogue in classes...
>
> What I had done the previous time (an earlier attempt at change), and I taught this course every other year, was to take a five-ten minute break in the middle of lecture—but it was still me. I would try to change pace and talk more conversationally and get some questions going and so on. And I finally woke up one morning and said 'Dr. Temple you've got to get yourself out of there to do something very different. . . not just me fast, me slow and then me fast again.' (Dr. Temple's Interview, 12/12/01)

Facilitating student learning

During the May 17, 2002 interview, the scientist-professor related the differences in traditional classes and the Do-It! class. The scientist-professor is familiar with Bloom's Taxonomy and was asked to look at the different levels of expectations for student learning in relation to a traditional class and a Do-It! class. The scientist-professor was provided with a Bloom's Taxonomy chart (Appendix 4.3) for this focused interview. When asked to comment on Level One of Bloom's Taxonomy with regard to a traditional science course and the Do-It! course, the scientist-professor responded:

> Well knowledge, up front, I would think the traditional course is more focused on that in terms of talking specific content knowledge, subject matter, ideas, events, places, information, recall—all that. And, I think, in the traditional course that's a large component of it. Whereas in the Do-It! course, it's a relatively small component. And the testing, the assessment in traditional courses is really based on content knowledge. We try to bring in things like comprehension and application and things, but the testing is really just targeted for knowledge recall. (Dr. Temple's Interview, 5/17/02)

Further, the scientist-professor states that Level Two of Bloom's Taxonomy (Comprehension) is something desired in a traditional class, but difficult to assess. However, in the Do-It! class, he recognizes that comprehension is emphasized.

> In the traditional course, comprehension is something we want them to have to be able to compare things and go through various levels of understanding. But, then again, that's presented more in the lecture and a lot of times it's very difficult to assess that comprehension in the traditional method. And to stick with comprehension, with the Do-It! type of course there's a large emphasis on comprehension, but in a different sense. It's comprehending--maybe the system that you're looking at in an experimental fashion, comprehension of the whole process of looking at things...(Dr. Temple's Interview, 5/17/02)

The scientist-professor indicates that Level Three (Application) and Level Four (Analysis) of Bloom's Taxonomy are usually not evident in a traditional class. When speaking of the traditional course and the Application and Analysis level, the scientist-professor reports that:

> The real application is having students able to sit down with something that is totally unfamiliar and use information and skills and thought processes that they've developed to address that new situation. And I think that's where we fail to really show (in a traditional class). I think the Do-

> It! class pushes at that as a major thing, because I don't tell them to come in with their minds blank. I tell them to come in with all of the knowledge they have, including knowledge that they can bring in through books and internet sources and so on. And in the traditional course, even though there's intent there, it's really seldom realized...other than through basic problem solving. That's a situation where we take them through a three-point test cross procedure. It is a fairly complicated logical procedure where they have to go through a thought process. More often than not, they just memorize the steps and the only new application that we have is maybe a different type of problem or a different type of organism or something but it's really the same thing. (Dr. Temple's Interview, 5/17/02)

At the highest levels of cognitive learning (as described in Bloom's Taxonomy,) the traditional class falls short of providing experiences with Synthesis or Evaluation. However, he reports that the Do-It! course does provide this opportunity.

> In a traditional course, there's very little opportunity, if any at all, to come up with an original concept to combine an application or analysis and then come up with some sort of really new viewpoint or question...With the Do-It! course, I think there are examples of that happening on a regular basis. Students, last semester for instance, by their observations of another phenomenon found that when you shined light on chloroplasts, they actually moved. When you put them in the dark, they moved some place else. So that was, for them, a totally new phenomenon that they discovered and described and actually had a very nice experiment designed to show that. Another one (student) did this wonderful thing with mealy bugs and basically their preference for surface texture and he came up with a way to combine his very crude observations with a way he could actually get a mealy bug to go through a maze. It was just a wonderful experiment. That's synthesis, that really puts things together. What a buzz it was for the kids too! (Dr. Temple's Interview, 5/17/02)

When the scientist-professor talks about Level 6 on Bloom's Taxonomy, evaluation, he contrasts the evaluation efforts of traditional students and Do-It! students.

> There's little of that (evaluation) in the traditional course. To give you a really good example...in my traditional course, I had a small component where the students would give these presentations in the middle of the lecture period and they would be like five or ten minute presentations. I had students grading them as peer graders and with very, very few exceptions (I think we went through 50 of these presentations...there were

> 50-70 students grading 50 presentations) and with very few exceptions, they gave them four out of four. It was very uncritical.
>
> ...in the non-traditional genetics course that I'm teaching (the Genetics and Society course) I actually had a peer-grading component in there. In a group within a group grading as well as peer grading, outside group grading... pretty complicated, they were critical (very nicely critical), it was probably the way it was structured, as well, because I had some oversight and I was actually "grading their grading." It turned out that they were very critical in many of the same ways that I was with certain presentations and papers.
>
> In the Do-It! class, I encourage them to critique (and this is verbally) right at the time...it's not anything that's done anonymously...encourage them to critique other presentations, experimental designs and so on. Not one hundred percent of them, but a good number of them actually do that quite well and are critical. That opportunity is not presented other places...to do some critical evaluation and judging. (Dr. Temple's Interview, 5/17/02)

In the interviews, the scientist-professor reflects on his continued struggle over eliminating some content for the benefit of greater conceptual understanding.

> For the Do-It! course, I probably spend more time after each period sort of mentally assessing and reflecting on what has happened. That probably was preparatory for the next class. So it was sort of a reverse order preparation. How this was affecting students was a big concern...and it still is. Am I ruining their life and careers? Are they going to be a doctor that kills so many because they don't know something? I pretty well dismissed that because I'm pretty well convinced that if you ask this question when you are teaching in the traditional way and really ask it, then you find out you weren't doing much for the kids. So I feel like I'm not hurting them. You know, first do no harm. (Dr. Temple's Interview 12/12/01)

Evidence of the scientist-professor's support from the science educator, Dr. Taylor, is also conveyed in the interviews. The following refers to the scientist-professor's progression through the different stages of the change process as experienced by him and as described in CBAM. The following quotes were responses to a question about the types of assistance he had as he transitioned through the stages.

> ...probably conversations with Dr. Taylor, not specifically about that (stages of change), but conversations about what are students really learning when you give them a lecture class and traditional assessment. Once you start thinking about that, give yourself this free line to really think about it you can honestly ask—"what are we doing for these kids?" That all came together and pretty much convinced me that I am doing no harm. (Dr. Temple's Interview, 5/17/02).

However, even in 2002, the scientist-professor has concerns over his professional change and a deep concern that he is somehow reducing his own content (and teaching) standards in spite of the fact that he believes he is doing no harm to the students.

> I am still frustrated and still dealing with it. I have a lingering fear that I have gone soft in my old age and now I have really dropped my standards ...what I thought were standards relative to content. The biggest change is stepping off that level of complacency and trying to figure out if you are, in fact, accomplishing anything in your teaching and how you might do better. But I am always worried that what I am doing now is not as rigorous, is deficient in content, and not effective. I know deep down...I think it is effective and it goes along with everything that I get from the college of education...that there is a better way of teaching and learning. But there is this deep fear that Dr. Temple's gone soft... (Dr. Temple's Interview, 12/12/01)

Even as he struggles with his own personal and professional change issues, the scientist-professor continues to have conversations with his colleagues about teaching and learning. In one case he shares that he challenges his colleagues on the amount of content retained by students.

> I really realize now and I challenge my colleagues on this now, a lot, and we all know this but we don't say it so much. If you have a semester's worth of material that you are presenting to the students and they have to jump these things called 'test hurdles' and put what they know down (on a test), we know that two weeks after the class they don't probably have recall on more than 20% of it (just a figure to pull out of the air). The material that I presented to them was absolutely the stuff that I know they will need for the GRE and so on and so forth...and that was really hammered in well. (Dr. Temple's Interview, 12/12/01)

In fact, the scientist-professor recalls his own experience with memorizing information for the short term. He states this is a very clear recollection after many years.

> I remember walking into this new lab at a new university, first-year doctoral student, masters in botany and this lab was working on the fern life cycle. I really wasn't quite sure what the fern life cycle was and this was after six years of undergraduate and graduate school and, so it's clear, now looking back I remember that time, going in there and fudging my way through conversations.
>
> Then I remember another issue in undergraduate school. The experience came in graduate school again at the doctoral level. I was looking at my initial research project and it turned out to be a mutant situation. It was actually a hybrid that had some very abnormal chromosome behavior in meiosis. Well, I never understood meiosis until I was analyzing that hybrid. And, I still remember when I was an undergraduate...I remembered meiosis as pmat (prophase, metaphase, anaphase...). I had to do that. It was just this 'little thing' that you use to memorize. That just tells that that level of knowledge that I had for many, many years was a memorization trick.
>
> ...I realized, after six years, that you really are understanding concepts (such as mitosis and meiosis) when you put your hands on them usually in a situation that's unfamiliar to you and you have to make sense out of it. To quote stuff that I'm reading now, it's just experiential learning. It's that precisely. (Dr. Temple's Interview, 5/17/02).

To a lesser degree the scientist-professor is concerned about what his colleagues think, but he continues to deal with skepticism in a positive manner and believes he is making progress with some other faculty members in his department.

> There has been some other dialogue with one of my colleagues who is now involved with the Scholars in the Schools program here at UT. We've had what you might call friendly arguments about the whole idea between content and pedagogy and what he's doing and thinks he's doing and so on. These have been some wonderful conversations; we've probably had about three to four in the last year, some of them quite loud in the main office. But he (the colleague) is coming across, slowly, and is now thinking more that well maybe we can drop some of the content and

> do other things...When I say coming across, he's not as combative in our conversations. We would have conversations like, 'well, look; our way of doing things has worked for many, many years. Look at all the Ph.D.'s and physicians we've turned out' and my question was 'what percent of (all the) students were those Ph.D.'s and physician end products and where were all the other ones (students) and do you know if you did anything effective with them?' So bringing up things like that has more than anything made him think about what he's doing and made him look at the class rather than looking at the top 10-20%...looking at it more as a group of individuals that are all going to go on and do something...paying more attention to educating the other 80%. (Dr. Temple's Interview, 12/12/01)

In fact, this same idea is documented in Reinventing Undergraduate Education: A Blueprint for America's Research Universities (Kenny, 1998), a report prepared for the Boyer Commission on Educating Undergraduates written by Robert W. Kenny (President, State University of New York at Stony Brook). A quote closely aligned to the scientist-professor's position follows.

> Universities take great pleasure in proclaiming how many of their undergraduates win Rhodes or other prestigious scholarships and how many are accepted at the most selective graduate schools, but while those achievements are lauded, too many students are left alone to pursue them. And the baccalaureate students who are not in the running for any kind of distinction may get little or no attention. (Kenny, 1998)

Also the scientist-professor shares his ideas in regard to influencing others at the University through bringing up issues about teaching at faculty meetings.

> And, I have frequently asked the question, 'well how do we know that we are good teachers?' And people grumble about that a little bit. Usually the response is that we get good student feedback, students like us, like the course. And then I still ask the same question—how do we know we are good teachers?...So there is a constant effort on my part to get some dialogue in the department going, but it's very limited. It is tough to get that dialogue going. (Dr. Temple's Interview, 5/17/02).

When asked if there was any advice he would like to share with other university professors considering making a similar change in their instructional style, the scientist-professor offered several comments. First, he indicated this type of change might not be appropriate for new faculty seeking to establish themselves (and their reputation) within a Research I university setting or for those seeking tenure. He believes he was able to make this change because of his established research and publishing reputation, his longevity and tenure with the university, and his strong desire to make this change even if criticized.

When asked if there was anything he would like to share about his personal change in instructional practice, the scientist-professor shared this:

> Oh, gosh, it is hard to teach. It is easy to lecture. You know we are all brought up in a research seminar mode and basically our teaching, I think, is largely a research seminar that is modified to a classroom situation and maybe extended to 75 minutes. But it is all based on that. So, when you change out of that lecture format and actually try to teach—I say that a little sarcastically but with some meaning behind it—it is very difficult. (Dr. Temple's Interview, 12/12/01).

SUMMARY OF THE DOMINANT THEMES

Two dominant themes associated with changed practice emerged from the 1997-2000 data. Those themes were facilitating student learning and becoming a reflective practitioner. Two other less frequently used themes, associated with changed practice, were also identified. Figure 4.2 illustrates the major and minor themes found in this case study and the reference dates for each theme.

The four themes have been operationally defined in this chapter on pages 76, 83, and 84. Throughout the research study period, 1997-2000, the dominant themes persisted. These themes were also found in the 2001-2002 interviews and conversations. The emergent themes align with the literature cited in Chapter II and are presented in the analysis.

Of the lesser codes, the scientist-professor's constant observance of student behaviors and how he dealt with those observations and related their behaviors to learning is the most significant in this case study.

Major and Minor Themes

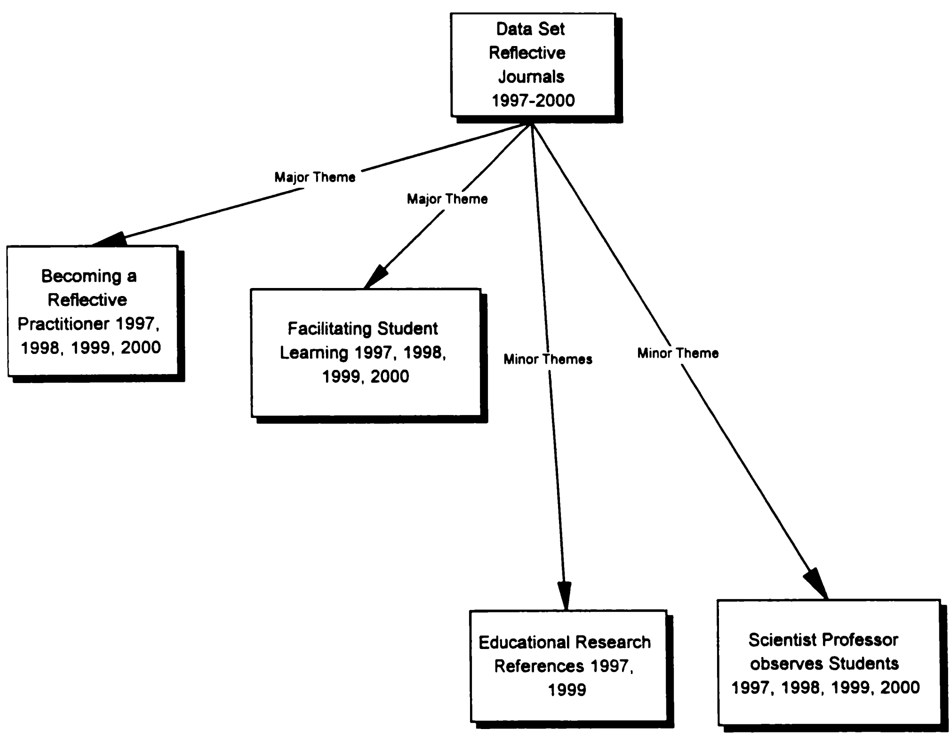


Figure 4.2 Major and Minor Themes

ANALYSIS: THE EMERGENT THEMES AND RESEARCH

The Change Process

The initial involvement with Dr. Taylor began as an interest in and a need for assistance with an educational component of a National Science Foundation grant.

> It was obvious that we needed some contact with somebody that could give us feedback on the pedagogical aspects of what we were doing. That led to contacting Dr. Taylor...we had a conversation and in that conversation she brought up the idea of her feeling that students weren't getting adequate research experiences (Dr. Temple's Interview, 1/3/02).

Prior to his need for assistance and Dr. Temple's and Dr. Taylor's first conversation, he reports that he was a "0" on the CBAM scale of Stages of Concern (Appendix 2.1) with regard to changing his teaching pedagogy. Following that first conversation his level of concern advanced to a Stage "4" (Consequence) as he considered the impact of a new pedagogy on his students. Since that time, the scientist-professors reports that he is comfortable with his new teaching style and is now functioning at the CBAM Stages 5 and 6 (Collaborating and Refocusing). His collaboration with the college of education continues and he is now attempting to influence other science faculty. His Refocusing efforts continue through the Do-It! course, a Genetics and Society course and, most recently, a new freshman course offered for the first time in fall 2002.

The scientist-professor's Reflective Journals and Interviews document a change in academic perspective and pedagogy over the four-year period and some evolution in instructional design for the class. This change is also evidenced in the course syllabi through the addition of rubrics. The scientist-professor reports finding personal and professional rewards in teaching rather than lecturing, although he admits that really teaching is much more difficult than lecturing.

Moreover, the scientist-professor's conversations with other faculty members discussing the effectiveness of traditional teaching methods and about making any instructional change also meets with the common change phenomena: "change is resisted." According to his December 12, 2001 interview, some of the resistance, although it is shared in "wonderful conversations," has, on occasion, been "quite loud."

Assistance through Change by LPP and ZPD

The dominant themes clearly indicate that the scientist-professor is supported through the change process by the science educator. This support comes through assistance as described in the theoretical frameworks of Zone of Proximal Development (ZPD) and Legitimate Peripheral Practice (LPP). ZPD and LPP are discussed in Chapter II on pages 21 and 23. The following quote from the scientist-professor supports the concept of LPP (Lave & Wenger, 1991) and ZPD (Vygotsky, 1978) as the science educator assisted the scientist-professor through the change process.

> Dr. Taylor was a major influence in sort of pushing me down this path, but because it's so different from what I'd been through traditionally, I still have these reservations. There are all kinds of opportunity for me to wonder and question what I'm doing. (I wonder) whether I'm doing it properly, or whether I'm doing it right, or if it's even the right thing to do? Dr. Taylor has been a good source of feedback in that sense. She sat in on a few of my courses in the alternative genetics course, Genetics and Society, and, at that time, I was really having some doubts as to whether or not I was totally going off the deep end. But she would really provide some comments and encouragement, gave me enough confidence that I was doing something meaningful that I've carried on with it. (Dr. Temple's Interview, 5/17/02)

The change process literature is also validated throughout this study. The four-year term of this study attests to the notion that change is complex, takes time, and must be supported. The recursive loop diagram for ZPD graphically shows how continuous improvement can be accomplished and also how adjustments can be systematically incorporated into this cycle.

The researcher asserts that the assistance provided by Dr. Taylor was absolutely necessary for the scientist-professor as he moved forward in the instructional change process. Furthermore, the scientist-professor's May 17, 2002, comment "...I still have these reservations (about what he is doing)" validates the need for continued support because "change takes time" (Hord, et al, 1987).

The assistance provided to the scientist-professor, especially in Stage I of the recursive loop, was from Dr. Taylor, the science educator. It is asserted that the scientist-professor moved forward into Stages II and III through personal "reflection on action and reflection in action" regarding his instructional practice (Schon, 1983). However, the assistance available throughout this time from Dr. Taylor greatly facilitated the scientist-professor's growth through ZPD. As Dr. Taylor brings the scientist-professor deeper into the culture of education, he recognizes the importance of the collaboration with her in the interview excerpt below.

> In order to effect change, you have to have a meshing some way. You have to be interconnected between the two cultures. And, that's usually like any other thing in a collaborative arrangement; one would have to come up with a collaborative arrangement of mutual respect, something that works. I think that's what Dr. Taylor and I have...

> ...you just can't take any old scientist and any old College of Ed person and put them together and expect anything to come of it. It has to be a good match. What makes a good match is—who knows? (Dr. Temple's Interview, 5/17/02).

The mechanism for assistance through collaboration is further illustrated in the Tharp and Gallimore (1988) diagram of the Recursive Loop of the Zone of Proximal Development in Figure 4.3.

The researcher asserts that the following assistance is offered in Stages I and II in the change process.

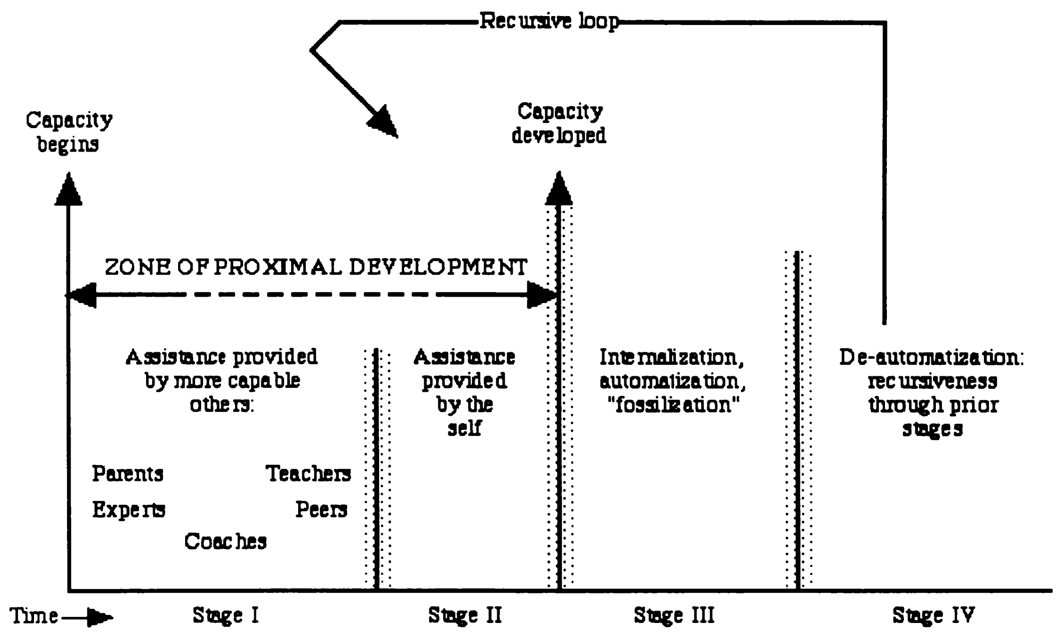
Stage I	Assistance:	Science Educator to Scientist-Professor Scientist-Professor to Do-It! Students Science Educator to Do-It! Students
Stage II	Assistance:	Scientist-Professor to self through reflection, observation of students, and previous experiences in the Do-It! course

Further, the researcher asserts that over time and at the higher levels of capacity, assistance continues to be available through Stages III and IV by cycling back through the 'recursive loop' and continuing to work with more capable others.

Facilitating Student Learning

Dr. Temple also reports changing his educational perspective from that of a "teaching curriculum" through preparation of lectures and monologues to that of dialogue and a "learning curriculum" for the Do-It! students (Lave & Wenger, p.97). This change is also shared in references to his class preparation being in "reverse order" as described in his interview of December 12, 2001. In this interview he describes his planning process as primarily a reflection of the previous class and his analysis of the level of

Graphic Representation of Recursive Loop of ZPD



(Tharp & Gallimore, 1988)

Figure 4.3. Recursive Loop of the Zone of Proximal Development

student learning. The instructional focus in the Do-It! course is shifted from teaching to learning with student learning being facilitated by thought provoking dialogue, often by the scientist-professor asking questions of the students.

Reflective Practice

A dominant area of inquiry that was discovered late in this study was that of reflective practice. The scientist-professor is constantly involved in analysis of his teaching and the student learning process. Again, as the scientist-professor's self-analysis and reflection is coupled with the (scaffolded) support from Dr. Taylor there is an opportunity for identifying personal theories and ideas about teaching and learning and improving professional practice.

Educational Research References

In his January 3, 2002, interview Dr. Temple states he has also become more aware of the importance of individual learning styles and their implication for instruction.

> One of the main things was getting out of the mindset that everyone in that class ought to be able to learn like I learned by just practicing more, learning how to take notes, and learning how to sit there and be receptive. That's probably the biggest lesson (I've learned) – realizing that some kids are never going to get to that stage because they don't do it (learn) that way. And that's also the big message that I try to get across to colleagues as well...which is very difficult. (Dr. Temple's Interview, 1/3/02)

The scientist-professor acknowledges the two different cultures of scientist and educators and the importance of those two cultures communicating with each other.

> There's no doubt that there are two cultures. I think that there's more familiarity of the scientists' culture by the College of Ed people than there is in reciprocal fashion because I think most of us dismiss the College of Ed type of culture as 'something else.' The connections between what we're doing here and what the ultimate product is for some of the students being teachers aren't really fully made by a lot of (science) faculty. So there's that disconnect, but I think the 'disconnect' is mostly this way (by the science faculty) to the College of Ed. The College of Ed, I think, has a realization that there's a different culture over here and that culture is what's producing the product that they have to work with to turn into teachers. So, because of that, they're fully cognizant of what is happening or not happening over here. In order to effect change, you have to have a meshing some way. There has to be interconnectedness between the two cultures. And that's usually like any other thing in a collaborative arrangement; one would have to come up with a collaborative arrangement of mutual respect, something that works. I think that's what Dr. Taylor and I have. I didn't know and I still don't know much about her subject material, the whole process of teaching and learning, but I have respect

> that she's a fairly good practitioner in that area. And probably equal with that is the recognition that she's passionate about it, really is concerned and wants to do things better, and wants us to do things better. So I think that mutual respect is hugely important. It has to be a working relationship that works, you just can't take any old scientist and any old College of Ed person and put them together and expect anything to come of it. It has to be a good match. What makes a good match is—who knows? Dr. Taylor and I are just so different that I sometimes say that it's my curiosity to try to figure out what the heck she's about. That is the thing, the glue and it may be (what makes a good match?), I don't know (Dr. Temple's Interview, 1/3/02).

As indicated in the Salish final report (1997), there are different perspectives on teacher preparation in the science (and mathematics) content area. The following research citation further supports the Salish findings and amplifies the scientist-professor's ideas about the need for improved collaboration and communication.

> In the United States, precollege teachers are educated in the same universities and colleges as the general population. In most institutions, two independent administrative units are involved: a college or school of education that offers courses on the psychological, social, and cultural aspects of teaching, and a college of arts and sciences (or equivalent) that provides instruction in various disciplines. Whereas the preparation of K-12 teachers may be central to faculty in education, such a function is often considered peripheral to the mission of a science department. Most faculties in the sciences take the position that responsibility for the professional development of teachers resides solely within colleges of education. This point of view ignores the fact that almost all the instruction that precollege teachers receive in the sciences takes place in science departments. If the current national effort toward reform in K-12 science education is to succeed, science faculty must take an active role in the preparation of teachers in their disciplines. (McDermott & Dewater, 2000, p. 241-242)

Application of the Innovation: Science Inquiry

The implementation of science inquiry in colleges and universities is the key to this study. Although the Benchmarks for Science Literacy (American Association for the

Advancement of Science, 1993) and National Science Education Standards (National Research Council, 1996) recommend inquiry as an important component for science education, little is done outside colleges of education to prepare teachers to implement inquiry in their own classrooms. The Knowing and Teaching Science: Just Do-It! course provides this experience. The research of Wiske (1994) speaks of the necessary "fundamental re-negotiation of intellectual authority" needed to conduct inquiry in a classroom. The scientist-professor calls this "relinquishing control." In fact, Roth (1993a) believes relinquishing control is necessary for student construction of knowledge and meaning.

The Knowing and Teaching Science: Just Do-It! Class has, what the Inquiry and the National Science Education Standards (NAS, 2000) calls, the essential features of classroom inquiry. Table 4.1 provides details on the variations of inquiry learning.

The research cited in the Boyer Report (Kenny, 1998) below demonstrates the importance of this work at the University of Tennessee and this type of experience for all students.

> The inquiry-based learning urged in this report requires a profound change in the way undergraduate teaching is structured. The traditional lecturing and note-taking, certified by periodic examinations, was created for a time when books were scarce and costly; lecturing to large audiences of students was an efficient means of creating several compendia of learning where only one existed before. The delivery system persisted into the present largely because it was familiar, easy, and required no imagination. But education by inquiry demands collaborative effort; traditional lecturing should not be the dominant mode of instruction in a research university (Kenny, 1998).

As shown in Table 4.1, the essential features of inquiry are those that require the student to (1) ask their own questions, (2) utilize evidence, (3) formulate their own explanations based upon evidence, (4) relate their explanations to scientific knowledge and (5) communicate the acquired knowledge. In the Do-It! course the student successes with inquiry are realized when the actions and activities are consistent with statements in the far left-hand column of the Essential Features of Classroom Inquiry table.

According to the Do-It! course introduction statements (1997-2000), Dr. Temple has the expectation that students pose their own questions. They are to 'learn more' about the organism, not identify it. The Do-It! course requires well-designed experiments which provide good data (evidence) to the questions posed. Experimental design, including the collection of data, is a primary focus. The Do-It! course requires that students use their data to give good descriptions of their organism. The Do-It! course also requires that students use prior knowledge to support their research. In many cases, this requires independent research from various sources. Furthermore, the knowledge they use must be integrated into their results. Early in each semester there are occasional guiding questions and assistance from the scientist-professor to direct students to sources. Also, the Do-It! students are occasionally guided through questioning by the scientist-professor toward good experimental design.

Lastly, the Do-It! course requires that students share their results to others. This means that students are able communicate and justify their results to others.

Table 4.1 Essential Features of Classroom Inquiry

Essential Features of Classroom Inquiry

Variations

More--------------------------------Amount of Learner Self-Direction------------------------Less

Less--------------------Amount of Direction from Teacher or Material---------------------More

1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies questions provided by teachers, materials or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Leaner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use and sharpen communication	Learner given steps and procedures for communication

Table 4.1. Adapted from Inquiry and the National Science Education Standards (NAS,2000), p. 29.

SUMMARY OF THE RESEARCH FINDINGS

The findings in this case study clearly show a pedagogical and philosophical change in the instructional practice of the scientist-professor. Clearly documented are facilitation of learning, reflective practice, attention to instructional pedagogy and social constructivism. Moreover, the scientist-professor's demonstrated changes are evident in other aspects of his professional work. Notable changes include the types of conferences he attends, his interest and involvement in educational research, his professional relationships outside of his department, dialogue as a critical component of instruction, the manner in which he prepares for instruction and the design and delivery of other modified courses. The change is so dramatic, even in his eyes, that he references his "previous life" prior to this change of practice.

One major finding regarding traditional course expectations and Do-It! course expectations is that students in the Do-It! Course have multiple opportunities to learn. The expectations for Do-It! students learning at higher cognitive levels, according to Bloom's Taxonomy, are greater. The opportunity to learn through multiple pedagogies is significantly increased.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the purpose of the study and the findings. Following a discussion of the purpose of the study, the chapter is organized in three sections:

(1) Findings

(2) Conclusions

(3) Recommendations

PURPOSE OF THE STUDY

As documented in Chapter II, an abundance of educational reform efforts have been funded and attempted over the past fifty years. In reality, little has changed. Many reform efforts have focused on professional development and assistance to veteran teachers through inservice programs. Public and private agencies continue to issue Requests for Proposals (RFPs) to solicit ideas to fund targeted professional development for veteran teachers. There is no question that teachers need opportunities for continuing education. In fact, the National Science Education Standards (NRC, 1996) devotes a full chapter to an elaboration of the *Standards for Professional Development for Teachers of Science.* However, the effectiveness of many professional development programs is questionable and there are research studies underway to study their effect. Science education researchers such as Thompson and Zeuli believe that for professional development to be effective, it must be a "transformative" experience for the participants (Thompson & Zeuli, 1997). They assert that effective professional development goes beyond additive features and "tinkering" on the fringes of instruction.

This case study sought to document the change experiences of a scientist-professor at a large Research I university as he facilitated inquiry instruction with preservice teachers. Specifically, this single case study documented the pedagogical philosophy and practice changes of the scientist-professor and his "transformative" experiences.

There were no pre-established research questions. This research concentrated on analysis of four years of journal entries (1997-2000) from the scientist-professor and the student participants and, subsequently, interviews (2001-2002) with the scientist-professor. The student's reflective journals (1997-2000) were correlated to the scientist-professor's reflections and interviews. During the analysis, theoretical frameworks were examined and compared to the emergent themes identified in the archival records as reported in Chapter IV.

Review of the Research Methods

To conduct this research, multiperspectival analyses and qualitative methods appropriate for a single case study were used. There were no expectations of generalizability to a larger group, no research questions to prove or disprove, and no theories to challenge or confirm. Because of the uniqueness of the research topic, a single case study is the most appropriate research method. Data sources utilized were the scientist-professor's journals (1997-2000) and interviews (2001-2002) and the Do-It student journals (1997-2000).

Transcripts from the identified sources were coded using HyperRESEARCH 2.03 software. There were no pre-established codes. The codes utilized were original and generated by the researcher as she examined the transcripts. Subsequent readings of the sources afforded the opportunity to regroup codes by major and minor occurrences, based upon frequency. Ultimately, two codes emerged as major themes and two codes were retained as minor themes. It is important to note that there is overlap of themes particularly in two areas, reflective practice and observation of students. This overlap exists because no other codes are possible without reflection by the scientist-professor and the scientist-professor's observation of students.

The data are presented chronologically and thematically in the text of Chapter IV. There are supporting quotations for each identified theme. Chronologically correlating quotes from the Do-It students are provided on either the exact dates of (or on dates closely following) scientist-professor's significant quotes. Exact date matches were not always possible because of the Do-It students' assignment schedule for journal entries. For reference purposes, the data are also presented by theme and in chronological order on a table at the end of Chapter IV.

FINDINGS

The Scientist-professor

Personal History

The scientist-professor's personal history as shared in the interview process is shown to have a significant influence on his interest in effective science pedagogy and educational reform. He has had good and bad experiences in his educational preparation. He cites and recalls his 8^{th} grade science experience as something that piqued his interest in biology and a high school experience that was not as positive. When asked about the origin of his interest in science, he said:

> It came from a very wonderful 8th grade teacher who was just extremely disciplined in his approach to having a class, but was also just wonderful as a biologist. He had us dissecting pigs and frogs and things in 8th grade. He was just wonderful. He got us out into the field. I remember a lot of those kinds of experiences, so much so, that when I finally took biology in high school in another school with another person, it was a huge let down. That 8th grade experience was really very formative (Dr. Temple's Interview, 12/12/01).

In a later conversation about the high school class referenced above he said:

> I can't remember anything about his class other than "thank God" I was still interested in biology after I took it. There is nothing that is memorable about that class (Dr. Temple's Interview, 1/3/02).

The researcher argues these two experiences influence his attention to course content and quality for his students. The scientist-professor is also very aware of his 'learning' or 'lack of learning' in each of the aforementioned classroom situations.

The scientist-professor reported issues of personal history when he was confronted with his own superficial understanding of science concepts–even as a graduate student. The following quote is also found in the data presentation in Chapter IV.

> Then I remember another thing in undergraduate school. The experience came in graduate school again at the doctoral level. I was looking at my initial research project and it turned out to be a mutant situation. It was actually a hybrid that had some very abnormal chromosome behavior in meiosis. Well, I never understood meiosis until I was analyzing that hybrid. And I still remember when I was an undergraduate...I remembered meiosis as pmat (prophase, metaphase, anaphase. . .). I had to do that. It was just this 'little thing' that you use to memorize. That just tells me that the level of knowledge that I had for many, many years was a memorization trick (Dr. Temple's Interview, 5/17/02).

The researcher argues that this experience focuses the scientist-professor's attention on deeper conceptual understanding, what <u>Science for All Americans</u> (American Association for the Advancement of Science, 1989) would call science literacy. It is asserted that the "instruction by questioning" strategies described by the scientist-professor in his journals and interviews and also by the Do-It students in their journals, is directly related to a desire for the Do-It students to experience a deeper understanding of basic concepts.

Alignment to Educational Research

The scientist-professor's educational philosophy for the Do-It course, as expressed in his interview statements, are very closely aligned to the findings and expectations reported in the Boyer Report. The scientist-professor as a scholar-teacher and the Do-It course structure fits well within the model described below.

> In the model the Commission proposes, scholar-teachers would treat the sites of their research as seminar rooms in which not only graduate students but undergraduates observe and participate in the process of both discovery and communication of knowledge. Those with knowledge and skills, regardless of their academic level, would practice those skills in the research enterprise and help to develop the proficiency of others. Even though few researchers ever escape the human temptation to compete for rewards, this model is collaborative, not competitive. It assumes that everybody—undergraduate, graduate student, and faculty member alike—is both a teacher and a researcher, that the educational-research process is one of discovery, not transmission, and that communication is an integral part of the shared enterprise (Kenny, 1998).

The major findings of this case study are presented in the Change and Evidence chart with a quotation(s) reference. An additional elaboration of the major findings follows the Table 5.1.

1. Comparison of and differences in expectations for the Do-It students and Dr. Temple's traditional students as referenced to Bloom's Taxonomy

When referencing Bloom's Taxonomy, the scientist-professor reports higher levels of learning expectations, abstractions, and questions for the Do-It students.

Table 5.1 Major Findings of Change with Examples of Evidence

Change	Evidence
1. Comparison of and differences in expectations for the Do-It students and Dr. Temple's traditional students as referenced to Bloom's Taxonomy	Appendix 4.2: Journal Entries and Interviews 01/02:II.A-G
2. Description of movement through the CBAM Stages of Concern	Appendix 4.2: Journal Entries and Interviews, 01/02:II.P, Appendix 5.1
3. Description of collaboration and support from the college of education	Appendix 4.2: Dr. Temple's Interview, 5/17/02
4. Self-identified description of 'previous life' from a researcher/teacher to a scientist/educator	Appendix 4.2: Journal Entries and Interviews: 00.III.A
5. Development of two other courses patterned after the Do-It course	Appendix 4.2: Dr. Temple's Interview, 12/12/01
6. Presentation at and participation in national and regional science education conferences	Analysis and summary of vita, summary in Chapter IV
7. Attempts to influence university colleagues regarding teaching and learning	Appendix 4.2: Dr. Temple's Interview, 12/12/01

This is documented in the Journal Entries and Interviews charts Journal Entries and Interviews 01/02.II.A-G on 5/17/02. Additionally, he reports there are additional opportunities for student learning which exist in the Do-It course and which are desirable, but not present, in the traditional classroom. For example, in the Do-It course there are opportunities for synthesis and evaluation by the students. He reports this opportunity is seldom the case in a traditional course.

2-3. Description of movement through the CBAM Stages of Concern and Description of collaboration and support from the college of education

The scientist-professor reports his personal change as described by the CBAM Stages of Concern in the 5/17/02 interview. His quotes describe the assistance he received from the science educator at several critical points over the four-year period. Additional evidence for the scientist-professor's progression through CBAM's Stages of Concern 0-6 is found in Appendix 5.1.

The researcher believes the science educator's professional interactions with and assistance to the scientist-professor contributes to the change process.

4. Self-identified description of 'previous life' from a researcher/teacher to a scientist/educator

This reference is particularly revealing because the scientist-professor self-reports as a different person within the scientist and educator world. He reads education research materials and reflects on his teaching. Moreover, he challenges colleagues about their own teaching and if their students are really "learning" science.

5. Design and delivery of two other courses patterned after the Do-It course

The scientist-professor has developed and is delivering a Genetics and Society course which was modified to include Do-It-type characteristics. Genetics and Society usually has a mixed group of students, non-majors and majors in biology. The scientist-professor has created a non-lecture approach for this content-heavy course and reports that it is working very well.

The scientist-professor has also recently negotiated the implementation of another inquiry-driven, Do-It-type course for incoming freshmen students. The course is alternative to the freshmen survey course in biology, which is traditionally "a broad overview of biology." The new freshmen course provides the students with "more actual experiences with doing science...getting away from the cookbook labs..." (Dr. Temple's, Interview 12/12/01). The scientist-professor plans to conduct a longitudinal study with this new group of undergraduate science students over their four-five years at the University. This course began fall semester 2002. This new course is consistent with changes as proposed in the Boyer Report.

> The first year of a university experience needs to provide new stimulation for intellectual growth and a firm grounding in inquiry-based learning and communication of information and ideas (Kenny, 1998).

6. Presentation at and participation in national and regional science education conferences

The scientist-professor's interest in science pedagogy has increased. This is shown through his current vita that has, since 1996, included science pedagogy as a research interest. Also, since 1996, the scientist-professor has been both a participant and a presenter at national and regional science education conferences. He has also co-authored numerous papers with science educators.

7. Attempts to influence university colleagues regarding teaching and learning

And, as previously quoted in Chapter IV, the scientist-professor is now attempting to facilitate change across his department. He is challenging his colleagues to pay closer attention to all students, not just those who are destined to go on for graduate studies or medical school. Although this is a new role for him, it is consistent with education reform at all levels. The quote from the Boyer Report (Kenny, 1998) on page 97 further supports the scientist-professor's work.

Relevant Findings

According to the data collected, the emergent themes of facilitating student learning and reflective practice were consistent. Over the four year period, there was a focus on: (1) dialogue (Love, 2002) and "questioning for instruction" between the Professor and the students as a means to understanding and increased conceptual knowledge, (2) students and groups of students collaborating to construct their own meaning and knowledge, and (3) attention to instructional improvement through the scientist-professor's reflective practice and (4) his constant attention to student behaviors. The scientist-professor established himself and remained a facilitator of learning, not the transmitter of knowledge. To maintain this position, he reported that he frequently had to refrain from "giving too much information to students." Often he left the classroom to accomplish this goal. The course emphasis was always on student learning, not on "transmission" teaching. This focus on student learning is directly correlated to his reference on "reverse order" (Dr. Temple's Interview, 12/12/01) preparation for the Do-It course. This could also be described as a "recursive loop" in building knowledge.

The continued, positive relationship and influence of the science-educator and the scientist-professor is seen as a powerful force in this study. All of these facets of the course design and of the scientist-professor's behaviors contribute to the results of the case study.

CONCLUSIONS

There is clear evidence that the scientist-professor experienced "transformative changes" over the study period 1997-2000. In fact, he readily aligns himself with this change and attempts to work with others on their instructional practice. Furthermore, the interviews conducted in 2001-2002 suggest that the change process is continuing. These statements are well-documented in the journals and interview quotes provided in this dissertation. Moreover, the research cited and archival data are closely aligned. The scientist-professor is now a participant in and consumer of educational research articles.

Evidence of dialogue (Love, 2002) for construction of knowledge between the scientist-professor and students is frequent. References to conversations between the scientist-professor and science educator imply that there is also pedagogical content knowledge being constructed at that level. The research cited and archival data are closely aligned.

A Personal Perspective

The Do-It course is a valuable addition to the University's teacher preparation program for several reasons. First, the National Science Education Standards (National Research Council, 1996) call for science teachers to provide inquiry experiences for their students. Teachers of science need to be prepared for this type of instruction during their preservice program. Second, science teachers need to experience science with and as a scientist (Melear, 1999). This means that science should be experienced…not just in a lecture hall, not learned only as vocabulary, and not only accountable at the vocabulary-driven "Knowledge" level as described in Bloom's Taxonomy. Science needs to be contextualized and comprehended. In most cases, science teachers need preparation to apply science concepts in new situations. The Do-It course offers the opportunity for that level of science instruction.

RECOMMENDATIONS

The historical overview of science education reform presented in Chapters I and II clearly shows that reform is a long-term process. This long-term position on reform is documented by the CBAM statement that "change takes time." From the research cited in Chapter II, this researcher argues that continuing to "re-teach or re-train" veteran teachers for both content and pedagogy through professional development efforts and is an expensive and somewhat misguided effort. There are decades of research as cited in Chapter II supporting this notion. With one notable exception, Biological Sciences Curriculum Studies (BSCS), few of the many curriculum or pedagogical reforms are still in existence.

The researcher believes there is need for fundamental changes in teacher preparation programs, especially in the way teachers are prepared in the science content area and in the type of pedagogy they experience in content preparation. By the time science teachers are ready to "teach" they may have had 16 years or more of "stand and deliver" pedagogy. And, more than likely, they will teach as they were taught. To break this cycle requires significant change at all levels. In this researcher's opinion, teachers need to have a Do-It type course in their teacher preparation program. Teachers need to understand the process of science beyond "Knowledge" level instruction in a college's or university's large lecture halls.

Areas for Further Investigation

Scientist Studies

As this was a single case study, unique in several regards, and not generalizable to a larger audience, more case studies should be done as other university faculty members attempt similar changes in course design and instructional delivery. The same theoretical framework might be used in these studies: reflective practice, facilitating student learning, etc. However, in this instance, the supports for change might come from another scientist, such as Dr. Temple, as well as from the college of education.

Other possibilities for data correlation might be student evaluations of the scientist's class, attitudinal changes of students, changes in students' understanding of the nature of science, follow-up of the students' selection of other courses with the same professor or another course with a similar format, changes in students' major field of studies, decisions about graduate school programs and so on. If GRE scores could be correlated in some fashion to students participating in inquiry-driven courses, this could make a powerful study.

College Student Studies

A second possibility for investigation is a four-year study of the students in the new freshman course being taught by the scientist-professor. Currently, P. J. Stinger-Barnes is evaluating this study and has initially entitled it "Undergraduate Student Response to Inquiry and Traditional Instruction During an Introductory Biology Course for Majors" (Stinger-Barnes, P.J., Work in Progress). Because the 24 students in this cohort were selected somewhat randomly from a large incoming class of approximately 500 students, a good study from that group holds promise. The student group could be followed through their undergraduate program with particular attention being given to attitudinal changes of students, changes in students' understanding of the nature of science, follow-up of the students' selection of other courses with the same professor or another course with a similar format, changes in students' major field of studies, decisions about graduate school programs, GRE scores, etc., similar to the study proposed above.

Another case study of the scientist-professor is also possible since the students in this cohort are not necessarily teacher candidates.

Do-It Teacher Follow-up Studies

A third and most interesting possibility is a longitudinal study of the Do-It graduates. This could be accomplished as either a single or multiple-case study of the classroom science teacher with their students. In a middle school or high school setting, the students of the Do-It teachers could keep reflective journals that could be used as data for triangulation or in another study such as achievement and understanding of the nature of science. Some studies of the Do-It graduates are underway.

Brown (2002) has recently conducted a longitudinal study on Do-It! graduates using two instruments used in the Salish I Research Collaborative Study, the Science Teacher Analysis Matrix (STAM) and the Teacher Pedagogical Philosophy Interview (TPPI). Her work focused on evaluation of inquiry in the teachers' classrooms, specifically looking at "espoused teaching beliefs and observable teaching style" (Brown, S., 2002).

Related Studies

Lunsford (2002) has completed a study of preservice science teachers who were enrolled in the Do-It! course. Lunsford's study included an evaluation of the increase in their inquiry skills and their ability to design and conduct successful experiments and use of an inscriptions rubric (Lunsford, B.E., 2002). A longitudinal study of the classroom implementation of inquiry and the types of experiments offered by this cohort of science teachers as they begin their teaching careers might be a valuable study.

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Appendices

National Science Foundation Timeline

April 3, 1944	Vannevar Bush is on the cover of Time Magazine as the "General of Physics"
November 17, 1944	President Roosevelt sends a letter to Vannaver Bush with postwar science questions
August 6, 1945	The atomic bomb nicknamed Little Boy is dropped on Hiroshima, Japan.
August 9, 1945	Fat Man, another atomic bomb, is dropped on Nagasaki, Japan.
August 15, 1945	Japan surrenders ending World War II.
October 9, 1945	Bureau of the Budget (BoB) states that the President and the BoB need scientific advice
August 1, 1946	The Department of the Navy Creates the Office of Naval Research
August 1, 1946	The Atomic Energy Act of 1946 creates the Atomic Energy Commission (AEC) to control nuclear energy development and explore peaceful uses of nuclear energy.
October 17, 1946	Establishment of the President's Scientific Research Board
July 22, 1947	The United States House and Senate pass legislation to create the National Science Foundation (NSF)
August 6, 1947	National Science Foundation Act of 1947 is vetoed by Harry S. Truman
August 20, 1947	Release of the 1st volume of Science and Public Policy: A Program for the Nation written by Steelman
September 13, 1948	Harry S. Truman proposes a national science policy at the opening session of AAAS's Centennial Meeting in Washington, D.C.

April 27, 1950	Final passage by House of Representatives of bill creating the National Science Foundation. The House passed the original bill on March 1.
April 28, 1950	Final passage of science bill by the Senate. Original Senate bill was passed on March 18.
May 10, 1950	National Science Foundation Act of 1950 signed by Harry S. Truman
September 27, 1950	NSF's first budget of $225,000 was approved by President Truman.
November 2, 1950	President Truman announced his appointments to the National Science Board.
December 12, 1950	The first meeting took place of the National Science Board in the White House.
May, 1951	NSF receives BoB's approval for a budget request of $13.5 million for fiscal 1952
October, 1951	Congress appropriates $3.5 million to NSF

Appendix 1.2

Fifteen Years After *A Nation at Risk*

General Findings

That Was Then: 1983	This is Now: 1998
International comparisons of student achievement reveal that on 19 academic tests American students were never first or second and, in comparison with other industrialized nations, were last seven times.	The recently released Third International Mathematics and Science Study (TIMSS) study shows that American 12th graders rank 19th out of 21 industrialized nations in mathematics achievement and 16th out of 21 countries in science.
Some 23 million American adults are functionally illiterate by the simplest tests of everyday reading, writing, and comprehension.	A 1992 survey estimated that 1/5 of the adult population has only rudimentary reading and writing skills. These adults can pick out key facts in a newspaper article, for example, but cannot draft a letter explaining an error on their credit card bill.
About 13% of all 17-year-olds in the United States can be considered functionally illiterate. Functional illiteracy among minority youth may run as high as 40%.	The literacy level of young adults ages 15-21 dropped more than 11 points from 1984 to 1992. 25% of 12th graders scored below "basic" in reading on the 1994 National Assessment of Educational Progress (NAEP).
The College Board's Scholastic Aptitude Tests (SAT) demonstrate a virtually unbroken decline from 1963 to 1980. Average verbal scores fell over 50 points and average mathematics scores dropped nearly 40 points.	SAT scores rose slightly from 1984 to 1995, gaining 2 points on the verbal test and 11 points in mathematics. The average combined score in 1995 (before "re-centering") was still 70 points lower than in 1963.
There was a steady decline in science achievement scores of U.S. 17-year-olds as measured by the National Assessment of Education Progress in 1969, 1973, and 1977.	The performance of 17-year-olds on the science portion of the National Assessment of Educational Progress has increased slightly since 1982, but the average in 1994 remained lower than in 1969.
Between 1975 and 1980, remedial mathematics courses in public 4-year colleges increased 72% and now constitute one-quarter of all mathematics courses taught in these institutions.	In 1995, nearly 30% of first-time college freshmen enrolled in at least one remedial course and 80% of all public 4-year universities offered remedial courses.
Business and military leaders complain that they are required to spend millions of dollars on costly remedial education and training programs in such basic skills as reading, writing, spelling, and computation	According to U.S. manufacturers, 40% of all 17-year—olds do not have the math skills and 60% lack the reading skills to hold down a production job at a manufacturing company.
Over half the population of gifted students do not match their tested ability with comparable achievement in school	U. S. physics and advanced mathematics students scored least among 16 nations on the "advanced" portion of the recent TIMSS test.

Findings Regarding Content

That Was Then: 1983	This is Now: 1998
Secondary school curricula have been homogenized, diluted, and diffused to the point that they no longer have a central purpose. In effect, we have a cafeteria style curriculum in which the appetizers and desserts can easily be mistaken for the main courses. Students have migrated from vocational and college preparatory programs to "general track" courses in large numbers. The proportion of students taking a general program of study has increased from 12% in 1964 to 42% in 1979.	High school graduates taking a "college prep" program of study rose from 9% in 1982 to 39% in 1994, while the percentage taking a vocational program dropped from 23% to 6%.
This curricular smorgasbord, combined with extensive student choice, explains a great deal about where we find ourselves today. We offer intermediate algebra, but only 31% of our recent high school graduates complete it; we offer French I, but only 13% complete it; and we offer geography, but only 16% complete it. Calculus is available in schools enrolling about 60% of all students, but only 6% of all students complete it.	In 1994, 58% of high school graduates passed Algebra II, only 18% passed French I, only 25% passed geography, and only 16% passed Calculus. In 1994, 39% of high school graduates had studied most of the "New Basics" (4 years of English, 3 years each of math, science, and social studies), up from 14% in 1982.

Findings Regarding Expectations

That Was Then: 1983	This is Now: 1998
The amount of homework for high school seniors has decreased (two-thirds report less than1 hour per night).	In 1966, 64% of high school seniors reported doing less than 1 hour of homework a night.
A 1980 State-by-State survey of high school diplomat requirements reveals that only eight States require high schools to offer foreign language instruction, but none requires students to take the courses. Thirty-five States require only 1 year of mathematics, and 36 require only 1 year of science for a diploma.	In 1996, only four States required students to take a foreign language in order to graduate. Twenty-six States required two or fewer years of mathematics, and 32 required 2 or fewer years of science.
In 13 States, 50% or more of the units required for high school graduation may be electives chosen by the student. Given this freedom to choose the substance of over half or more of their education, many students opt for less demanding personal service courses, such as bachelor living.	In 1994, only 41% of high school students' courses were required by States to be spent studying a core academic curriculum. The remaining amount was available for electives.
"Minimum competency" examinations (now required in 37 States) fall short of what is needed, as the "minimum" tends to become the "maximum," thus lowering educational standards for all.	By January 1998, 38 States had drafted academic standards in core subjects and 34 States used standards-based assessment of math and English. But scholars engaged by the Thomas B. Fordham Foundation found that only 1 state had truly rigorous and clear standards in English, 1 in history, 3 in geography, 3 in math, and 6 in science. Failing grades were earned by state standards as follows: 12 of 28 in English, 19 of 38 in history, 18 of 39 in geography, 16 of 48 in math, and 9 of 36 in science.

Findings Regarding Content

That Was Then: 1983	This is Now: 1998
In England and other industrialized countries, it is not unusual for academic high school students to spend 8 hours a day at school, 220 days per year. In the United States, by contrast, the typical school day lasts 6 hours and the school year in 180 days.	In 1991, the average school year in the U.S. was 178 days, 20 days shorter than the international average.
A study of the school week in the United States found that some schools provided students only 17 hours of academic instruction during the week, and the average school provided about 22.	The 1994 report of the National Commission on Time and Learning estimated that French, German, and Japanese students receive more than twice as much core academic instruction over four years as American students.
In most schools, the teaching of study skills is haphazard and unplanned. Consequently, many students complete high school and enter college without disciplined and systematic study habits.	A recent survey found that 76% of professors and 63% of employers believe that "a high school diploma is no guarantee that the typical student has learned the basics." Most judge students weak on skills needed to success in college or on the job.

Findings Regarding Teaching

That Was Then: 1983	This is Now: 1998
Half of the newly employed mathematics, science, and English teachers are not qualified to teach these subjects; fewer than one-third of U.S. high schools offer physics taught by qualified teachers.	In 1993-94, 40% of public high school science teachers had neither an undergraduate major nor minor in their main teaching field and 34% of public school math teachers did not major or minor in math or related fields. In 1990-91, 56% of high school students taking physical science were taught by out-of-field teachers, as were 27% of those taking mathematics and 21% of those taking English. Among public school academic teachers in schools where more than 40% of the students received free or reduced-price lunches, 47% had neither a college major nor minor in their main assignment fields.
Too many teachers are being drawn from the bottom quarter of graduating high school and college students.	SAT scores of prospective education majors rose from 807 in 1980 to 850 in 1992. However, they still trailed the national average for all students by 49 points.
Individual teachers have little influence in such critical professional decisions as, for example, textbook selection.	In 1990, 34% of teachers reported they had control over selecting textbooks, 36% reported control in selecting course content and topics, and 35% reported control in disciplining students.
The average salary after 12 years of teaching is only $17,000 per year.	The average public school teacher salary in 1996-97 was $38,509 (in 1996 dollars), up 12% in real terms from 1983.

Concerns and the Facilitation of Change

A first step in using concerns to guide interventions is to know what concerns the individuals have, especially their most intense concerns. The second step is to deliver interventions that might respond to those concerns. Unfortunately, there is no absolute set of universal prescriptions, but the following suggestions offer examples of interventions that might be useful.

Stage 0--Awareness Concerns

a. If possible, involve teachers in discussions and decisions about the innovation and its implementation.
b. Share enough information to arouse interest, but not so much that it overwhelms.
c. Acknowledge that a lack of awareness is expected and reasonable, and that no questions about the innovation are foolish.
d. Encourage unaware persons to talk with colleagues who know about the innovation.
e. Take steps to minimize gossip and inaccurate sharing of information about the innovation.

Stage 1--Informational Concerns

a. Provide clear and accurate information about the innovation.
b. Use a variety of ways to share information--verbally, in writing, and through any available media. Communicate with individuals and with small and large groups.
c. Have persons who have used the innovation in other settings visit with your teachers. Visits to user schools could also be arranged.
d. Help teachers see how the innovation relates to their current practices, both in regard to similarities and differences.
e. Be enthusiastic and enhance the visibility of others who are excited.

Stage 2--Personal Concerns

a. Legitimize the existence and expression of personal concerns. Knowing these concerns are common and that others have them can be comforting.
b. Use personal notes and conversations to provide encouragement and reinforce personal adequacy.
c. Connect these teachers with others whose personal concerns have diminished and who will be supportive.
d. Show how the innovation can be implemented sequentially rather than in one big leap. It is important to establish expectations that are attainable.

e. Do not push innovation use, but encourage and support it while maintaining expectations.

Stage 3--Management Concerns

a. Clarify the steps and components of the innovation. Information from innovation configurations will be helpful here.
b. Provide answers that address the small specific "how-to" issues that are so often the cause of management concerns.
c. Demonstrate exact and practical solutions to the logistical problems that contribute to these concerns.
d. Help teachers sequence specific activities and set timelines for their accomplishments.
e. Attend to the immediate demands of the innovation, not what will be or could be in the future.

Stage 4--Consequence Concerns

a. Provide these individuals with opportunities to visit other settings where the innovation is in use and to attend conferences on the topic.
b. Don't overlook these individuals. Give them positive feedback and needed support.
c. Find opportunities for these persons to share their skills with others.
d. Share with these persons information pertaining to the innovation.

Stage 5--Collaboration Concerns

a. Provide these individuals with opportunities to develop those skills necessary for working collaboratively.
b. Bring together those persons, both within and outside the school, who are interested in collaboration.
c. Help the collaborators establish reasonable expectations and guidelines for the collaborative effort.
d. Use these persons to provide technical assistance to others who need assistance.
e. Encourage the collaborators, but don't attempt to force collaboration on those who are not interested.

Stage 6--Refocusing Concerns

a. Respect and encourage the interest these persons have for finding a better way.
b. Help these individuals channel their ideas and energies in ways that will be productive rather than counterproductive.
c. Encourage these individuals to act on their concerns for program improvement.

d. Help these persons access the resources they may need to refine their ideas and put them into practice.

e. Be aware of and willing to accept the fact that these persons may replace or significantly modify the existing innovations.

Individuals do have concerns about change, and these concerns will have a powerful influence on the implementation of change. The CBAM offers several easy ways to identify these concerns. It is up to those who guide change to identify concerns, interpret them, and then act on them.

Excerpt from Benchmarks for Science Literacy on Scientific Inquiry (1B)

Scientific inquiry is more complex than popular conceptions would have it. It is for instance, a more subtle and demanding process than the naïve idea of "making a great many careful observations and then organizing them." It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as "the scientific method." It is much more than just "doing experiments," and it is not confined to laboratories. More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or alter strict logic and empirical evidence must have their day. Individual investigators working alone sometimes make great discoveries, but the steady advancement of science depends on the enterprise as a whole. And so on.

If students themselves participate in scientific investigations that progressively approximate good science, then the picture they come away with will likely be reasonably accurate. But that will require recasting typical school laboratory work. The usual high-school science "experiment" is unlike the real thing: The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for criticism; and, to top it off, the correct answer is known ahead of time.

Of course, the student laboratory *can* be designed to help students learn about the nature of scientific inquiry. As a first step, it would help simply to reduce the number of experiments undertaken (making time available to probe questions more deeply) and eliminate many of their mechanical, recipe-following aspects. In making this change, however, it should be kept in mind that well-conceived school laboratory experiences serve other important purposes as well. For example, they provide opportunities for students to become familiar with the phenomena that the science concepts being studied try to account for.

Another, more ambitious step is to introduce some students investigations that more closely approximate sound science. Such investigations should become more ambitious and more sophisticated. Before graduating from high school, students working individually or in teams should design and carry out at least one major investigation. They should frame the question, design the approach, estimate the time and costs involved, calibrate the instruments, conduct trial runs, write a report, and finally, respond to criticism.

Such investigations, whether individual or group, might take weeks or months to conduct. They might happen in and out of school time and be broken up by periods when, for technical reasons, work cannot go forward. But the total time invested will probably be no more than the sum of all those weekly one-period labs that contribute little to student understanding of scientific inquiry.

Excerpt from National Science Education Standards

INQUIRY. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already know in light of experimental evidence, using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries.

Although the Standards emphasize inquiry, this should not be interpreted as recommending a single approach to science teaching. Teachers should use different strategies to develop the knowledge, understandings, and abilities described in the content standards. Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry. Attaining the understandings and abilities described in Chapter 6, cannot be achieved by any single teaching strategy or learning experience.

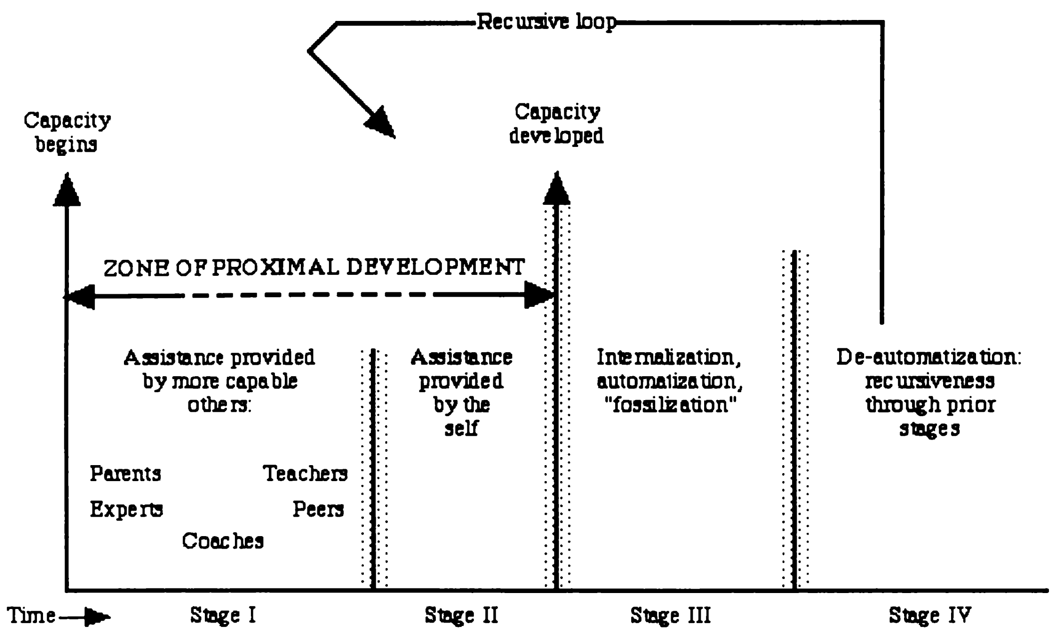
Excerpt from NSES Chapter 6

In the vision presented by the Standards, inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. The new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop

- Understanding of scientific concepts.
- An appreciation of "how we know" what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skills, abilities, and attitudes associated with science

Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities. The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. The science as inquiry standards are described in terms of activities resulting in students' development of certain abilities and in terms of student understanding of inquiry.

Graphic Representation of Recursive Loop of ZPD



(Tharp & Gallimore, 1988)

Stage I Assistance:	Science Educator to Scientist-Professor Scientist-Professor to Do-It Students Science Educator to Do-It Students Do-It Students with other Do-It Students
Stage II Assistance:	Scientist-Professor to self through reflection, observation of students, and previous years experiences in the Do-It course.

Teaching Science: Just Do It!

Botany 441/442 (531) – 3 credits
Fall 1997
INSTRUCTORS

Drs. Les Hickok and Tom Warne (Dept. of Botany) and Claudia Melear (EdSMART)
(lhickok@utk.edu, twarne@utk.edu, ctmelear@utk.edu)

Course Intent: In order to effectively teach science, one must be able to DO science! This course provides the opportunity to conduct hands-on investigative-based research with a unique "tool" that provides interest, flexibility and speed in the teaching laboratory setting. Students will receive ample opportunities to design and carry out experiments and will gain experience in the oral and written presentation of scientific data. Translation of this experience into the development of laboratory applications suitable for use in a 7-12 or undergraduate classroom will also be a principal outcome of the course.

Required Materials: A standard Laboratory Research Notebook (carbonless) with 200 sheets (100 sets); e.g., National Brand 43-644. Pages 1 – 67 will be used as a standard laboratory notebook to record, on a daily basis, all activities, experiments, calculations, data, etc. associated with individual and group research projects. Pages 68 – 100 will be used as a section on reflective thinking to document each student's perception of her/his progressive development in the area of scientific/critical thinking. Copies of each section are to be handed into the instructors on a weekly basis.

Location: Rm 230 Hesler Biology Bldg.
Class Times: TR 1:25 – 4:25

Grading: Equal emphasis will be given to the following components –
1) Participation – active participation in all individual and group activities throughout the semester.
2) "Journal Club" presentation – A scientific paper from the current literature will be presented orally by individuals or groups of two to the rest of the class.
3) "Journal Style" presentation – Each student will present results from one or more of his/her own experiments during the semester in a written, "journal style" format. This will be followed by an oral presentation using slides, transparencies or a poster presentation.
4) Development of a laboratory application/'lesson plan' suitable for use in a 7-12 or undergraduate classroom.

Organization: Most class periods will involve independent design, implementation and observation of experiments. Because experiments with living organisms typically do not limit themselves to a TR schedule (!) it is expected that, as necessary, students will work in the lab outside of regular class hours.

Important Dates:
August 28 – the first class!
October 14 – begin "Journal Club" presentations.
November 11 – draft of "Journal Style" presentation due.
November 20 – begin oral presentations of individual research.
December 2 – begin presentations of laboratory application/'lesson plans'.
December 9 - final draft of "Journal Style" presentation due.
December 11 – the last class!!
December 16 – Final Period.

Teaching Science: Just Do It!

Botany 531 – 3 credits
Fall 1998

INSTRUCTORS
Drs. Les Hickok and Tom Warne (Dept. of Botany) and Claudia Melear (EdSMART)
(lhickok@utk.edu, twarne@utk.edu, ctmelear@utk.edu)

Course Intent: In order to effectively teach science, one must be able to DO science! This course provides the opportunity to conduct hands-on investigative-based research with a unique organism that provides interest, flexibility and speed in the teaching laboratory setting. Students will have ample opportunities to design and carry out experiments and will gain experience in the oral and written presentation of scientific data. Translation of this experience into the development of laboratory applications suitable for use in a 7-12 or undergraduate classroom will also be a principal outcome of the course.

Required Materials: 1) A standard Laboratory Research Notebook (carbonless) with 200 sheets (100 sets); e.g., National Brand 43-644. Pages 1 – 67 will be used as a standard *Research Notebook* to record, on a daily basis, all activities, experiments, calculations, data, etc. associated with individual and group research projects. Pages 68 – 100 will be used as a *Reflective Journal* to document each student's perception of her/his progressive development in the area of scientific/critical thinking. In addition, the *Reflective* section will be used to record student 's thoughts on the design and implementation of inquiry-based lessons for grades 7 – 12. Copies of the *Research* and *Reflective* sections are to be handed into Drs. Warne/Hickok and Dr. Melear, respectively, on a weekly basis. 2) A VHS videotape and 3.5" formatted disc for documentation and transcript analysis of the pre- and post-course interviews. Please bring the videotape to class on Sept. 2. 3) A copy of the Myers-Briggs Type Indicator, available at the Service Desk in the Bookstore.

Location: Rm. 219 Hesler Biology Bldg.
Class Times: TR 1:25 – 4:25

Organization: Most class periods will involve collaborative and independent design, implementation and observation of experiments. Because experiments with living organisms typically do not limit themselves to a TR schedule (!) it is expected that, as necessary, students will work in the lab outside of regular class hours. All participants will have open access to the lab room.

Presentations:
1. Journal Club Presentation – individual. Choose an interesting paper from current scientific periodicals (biology) and present a critical overview and analysis to the class, ca. 15 min. (oral with visuals/handouts).
2. Research Presentation on 'unknown' – individual or group of 2-3. Present a component(s) of the experimental work that you or your group have completed in your investigations of the 'unknown', ca. 15-30 min. (oral with visuals and a 'draft' of a formal written research report in the format of a scientific paper, final version due two weeks later).
3. Presentation of an Inquiry-based Lesson suitable for grades 7-12 – individual. This should be based on your work with the 'unknown', the 2nd organism studied, or any other living materials, ca. 15 min. (oral with visuals and a formal written version) .

Grading: Equal emphasis will be given to the following components –
Sample scoring rubrics will be distributed to all students within the first two weeks of the class.

1. Participation – active participation in all individual and cooperative activities and discussions throughout the semester.
2. Journal Club presentation.
3. Research presentation.
4. Inquiry lesson.
5. Transcript and analysis of video from pre- and post-class interviews.

WEEK	MONTH	TUESDAY	THURSDAY
one	**August**		27 –1st class period
two	**September**	1: pre-class interviews	3
three		8	10
four		15	17
five		22: **Journal Club oral presentations**	24
six	**October**	29	1: mid-interviews
seven		6	8
eight		13	15: Fall Break
nine		20: Begin consideration of 2nd organism options	22
ten		27: **Oral Research presentations,** 1st written 'draft' due.	29
eleven	**November**	3:Continue with 'unknown' or begin work with other organism	5
twelve		10: Deadline for written research paper on 'unknown'.	12
thirteen		17	19: (NSTA Birmingham) – A discussion of Inquiry lessons with Dr. Melear
fourteen		24	26:Thanksgiving
fifteen	**December**	1	3
sixteen		8: **Presentation of Inquiry-based exercises** (written and oral)	8:Last class period - post-class interviews
seventeen		15:Finals period (12:30) – video transcripts and analysis due	

Teaching Science: Just Do It!

Botany 531 (24703) – 4 credits
Fall 1999

INSTRUCTORS
Drs. Les Hickok and Tom Warne (Dept. of Botany) and Claudia Melear (Coll. of Ed.)
(lhickok@utk.edu, twarne@utk.edu, ctmelear@utk.edu)

Course Intent: In order to effectively teach science, one must be able to DO science! This course is about doing science. It provides the opportunity to freely conduct hands-on investigative-based research with a living organism. Students will have ample opportunities to design and carry out experiments and will gain experience in the oral and written presentation of scientific data. Although this is not a course in "teaching methods", it will provide an opportunity to translate your experiences into the development of laboratory applications suitable for use in a 7-12 or undergraduate classroom.

Required Materials: 1) A standard Laboratory Research Notebook (carbonless) with 200 sheets (100 sets); e.g., Roaring Spring 77644. Pages 1 – 67 will be used as a standard *Research Notebook* to record, on a daily basis, all activities, experiments, calculations, data, etc. associated with individual and group research projects. Pages 68 – 100 will be used as a *Reflective Journal* to document each student's perception of her/his progressive development in the area of scientific/critical thinking. In addition, the *Reflective* section will be used to record student 's thoughts on the design and implementation of inquiry-based lessons for grades 7 – 12. Copies of the *Research* and *Reflective* sections are to be handed into Drs. Hickok/ Warne and Dr. Melear, respectively, on a weekly basis. **2)** A VHS videotape and 3.5" formatted disc for documentation and transcript analysis of the pre- and post-course interviews. Please bring the videotape to class on Aug. 31. **3)** A copy of the Myers-Briggs Type Indicator, available at the Service Desk in the Bookstore.

Location: Rm. 219 Hesler Biology Bldg.
Class Times: TR 1:25 – 4:25

Organization: Most class periods will involve collaborative and/or independent design, implementation and observation of experiments. Because experiments with living organisms typically do not limit themselves to a TR schedule (!) it is expected that, as necessary, students will work in the lab outside of regular class hours. All participants will have open access to the lab room.

Presentations:

1. Journal Club Presentation – individual. Choose an interesting paper from current scientific periodicals (biology) and present a critical overview and analysis to the class, ca. 15 min. (oral with visuals and/or handouts). The chosen paper should contain original research, not a review or summary of previous work.
2. Research Presentation on 'unknown' – individual or groups of 2-3. Present a component(s) of the experimental work that you or your group have completed in your investigations of the 'unknown', ca. 15-30 min. (oral with visuals and a 'draft' of a formal written research report in the format of a scientific paper; final version due two weeks later).
3. Presentation of an Inquiry-based Lesson suitable for grades 7-12 – individual. This should be based on your work with the 'unknown', the 2nd organism studied, or any other living materials, ca. 15 min. (oral with visuals and a formal written version). Dr. Melear will provide additional information and guidelines as the course progresses.

Grading: Equal emphasis will be given to the following components –
Sample scoring rubrics will be distributed to all students within the first two weeks of the class.

1. Participation – active participation in all individual and cooperative activities and discussions throughout the semester. (individual)
2. Journal Club presentation. (individual)
3. Research presentation. (individual or group)
4. Inquiry lesson. (individual or group of 2)
5. Transcript and analysis of video from pre- and post-class interviews. (individual)

WEEK	MONTH	TUESDAY	THURSDAY
one	**August**		26 – Introduction and pre-testing
two		31: Pre-class video interviews	2
three	**September**	7	9*
four		14	16
five		21: **Journal Club oral presentations**	23
six		28	30: mid-interviews
seven	**October**	5	7
eight		12	14
nine		19: Begin consideration of 2nd organism options	21: Fall Break
ten		26: **Oral Research presentations**, 1st written 'draft' due.	28: (NABT Meeting – Ft. Worth) Dr. Melear will discuss development of Inquiry Lessons
eleven	**November**	2:Continue with 'unknown' or begin work with other organism	4
twelve		9: Deadline for written research paper on 'unknown'.	11
thirteen		16	18
fourteen		23	25:Thanksgiving
fifteen		30	2
sixteen	**December**	7: Post-class video interviews	9: **Presentation of Inquiry-based exercises** (written and oral)
seventeen		15 (WED):Finals period (12:30) – video transcripts and analysis due; post-testing	

An excerpt from: Shaping the Future, p. 4, National Science Foundation 1996 – Comments from a research chemist at a major university about undergraduate education in her field –
"The classroom – it is embarrassing. Chalk and blackboard. There are hands-on experiments the students can do. However, these are largely cookbook... The textbooks....are large collections of facts. What I see really missing from these textbooks is the process of science. And finally, the exams....are a really nice way to give the student a grade, but I doubt that they really measure what the students are learning, where their critical thinking skills are."

Expected Outcomes: increased confidence in working cooperatively and with minimal supervision, enhanced critical thinking skills, familiarity with the 'real' processes of science, increased familiarity with the formal aspects of scientific research (data collection, analysis and presentation).

Knowing and Teaching Science: Just Do It!

Botany 531 (24703) – 4 credits
Fall 2000

INSTRUCTORS
Drs. Les Hickok (Dept. of Botany) and Claudia Melear (Coll. of Ed.)
(lhickok@utk.edu, ctmelear@utk.edu)

Course Intent: In order to effectively teach science, one must be able to DO science! This course is about doing science. It provides the opportunity to freely conduct hands-on investigative-based research with a living organism. Students will have ample opportunities to design and carry out experiments and will gain experience in the oral and written presentation of scientific data. Although this is not a course in "teaching methods", it will provide an opportunity to translate your experiences into the development of laboratory applications suitable for use in a 7-12 or undergraduate classroom.

Expected Outcomes: Students will gain increased confidence in working cooperatively and with minimal supervision, enhanced critical thinking skills, familiarity with the 'real' processes of science, increased familiarity with the formal aspects of scientific research (data collection, analysis and presentation). Students will sharpen their ability to design scientifically sound experiments using a variety of organisms and approaches.

Required Materials: 1) A Laboratory Research Notebook. This will be used to record, on a daily basis, all activities, experiments, calculations, data, etc. associated with individual and group research projects. Number pages (if needed) and date all entries. Copies of completed sections are to be handed into Dr. Hickok as called for. Remember, this should be a complete journal showing everything. **2)** A VHS videotape and 3.5" formatted disc for documentation and transcript analysis of the pre- and post-course interviews. Please bring the videotape to the second class (Aug. 29). **3)** A copy of the self-scorable Myers-Briggs Type Indicator, available at the Service Desk in the Bookstore (under Melear Science Ed 496).

Location: Rm. 219 Hesler Biology Bldg.
Class Times: TR 1:25 – 4:25

Organization: Most class periods will involve collaborative and/or independent design, implementation and observation of experiments. Because experiments with living organisms typically do not limit themselves to a TR schedule (!!) it is expected that, as necessary, students will work in the lab outside of regular class hours. All participants will have open access to the lab room.

Presentations:

1. Journal Club Presentation – individual. Choose an interesting paper from current scientific periodicals (biology) and present a critical overview and analysis to the class, ca. 15 min. (oral with visuals and/or handouts). The chosen paper should contain original research, not a review or summary of previous work.
2. Research Presentation on 'unknown' – individual or group of 2-3. Present a component(s) of the experimental work that you or your group have completed in your investigations of the 'unknown', ca. 15-30 min. (oral with visuals and a 'draft' of a formal written research report in the format of a scientific paper; final version due two weeks later).
3. Presentation of an Inquiry-based Lesson suitable for grades 7-12 – individual. This should be based on additional work with another organism that you have learned to work with and experimented with. The lesson should be derived from an experiment that you have designed and carried out with the organism. Additional information and guidelines will be provided as the course progresses. (ca. 15

min. oral and a formal written version).

Grading: Equal emphasis will be given to the following components –
Sample scoring rubrics will be distributed to all students within the first two weeks of the class.

1. Participation and Reflective Journal – active participation in individual and cooperative activities and discussions throughout the semester and upkeep and completion (hard copy and disc) of your personal Reflective Journal. (individual)
2. Journal Club presentation. (individual)
3. Research presentation, oral and written. (individual or group)
4. Inquiry exercise and lesson. (individual)
5. Transcript and analysis of video from pre- and post-class interviews. (individual)

WEEK	MONTH	TUESDAY	THURSDAY
one	**August**		24 – Introduction
two		29: Pre-class video interviews	31
three	**September**	5: email MBTI results to Melear	7*
four		12	14
five		19: **Journal Club oral presentations**	21
six		27: pre- video transcript due	29
seven	**October**	3	5
eight		10	12: Fall Break
nine		17: Begin consideration of 2nd organism options for inquiry lesson	19 **Oral Research presentations**, 1st written 'draft' due.
ten		24: Oral presentations continued, if needed. Mid-term video interviews	26: (NABT Meeting – LH gone) Dr. Melear will discuss development of Inquiry Lessons
eleven	**November**	31:Begin work with other organism	2
twelve		7: Deadline for written research paper on 'unknown'.	9
thirteen		14	16
fourteen		21	23:Thanksgiving
fifteen		28	30
sixteen	**December**	5: Post-class video interviews and **Presentation of Inquiry-based exercises** (written and oral)	7: **Presentation of Inquiry-based exercises** (written and oral), continued, if needed.
seventeen		11: (MON) – video and video transcripts with analysis (disk and hard copy) and Journal file (disk and hard copy) due. ***If Dr. Melear does not receive these on this date an Incomplete will be issued for your grade.***	

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An excerpt from: Shaping the Future, p. 4, National Science Foundation 1996 – Comments from a research chemist at a major university about undergraduate education in her field –
"The classroom – it is embarrassing. Chalk and blackboard. There are hands-on experiments the students can do. However, these are largely cookbook... The

textbooks....are large collections of facts. What I see really missing from these textbooks is the process of science. And finally, the exams....are a really nice way to give the student a grade, but I doubt that they really measure what the students are learning, where their critical thinking skills are."

Notes about Reflective Journals: Part of the grade for the course will be determined by your weekly reflections for Dr. Melear. Use the following criteria to write about:

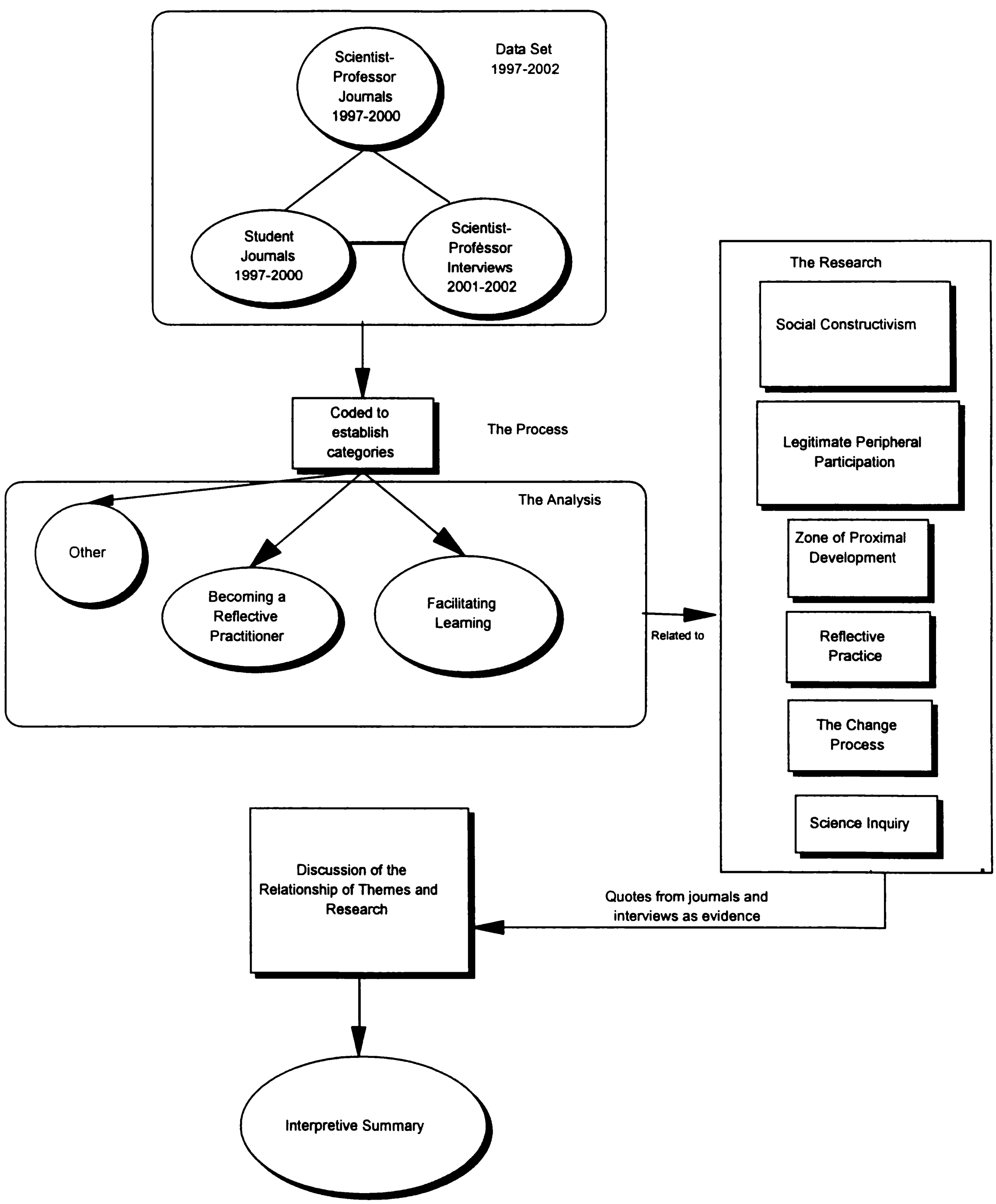
How do you feel about the course, so far?
What frustrations, if any, are you experiencing?
How are groups forming, if any?
How much do you understand about what you are supposed to be doing?
Is this course similar/dissimilar to previous science courses/experiences?
What is the nature of scientific thinking, and specifically, yours?
How is your own scientific thinking developing?
What is scientific thinking?
What is the nature of science?

Use any of the above topics in any order, in any frequency you wish.
(Note: Dr. Hickok will not have access to the Journals until after the class has been completed.)

Method of communication with Dr. Melear. Please **DATE ALL ENTRIES!**

1. Type your journal weekly or biweekly in a word processing program. Send it via email to ctmelear@utk.edu and bashe3@aol.com . In addition, print out the document and give it to Becky Ashe who will deliver it to Dr. Melear.
2. At the end of the semester, submit a computer disk with your entire journal file on it along with a hard copy of the file to Dr. Melear. Label the disk with the kind of word processing program on it and whether MAC or IBM. This is due the first day of finals week.

Design Schema for Data Analysis



Appendix 3.4

HyperRESEARCH 2.03 Sample Report

Case Code Frequency Type Reference Source
Hickok Journals.97 Asking instructional self-questions1 TEXT11000,11067
BothJournals.Hickok.97.plusS.txt
Source Material:
Should we indicate that two weeks is a major period in development?

Hickok Journals.97 Deviation from course intent by students4 TEXT
34067,34852 BothJournals.Hickok.97.plusS.txt
Source Material:
It also became clear during the period that the students knew some information about C-Fern. Apparently, they had seen the C-Fern information on the Botany bulletin board. Laura went to the internet and pulled up the C-Fern web page. She read some information on the introduction pages, but did not really get very much information. At any rate, the students did learn that it, the C-Fern, was an aquatic plant and obviously that it was probably a fern. I don't really think that they learned much more than that, however. An interesting point was that they attempted as a group to keep their knowledge of the C-Fern a secret. For some reason they did not want us to know that they in fact knew something from another source. We will try to bring this out next Tuesday in class.

Hickok Journals.97 Experimental design 1 TEXT87898,88163
BothJournals.Hickok.97.plusS.txt
Source Material:
In general it is quite obvious that they have come quite far and have of good familiarity with the organism. For the most part, experimental designs were reasonable, although we used the class, and encouraged questions, to polish up their experiment
Where needed.

Hickok Journals.97 Guiding students25TEXT2821,3175
BothJournals.Hickok.97.plusS.txt
Source Material:
Tom and I, after quietly observing them for awhile, asked some questions to try to steer them a bit. They talked in a very general way about things-did not focus in on the results of a particular treatment and its implications. We had to prompt them to write in their notebooks-they were still not sure what to write. So, we gave them some suggestions.

Hickok Journals.97 Guiding students25TEXT5321,5421
BothJournals.Hickok.97.plusS.txt

Appendix 4.1

CURRICULUM VITAE*

Leslie G. Hickok
Professor of Botany
The University of Tennessee
Knoxville, TN 37996-1100

Phone: 865-974-6215
Fax: 865-974-2258
email: lhickok@utk.edu
web page: cfern.bio.utk.edu

RESEARCH AREAS: Plant genetics and development, Teaching materials development, Science pedagogy.

Higher Education:

Institution	Major	Dates/Degree
University of Massachusetts Amherst, Massachusetts	Botany	1971-75/Ph.D.
Ohio University Athens, Ohio	Botany	1969-71/M.S.
Murray State University Murray, Kentucky	Biology	1967-69/B.A.
Adirondack Community College Glens Falls, New York	Liberal Arts	1964-67

Professional Experience:

1988-90	Director of Plant Physiology and Genetics Graduate Program, University of Tennessee, Knoxville (UTK)
1986-	Professor of Botany, UTK Member of Plant Physiology and Genetics Graduate Program, UTK Member of Biotechnology Graduate Program, UTK
1981-1986	Associate Professor of Botany, UTK Graduate Program Coordinator (1982-85)
1979-1981	Assistant Professor of Botany, UTK
1974-1979	Assistant Professor of Botany, Mississippi State University

Research Grants and Contracts:

N.S.F. Grant DEB76-09756, "Genetic control of meiotic chromosomes in plants," $33,000, 6/1/76 - 5/30/78.

N.S.F. Grant DEB78-02809, "Polyploid genetics in homosporous ferns," $32,752, 6/1/78 - 5/30/80. Transferred to University of Tennessee as DEB79- 095333, 4/79 - 9/81.

N.S.F. Grant DEB79-09533. Additional support for equipment, $5,983, 9/10/79.

N.S.F. Grant DEB80-14073, "Genetic controls of meiotic chromosome pairing, mutation induction, and intraspecific variation in the polyploid fern *Ceratopteris*," $40,000, 6/1/81 - 11/30/83.

Research Grants and Contracts (cont.):

Faculty Research Award, Graduate School, University of Tennessee, "Genetic studies of plant growth regulation," $4,800, Summer, 1983.

Contract - Martin Marietta Corporation, Baltimore, MD., "Genetic and physiological studies of paraquat resistance and oxygen toxicity in *Ceratopteris*," $228,888, 6/1/84 - 5/31/87, with O.J. Schwarz.

Contract - NPI, Salt Lake City, Utah, "Genetic applications of *Ceratopteris*," $46,398 9/4/84 - 9/3/85.

Contract - NPI, Salt Lake City, Utah, "Genetic applications of *Ceratopteris*" (cont.) - $54,392, 9/1/85 - 8/31/86.

N.S.F. Grant DCB-85-11273, "Use of developmental mutants in genetic and physiological studies of fern gametophyte development," $107,000, 9/1/85 - 8/31/87, with T. R. Warne.

N.S.F. Grant DCB-88-03620, "Physiological and genetic characterization of salt tolerant mutants in *Ceratopteris*," $172,500, 7/1/88 - 6/30/91. REU Supplement $3,000, 12/88. REU Supplement $6,350, 1/90.

USDA Competitive Research Grant 9237100-7673, "Physiological and genetic studies of salt tolerant mutants on *Ceratopteris*," $120,000, 8/1/92 - 7/31/94.

USDA Competitive Research Grant 9237100-7673, "Physiological and genetic studies of salt tolerant mutants in *Ceratopteris*"(cont.) - $103,000, 8/1/94 - 7/31/96.

NSF Grant DUE-9651045, "*Ceratopteris* - A simple model system for teaching and research", $279,178, 8/96 - 8/99.

NSF-DUE-9950522, "*Ceratopteris* teaching materials development: sporophytic and genetic applications", $310,000, 8/99-7/02.

U. S. Patent:

A method for producing genes conferring resistance to herbicides, growth regulators or other chemical agents in vascular plants. No. 4,528,773; 7/16/85. Assigned to University of Tennessee Research Corporation.

Inventions:

C-Fern ™, a derived strain of *Ceratopteris richardii* developed as a model organism for research and teaching applications. Assigned to University of Tennessee Research Corporation. Distribution of related educational materials and spore genotypes licensed to Carolina Biological Supply Co., Burlington, NC (September 1997).

Publications:

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Hickok, L. G. and E. J. Klekowski. 1974. Inchoate speciation in *Ceratopteris*: An analysis of the synthesized hybrid *C. richardii* X *C. pteridoides*. Evolution 28: 439-446.

Hickok, L. G. and E. J. Klekowski. 1975. Chromosome behavior in hybrid ferns: A reinterpretation of Appalachian *Dryopteris*. Amer. J. Bot. 62: 560- 569.

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Hickok, L. G. 1978. Homoeologous chromosome pairing: Frequency differences in inbred and intraspecific hybrid polyploid ferns. Science 202: 982-984.

Hickok, L. G. 1979. Apogamy and somatic restitution in the fern *Ceratopteris*. Amer. J. Bot. 66: 1074-1078.

Hickok. L. G. 1979. A cytological study of intraspecific variation in *Ceratopteris thalictroides*. Can. J. Bot. 57: 1694-1700.

Duckett, J. G., E. J. Klekowski, and L. G. Hickok. 1979. Ultrastructural studies of mutant spermatozoids in ferns. I. The mature nonmotile spermatozoid of mutation 230X in *Ceratopteris thalictroides* (L.) Brongn. Gamete Research 2: 317-343.

Hickok, L. G. 1983. Abscisic acid blocks antheridiogen-induced antheridium formation in gametophytes of the fern *Ceratopteris*. Can. J. Bot. 61: 888-892.

Hickok, L. G. and R. Kiriluk. 1984. Effects of auxins on gametophyte development and sexual differentiation in the fern *Ceratopteris thalictroides* (L.) Brongn. Bot. Gaz. 145: 37-42.

Publications (cont.):

Hickok, L. G. 1985. The genetics of gametophyte development. Proc. Roy. Soc. Edinburgh. 86B: 21-28.

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Hickok, L. G. and O. J. Schwarz. 1986. An in vitro whole plant selection system: Paraquat tolerant mutants in the fern *Ceratopteris*. Theor. Appl. Genetics 72: 302-306.

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Hickok, L. G. 1987. Applications of *in vitro* selection systems: Whole plant selection using the haploid phase of the fern *Ceratopteris*. In: "Biotechnology in Agricultural Chemistry"; H. M. LeBaron, R. O. Mumma, R. C. Honeycutt and J. H. Duesing, Eds.; Amer. Chem. Soc. Symposium Series 334; pp. 53-65.

Warne, T. R. and L. G. Hickok. 1987. (2-chloroethyl) phosphonic acid promotes germination of immature spores of *Ceratopteris richardii* Brongn. Plant Physiol. 83: 723-725.

Hickok, L. G., T. R. Warne and M. K. Slocum. 1987. *Ceratopteris richardii*: Applications for experimental plant biology. Amer. J. Bot. 74: 1304-1316.

Cooke, T. J., R. H. Racusen, L. G. Hickok and T. R. Warne. 1987. The photocontrol of spore germination in the fern *Ceratopteris richardii*. Plant and Cell Physiology 28: 753-759.

Warne, T. R. and L. G. Hickok. 1987. Single gene salt tolerant mutants in *Ceratopteris*: selection and genetic characterization. Plant Science 52: 49-55.

Scott, R. J., L. G. Hickok. 1987. Genetic analysis of antheridiogen sensitivity in the fern *C. richardii*. Amer. J. Bot. 74: 1872-1877.

Warne, T. R., L. G. Hickok and R. J. Scott. 1988. Characterization and genetic analysis of antheridiogen insensitive mutants in *Ceratopteris richardii.* Bot. J. Linn. Soc. 96: 371-379.

Carroll, E. W., O. J. Schwarz and L. G. Hickok. 1988. Biochemical studies of paraquat-tolerant mutants of the fern *Ceratopteris richardii.* Plant Physiol. 87: 651-654.

Hickok, L. G. and O. J. Schwarz. 1989. Genetic characterization of a mutation that enhances paraquat tolerance in the fern *Ceratopteris richardii.* Theor. Appl. Genetics 77: 200-204.

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Augé, R. M., L. G. Hickok and A. J. W. Stodola. 1989. Psychrometric pressure-volume analysis of osmoregulation in roots, shoots and whole sporophytes of salinized *Ceratopteris.* Plant Physiol. 91: 322-330.

Vaughn, K. C., L. G. Hickok, T. R. Warne and A. C. Farrow. 1990. Structural analysis and inheritance of a clumped-chloroplast mutant in the fern *Ceratopteris.* J. Heredity 81: 146-151.

Wright, S. R., L. G. Hickok and T. R. Warne. 1990. Characterization of mutants of *Ceratopteris richardii* selected on aluminum ($Al_2(SO_4)_3$-Na_2EDTA). Plant Science 68: 257-262.

Hickok, L. G., D. L. Vogelien and T. R. Warne. 1991. Selection of a mutation conferring high NaCl tolerance to gametophytes of *Ceratopteris.* Theor. Appl. Genet. 81: 293-300.

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Warne, T. R. and L. G. Hickok. 1991. Control of sexual development of *Ceratopteris richardii*: antheridiogen and abscisic acid. Bot. Gaz. 152: 148- 153.

Tai Chun, P. and L. G. Hickok. 1992. Inheritance of two mutations conferring glyphosate tolerance in the fern *Ceratopteris richardii.* Can. J. Bot. 70: 1097-1099.

Cooke, T., L. Hickok, W. J. Vanderwoude, J. Banks and R. Scott. 1993. Photobiological characterization of a spore germination mutant with reversed photoregulation in the fern *Ceratopteris richardii.* Photochem. Photobiol. 57:1032-1041.

Vogelien, D., L. Hickok, R. Augé, A. Stodola and D. Hendrix. 1993. Solute analysis and water relations of gametophyte mutants tolerant to NaCl in the fern *Ceratopteris richardii.* Plant Cell Environ. 16:959-966.

Banks, J. A., L. Hickok and M. A. Webb. 1993. The programming of sexual phenotype in the homosporous fern, *Ceratopteris richardii*. Int. J. Plant Sci. 154:522-534.

McGrath, J. M., L. G. Hickok and E. Pichersky. 1994. Restriction fragment length polymorphisms distinguish among accessions of *Ceratopteris thalictroides* and *C. richardii* (Parkeriaceae). Pl. Syst. Evol. 189:193-202.

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Hickok, L. 1995. Robert Michael Lloyd (1938-1994). American Fern Journal 85:69-74.

Hickok, L. G., T. R. Warne and R. S. Fribourg. 1995. The biology of the fern *Ceratopteris* and its use as a model system. International Journal of Plant Science 156:332-345.

Cooke, T. J., L. G. Hickok, and M. Sugai. 1995. The fern *Ceratopteris richardii* as a lower plant model system for studying the genetic regulation of plant photomorphogenesis. International Journal of Plant Science 156:367-373.

Renzaglia, K. S., T.R. Warne, and L.G. Hickok. 1995. Plant development and the fern life cycle using *Ceratopteris richardii*. American Biology Teacher 57: 438-442.

Vogelien, D. L., L. G. Hickok and T. R. Warne. 1996. Differential effects of Na, Mg^2, K, Ca^2 and osmotic stress on the wild type and NaCl-tolerant mutants, *stl2*, of *Ceratopteris richardii*. Plant, Cell and Environment 19:17-23.

Warne, T. R., L. G. Hickok, T. B. Kinraide and D. L. Vogelien, 1996. High salinity tolerance of the *stl2* mutation of *Ceratopteris richardii* is associated with enhanced K influx and loss. Plant Cell and Environment 19:24-32.

Hickok, L. G. and T. R. Warne. 1998. C-Fern: A dynamic approach to plant biology. Carolina Tips 61:1-4.

Hickok, L. G. and T. R. Warne. 1998. Laboratory investigations with C-Fern (*Ceratopteris richardii*). Proc. Assoc. Biol. Lab. Education 19:143-176.

Melear, C., L. G. Hickok, J. D. Goodlaxson, T. R. Warne. 1998. Responses of preservice secondary teachers to learning science in an apprenticeship: the research experience. *In*: Translating and Using Research for Improving Teacher Education in Science and Mathematics, Final report of ISTEP Research Project (R. E. Yager, P.I.), pp. 26-35.

Hickok, L. G. and T. R. Warne. 1998. *C-Fern Manual: Teaching and Research*. Carolina Biological Supply Company, Burlington, NC. 146 pp.

Hickok, L. G., T. R. Warne, S. Baxter and C. Melear. 1998. Sex and the C-*Fern*:Not just another life cycle. BioScience 48: 1031-1037.

Hickok, L. G. and T. R. Warne. 1999. Chemical attraction: *C-Fern* sperm chemotaxis. Supplement to *C-Fern Manual*, Carolina Biological Supply Company.

Warne, T. R., L. G. Hickok, D. L. Vogelien and C. Sams. 1999. Sodium/potassium selectivity and pleiotropy in *stl2*, a highly salt-tolerant mutation of *Ceratopteris richardii*. Plant Cell & Environment 22:1027-1034.

McGrath, J. M. and L. G. Hickok. 1999. Multiple ribosomal RNA gene loci in the genome of the homosporous fern *Ceratopteris richardii*. Can. J. Bot. 77: 1199-1202.

Hickok, L. G. and T. R. Warne. 2000. Short-circuiting the fern life cycle: apospory in *Ceratopteris richardii*. *In*: *Plant Tissue Culture Concepts and Laboratory*, 2nd ed., *Exercises* (Eds., R. Trigiano and D. Gray), pp. 397-405, CRC Press, NY.

Melear, C., J. D. Goodlaxson, T. R. Warne, L. G. Hickok. 2000. Teaching preservice science teachers how to do science: Responses to the research experience. J. Science Teacher Education 11: 1-14.

Davidson, K. A., L. G. Hickok and K. S. Renzaglia. Microscopic characterization of a mutant sperm line of the fern *Ceratopteris richardii*. Submitted: Microscopy and Microanalysis

Honors and Awards:

Chancellor's Research Achievement Award, UTK, 1997
Japan Society for the Promotion of Science, Research Fellowship, August-November 1993, Toyama University.
Member of College of Liberal Arts Board of Visitors, Ohio University, 1989.
Ohio University Alumni Award for Significant Achievement, 1989
Member of Science Alliance, A Centers of Excellence Program of the State of Tennessee. Selected for membership 1986-93, 95-98.
Faculty Teaching Award, Department of Botany, The University of Tennessee, 1987
Annual award of Pteridological Section, Botanical Society of America, 1987 (second author with R. J. Scott)
Annual award of Pteridological Section, Botanical Society of America, 1977.
National Institute of Environmental Health Sciences Postdoctoral Fellowship, 1974-declined.
Phi Kappa Phi Honor Society, Ohio University Chapter, 1971
National Science Foundation Traineeship, 1969-1970

Professional Societies:

American Association for the Advancement of Science
National Association of Biology Teachers
Sigma Xi
American Fern Society
International Association of Pteridologists

Invited Presentations at National or International Meetings:

International Symposium on the Biology of Pteridophytes, Edinburgh, September 1983. "The genetics of gametophyte development."

American Chemical Society, Agrochemicals Division, Symposium on The Applications of Biotechnology to Agriculture, September 1985. "Applications of *in vitro* selection systems."

U.S. - Japan Symposium on the Development of the Fern Haplophase, Nikko, October 1985. "Genetic approaches to the study of gametophyte development."

International Seminar on the Cytology and Biochemistry of the Fern Haplophase. 1987, Ulm, FRG. "Outstanding genetical problems in ferns."

International Conference on "Progress in Pteridology." 1990. Ann Arbor, MI. "Using *Ceratopteris* as a model genetic system for studying salt tolerance in plants."

3rd Gatlinburg Symposium. June 1992. Knoxville, TN. "*Ceratopteris richardii* as a model system for studying mechanisms of salt tolerance in plants."

American Biology Laboratory Educators (ABLE) meeting, University of Calgary, Alberta, Canada, June 1997. "Workshop presentation on C-Fern." (T. Warne, L. Hickok)

U.S.-Japan Symposium on Fern Development and Evolution, Purdue University, July 1997. "Ceratopteris as a Model Organization: where are we and where do we go from here? (L. G. Hickok)

U.S.-Japan Symposium on Fern Development and Evolution, Purdue University, July 1997. "High salinity tolerance and pleiotropy in the st12 mutation of Ceratopteris." (T. R. Warne and L. G. Hickok)

Council on Undergraduate Research - Research Link 2000 Conference, Whitewater, WI, November 1997. "Teaching with C-Fern." (L. Hickok and T. Warne)

Invited Seminars/Workshops:

Old Dominion University, Department of Biology - January 1978
Ohio University, Department of Botany - April 1979
Duke University, Department of Botany - March 1980
Maryville College, Department of Biology - April 1980
University of West Florida, Department of Biology - May 1980
Murray State University, Department of Biology - April 1983
Ohio State University, Department of Botany - April 1983
Ohio University, Department of Botany - October 1984
University of Tennessee, Plant & Soil Science Department - March 1985
Upjohn Co., Plant Genetics Department - April 1985
Knoxville Science Club - May 1986

Oak Ridge National Laboratories, Biology Division - October 1986
Ohio University, Department of Botany - April 1989
Appalachian State University, Biology Department - October 1990
Toyama University, Japan-October 1991.
Tokyo Metropolitan University, Japan-November 1991.
Riken Institute, Japan-November 1991.
Auburn University, Botany Department - October 1992
Toyama University, Japan-October 1993.
Hitachi Laboratories, Japan-November 1993.
University of Texas, Austin - October 1995
Cornell University, Ithaca, NY - February 1998
Idaho State University, Pocatello, ID - March 1998
Eastern Kentucky University, Richmond, KY - April 1998
University of Georgia, Dept. Botany, Athens, GA – February 1999
University of Georgia, Science Education, Athens, GA – February 1999
Toyama University, Japan-April 1999
Exploratorium, San Francisco, CA – seminar and workshop,November 1999
Research Link 2000-CUR, Michigan, C-Fern Workshop - August 1999.
NSTA (National Science Teachers Association) National Convention and Exhibition, Orlando, FL - April 2000.
Virginia Tech, Blacksburg, VA - June 2000.
The College of Wooster, Wooster, OH - June 2000
Keystone Resort and Conference Center, Keystone, CO - July 2000
Ferris State University, Big Rapids, MI - August 2000
Ferris State University, Big Rapids, MI - August 2000
NABT (National Association of Biology Teachers) National Convention and Exhibition, Orlando, FL - October 2000.
Invited Workshop, Southwestern University, Georgetown, TX – January 2001.
Research Link Workshop, St. Leo University, St. Leo, FL – February 2001.
NSTA – Carolina Biological Workshop, St Louis, MO – March 2001
Kennesaw State University, Kennesaw, GA – April 2001
Ameritech & Ferris State University, Big Rapids, MI – November 2001
Ferris State University, Big Rapids, MI – Research for the Science Connection (Eisenhower Grant) – March 2002.
NSTA Annual Meeting, San Diego, CA – Carolina Biological Workshop on Meet the *C Fern* - March 2002.
Biotechnology 2002 Conference, Virginia Tech University, *C-Fern* in the Laboratory July 2002
Botanical Society of America Annual Meeting, Forum on Education, Madison, WI – August 2002.
Research Link Institute, University of Tennessee, Knoxville, TN, *C-Fern* Workshop – October 2002 (planned)
NABT Annual Meeting, Cincinnati, OH, Carolina Biological Supply sponsored workshop – October 2002 (planned)
Tennessee Science Teachers Meeting, Nashville, TN, Carolina Biological Sponsored workshop – November 2002 (planned)

Presentations at Meetings (since 1990):

International Conference on Progress in Pteridology, Ann Arbor, MI. June 1990. "Characterization of a dark-germinating mutant in the fern *Ceratopteris richardii.*" (2nd author with R. J. Scott)

International Plant Molecular Biology Congress, Tucson, AZ, 6-11 October 1991. "Hormonal regulation of sex expression in *Ceratopteris.*" (3rd author with H. Banks, J. Ho and T. Cooke)

American Society of Plant Physiologists, Pittsburgh, PA, August 1992. "Characterization of mutants conferring NaCl tolerance in the fern *Ceratopteris richardii.*

XV International Botanical Congress, Yokohama, Japan, 1993. "Altered K^+ and Na^+ uptake are associated with enhanced salinity tolerance in a highly salt tolerant mutant of *Ceratopteris richardii.*" (3rd author with Vogelien, D. L., T. R. Warne, R. M. Augé, R. M.)

Annual Meeting of the American Association of Plant Physiologists, St. Paul, Minnesota, 1993. "Altered K^+ and Na^+ uptake are associated with enhanced salinity tolerance in a highly salt tolerant mutant of *Ceratopteris richardii.*" Plant Physiol. (Suppl.) 102:158. (5th author with Vogelien, D. L., T. R. Warne, R. S. Fribourg, R. M. Augé, R. M.)

Annual Meeting of the American Association of Plant Physiology, St. Paul, Minnesota, 1993. "*Ceratopteris richardii*: A simple model system for teaching and research." (3rd author with Warne, T. R., K. S. Renzaglia)

American Institute of Biological Sciences, Ames, Iowa, 1993. "*Ceratopteris richardii*: A simple model system for undergraduate teaching and research." (3rd author with Renzaglia, K. S., T. R. Warne)

Botanical Society of Japan, Toyama, Japan, 1994. "Action spectra for spore germination of wild and dark germinating mutant in *Ceratopteris richardii.*" (4th author with Okamoto, Kazuhisa, Michizo Sugai, Shigeru Matcunaga, T. J. Cook, Masakatsu Watanabe)

Gatlinburg Symposium, Knoxville, Tennessee, 1994. "High salinity tolerance converted by the *stl2* mutation in *Ceratopteris* is associated with altered K^+ transport at the plasmalemma." (2nd author with Warne, Thomas R., Dale L. Vogelien, Thomas B. Kinraide)

American Society of Plant Physiologists, Charlotte, North Carolina, 1995. "Salt tolerance conferred by the *stl2* mutation of *Ceratopteris richardii* is associated with altered K^+ and tolerance to Mg^{2+}. (2nd author with Warne, T., T. Kinraide, D. Vogelien)

Botanical Society of Japan, Kanazawa, Japan, 1995. "Photoregulation of spore germination and gametophyte morphogenesis in *Ceratopteris* mutants, dkg1 and germ 4. (3rd author with Okamoto, H, M. Sugai)

International Conference on Photobiology, Vienna, Austria, 1996. "Action spectra for spore germination of wild type and dark germination mutant (dkg1) in *Ceratopteris richardii.* (Sugai, M., K. Okamoto, T. Cooke, L. Hickok)

Global Summit National Science Teachers Association, San Francisco, California, 1996. "Teaching K-12 science with plants (ASPP): Sex and the C-fern." (Warne, T., L. Hickok)

American Society of Plant Physiologists, San Antonio, Texas, 1996. "The salt tolerant *stl2* mutant of *Ceratopteris richardii* exhibits enhanced selectivity for K^+ over Na^+." (2nd author with T. Warne, D. Vogelien.

Assoc. Edu. Teachers in Science Annual Meeting, Minneapolis, MN, January 1998. "Scientific research course for preservice science teachers to promote inquiry and critical thinking. (Melear, C., J. D. Goodlaxson, L. G. Hickok, T. R. Warne).

C-Fern Workshop as part of Wisconsin Fast Plants Workshop, University of Wisconsin, Madison, June 1998. (T. R. Warne, L. G. Hickok).

American Assoc. of Plant Physiol. Annual Meeting, Madison, Wisconsin, July 1998. "C-Fern (*Ceratopteris*) chemotaxis: where chemistry meets biology." (L. G. Hickok, T. R. Warne)

American Assoc. of Plant Physiol. Annual Meeting, Madison, WI, July 1998. "C-Fern: A simple system for teaching. Teaching booth display and demonstration. (L. G. Hickok, T. R. Warne)

National Science Teachers Assoc., Southern Section, Nashville, TN, Dec. 1997. "C-Fern: sex in a dish." (L. G. Hickok, T. R. Warne)

Appalachian Rural Systemic Initiative, Charleston, WV, March 1998. C-Fern booth, sponsored product showcase. (T. R. Warne, L. G. Hickok)

National Science Teachers Assoc. National Meeting, Las Vegas, NV, April 1998. C-Fern and Wisconsin Fast Plants shared booth, sponsored by Amer. Assoc. Plant Physiol. (L. G. Hickok, T. R. Warne)

Research Link 2000–CUR, Minnesota, August 1998. C-Fern Workshop. (T. R. Warne, L. G. Hickok)

West Virginia Science Conference, Snowshoe, WV, October 1998. C-Fern booth. (T. R. Warne, L. G. Hickok)

Tennessee Science Teachers Assoc., Nashville, TN, October 1998. C-Fern presentation/workshop. (L. G. Hickok, T. R. Warne)

National Science Teachers Assoc. (NSTA), Southern Region, Birmingham, AL, November 1998. C-Fern demonstration/workshop. (L. G. Hickok, T. R. Warne)

National Science Teachers Association, National meeting, Boston, April 1999. *C-Fern* – Fast Plants Booth/demonstration sponsored by American Society of Plant Physiologists. (Hickok, Warne, Baxter)

Research Link 2000–CUR, Michigan, August 1999. C-Fern Workshop. (S. Baxter, T. R. Warne and L. G. Hickok).

National Association of Biology Teachers, National meeting, Ft. Worth, TX, November 1999. *C-Fern* booth/demonstration.

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Appendix 4.2

Journal Entries and Interviews

1. Reference coding: Coding is done by year, subject correlation to roman numerals, and item identification. For example see 97.I.A below.
2. All quotations have been minimally edited for clarity.

I. Introduction 1997 (97.I.A)

97.I.A. In this first session I gave them a brief introduction of what the class was going to be about. And then the graduate student administered the testing portion to them. This took about one and one-half hours. After that they went back to the lab and we gave them more of an overview of what our intentions were. Then we let them loose. We gave them RN5 spores. The spores had been spiked with various types of "dirt" such as leaf debris dead insect parts, dust, etc. We did this because the spores themselves were too clean to give much fungal contamination. This turned out to be a good move in that later on it made the students a little bit more broad minded and skeptical about exactly what they were dealing with. We used the concept of this being Sojourner dust from Mars, the recent Mars mission, which was sent back to earth to find out if it indeed, as suspected, was a living type of material. It's important at this point to emphasize to them that we don't necessarily want them to tell us WHAT the material is, but to tell us ABOUT it. (Dr. Temple's Journal, 8/28/97)

I. Introduction 1998 (98.I.A-J)

98.I.A. In today's class we had a total of 11 students enrolled. Claudia took them for approximately one hour for testing. After that, we introduced ourselves, the whole class, and then I went to briefly some aspects associated with the syllabus. I think everything was fairly well covered and I tried to make a special emphasis on the fact that it was a free form, collaborative type of experience and that we really wanted them to learn about how inquiry is done or how science is done and specifically gave them the idea that this was the kind of class type situation that one would hope would be in their classrooms in the future. Claudia helped things along by adding in very pertinent ideas or suggestions as we went through some of the introductory material. . . (Dr. Temple's Journal, 8/27/98).
98.I.B. ...As opposed to last year, this class seemed to move along fairly well. There was not quite as much hesitancy and a feeling of 'what do we do now'. This may have been associated with a better introduction or it

98.I.B. (continued) may be associated with the fact that the class is been offered before and some information was out and available about it. Also, Claudia may have given them more indication in her comments and obvious enthusiasm for the class. Nonetheless, it really did go out a little more smoothly and perhaps best said is that it seemed more comfortable for the students than last year. I did not get the idea that any of the students' were excessively uncomfortable with the situation. (Dr. Temple's Journal, 8/27/98)
98.I.C. My initial thoughts about this class are that I am going to have to stretch my thinking capacity and go beyond the typical boundaries of a "normal" science class. Throughout school you are conditioned to perceive and think in a certain fashion about science. I believe it will take me a while to get a good grip on this class and, hopefully, I will challenge myself to do the best I possibly can in this class (Student: Eileen, 8/27/98)
98.I.D. I expected him to begin ... with "normal" teaching, taking up his prominent position in front, while the rest of his colleagues help him maybe to operate some equipment. ... He explained about the materials, and said "there is an unknown substance which you are required to find out about. Please go ahead." I thought he was joking. . . . They gave no clues at all as to what we should do. (Student: Kathy, 8/27/98)
98.I.E. This is a very frustrating project for me because I don't know what to do. All I can think of is trying to grow it and see what it turns into. Perhaps if I had more lab experience in public school, I would be more prepared (Student: DeLaine, 8/27/98).
98.I.F. I must admit that this class is going to be far more challenging than I first thought. One primary reason is that I was not expecting this format. . . .I thought it would be a "How to teach labs class" structured similar to an education course. . . I am worried about how well I will do. This course has definitely hit upon my weak points and, therefore, I am positive it will help me later in my career (Student: Louise, 9/2/98).
98.I.G. In all of my four years at UT for undergrad, only once was I, as part of a class, asked to design and experiment and that was in oceanography. We studied plankton and brainstormed on our goals, time constraints, weather conditions, available equipment and the relevance of our findings. Suddenly this seems really sad that only once in four years was I asked to come up with my own experiment (Student: Lacy, 8/27/98).

I. Introduction 1999 (99.I.A)

99.I.A. Because of our lack of readiness with the testing portion, we have postponed the pre-testing until next Tuesday. Consequently, for the first period I had all of the time available to talk to them and get them started. This seemed to work quite well. I spent perhaps 30 minutes going over the syllabus and talking about the philosophy of the course. I think they got the idea. I tried to be much more explicit than I had been in previous years. Then we talked about the unknown and now also set out some ground rules concerning outside sources of information. I indicated that since Dr. Summer and I have in fact worked with the UNKNOWN for quite some time that they should not look under any web pages in biology that had our names on. Also, I asked that they not look in any library research article sources that would contain our names. I indicated the point strongly that any other sources were fair game. I indicated that they would not necessarily need outside sources, but in the real research world outside sources are frequently consulted. So, I indicated that they could use textbooks or research articles and so on...

. . .for the first time, this year I introduced what I called a culture pod. I indicated that this would substitute for what has frequently been requested, namely a incubator. So, by doing this I was quite assured of them using it but yet I didn't really tell them to use it. Consequently they ended up putting three dishes into the culture pod. The temperature inside should maintain itself at 4-6 degrees above room temperature. This should assure that there is very adequate growth of material, both spores and contaminants, by the second class on Tuesday (Dr. Temple's Journal, 8/27/99).

I. Introduction 2000 (00.I.A-D)

00.I.A. The TA administered their questionnaire during the first part of the class. She also scheduled videotaping sessions with them for 10 minutes each next Tuesday. . .

After the TA administered her materials, I came into the class and went over the syllabus with them. I was careful to not talk too much about the process of science and how much this course would be different, because the TA's interview on Tuesday will touch on some of these issues. I did however give them a general overview of what the purpose of the course was in terms of giving them a genuine research experience than they normally would get in a laboratory type course. I brought in a cart full of

00.I.A. (continued) materials and miscellaneous things, including some petri plates with agar and a pink growth pod. I briefly showed them the materials and said something about some things but made the point that these were some things that they may have some use for and they should ask me for any additional supplies or materials that they need for the work that they're going to be doing. This seemed to go over pretty well. Then I presented 10 vials of the unknown to them. Two of the bottles were pre-sterilized and the others were not. I then emphasized that we wanted them to find out things about the unknown and I put it in the context of an unknown organism that had been found by an ecologist in a tropical rainforest. I told them that the National Science Foundation had provided the laboratory and funds that they were currently associated with to enable them to find out about the biology of this organism. I then left them. As I was leaving and talking with the Participant Observer and the TA in hallway I noticed that the students were holding the unknown up looking at it and having some limited conversation about it. I stuck my head in the door briefly and told them that the only absolute ground rule was that they could not search for information about the unknown using my name. They could however use any literature or textbook sources of that they were interested in. (Dr. Temple's Journal, 8/24/00)
00.I.B. This class is very curious. I never really experienced anything like this before. Every other science class has been much more rigid, especially in the lab. Never was I given liberty to do most anything I want. It seems that the guys are going to work together and Tanya and I are together. Connie seems to want to work alone. I hope she doesn't feel pushed away from the rest of us. I was a bit disappointed. (Student: Connie, 8/24/00)
00.I.C. I have never had any classes or laboratories like this one. I have had the "cookbook" labs previously where the factors and processes were already determined. (Student: Sam, 8/24/00)
00.I.D. After the first day of class, my emotions toward the class were uncertainty and fear. My personality is one that likes organization and straightforward expectations and guidelines. After discussing the outline of the class, and a little about the experiment involved, Dr. Temple's turned us loose to start our work. I had a horrible feeling as I tried to figure out what exactly he wanted from us. (Student: Tanya, 8/24/00)

II. Facilitating student learning 1997 (97.II.A)

97.II.A. We have given them a very large amount of guidance and instruction through the feedback on their write-ups of an experiment and also during the journal club presentations. That should be enough. We need to sit it out and see how things develop from here. Maybe the best role we can play is one of encouraging students to actively pursue their planned experiments and to help them in time management . . .

. . . At our wrap up session, Kurt brought up some observations he had made and, in a nutshell, he seemed to be saying that we were on the verge of perhaps giving too much instruction to the students. I agree. We need to sit, watch, and observe and not get into a situation where we are telling the students how many replicates, what the controls are and so on. Dr. Summer seems to have a slightly higher tendency to do this than I do, although, we both are very tempted at this point to give more guidance and instruction to the students. We have given them a very large amount of guidance and instruction through the feedback on their write-ups of an experiment and also during the journal club presentations. That should be enough. We need to sit it out and see how things develop from here. Maybe the best role we can play is one of encouraging students to actively pursue their planned experiments and to help them in time management. That is, helping them get through all of the experiments that they would need to get through in a timely fashion. There is still time to allow them to set up an experiment that doesn't have a perfect design and analyze the results, and then hopefully, re-do the experiment with a better design. That was the original intention of the course and we don't want to lose that as our objective. (Dr. Temple's Journal, 10/16/97)

II. Facilitating student learning 1998 (98.II.A-F)

98.II.A. It is the first example this year and last year in which Dr. Summer and I both felt that we have to make a major correction in the way in which somebody was running an experiment. This is an excellent example of a situation where if we had not stepped in and just let them continue going as they were all there experimental results would be very questionable or invalid. It certainly would not have been conscionable to let them proceed without this correction. It will be interesting to see if any

98.II.A. (continued) of their thoughts on this are recorded in their reflective journals. (Dr. Temple's Journal, 9/29/98)
98.II.B. We realized that we had not controlled all the variables as much as we had wanted to. The main problem was that after bleaching the unknown, we left it on top of our bench for 7-10 days before we used them. During this time, the same was exposed to light. So we essentially started off with all the samples exposed to light. We had not realized this! (Student: Kathy, 9/29/98).
98.II.C. Dr. Temple talked about protocol today. He questioned on group about why they waited after sterilizing a sample before putting it on the Petri dish. While the rest of us have sterilized a sample and immediately put (it) on our plate. He said that as a group we need to do the same protocol. . . (Student: Nancy, 9/29/98).
98.II.D. Dr. Temple and Dr. Summer indicated that our experiment was full of confounding variables. . . I'm not sure what everyone else is getting out of the course. I know that I personally go through periods of revelation and despair but, all in all, I feel almost empowered by everything we've done thus far. I used to feel intimidated to even be in the building. I was trying to get certified (to teach) in biology and didn't have a clue about science. I was a huge hypocrite and felt everyone could sense it. Now I feel confident walking down the hall! I've made my own media and I've put together a good (albeit, somewhat flawed) experiment. (Student: Nathan, 9/29/98).
98.II. E. Some mentioned the idea that if the lobes were bisexual then all they needed were themselves to reproduce and that would make sense if they were alone. So they were going well beyond the simple observational stage and actually making some interpretations based upon the biological contexts. I still have to push them into coming up with particular experiments to come to some sort of resolution about lobes purses grapes. The group including Cindy had an experiment going that fit into the discussion. They set up isolates, groups of five, and groups of 15. I asked that they analyze their data today and really think about. At the end of the day I looked at their results and the most striking thing was their failure to really use quantitative methods. Some of them had numbers but they did not put the numbers into any format such as averaging and graphing that would allow them to look at any sort of trend that was associated with the treatments. So, I encouraged them to do just that. To graph their data. This seems like another big leap for them to take. Very interesting! (Dr. Temple's Journal, 10/13/98)

98.II. F. They got to the point of suggesting that there may be some sort of chemical signal that was controlling the formation of grapes. I talked with them about that idea for a short while, but they never fully came up with a method of testing for the presence of the chemical (a bioassay!). But I left them with the challenge. I felt that if I stayed around for much 98.II.F (continued) longer, I would give them too much information. (Dr. Temple's Journal, 10/20/98)

II. Facilitating student learning 1999 (99.II.A-B)

99.II.A. I said things such as "Is exchange made only after day six? How do you know when they do exchange something?" This finally convinced them that they would also set up experiments by separating spores. (Dr. Temple's Journal, 9/9/99)

99.II.B. I did not want to give them excessive help with they're experiments but I did not want them to go off the deep. So I just hung around and listened. When I heard them talking about something that might be an experiment or that used a particular word or phrase that I thought could be used to develop a conversation, then I went to them, individual or group, and discussed it further mostly by asking questions. (Dr. Temple's Journal, 9/28/99)

II. Facilitating student learning 2000 (00.II.A-M)

00.II.A. Just as in the last class, I spent most of this classroom session going up and down from my laboratory and assembling different things that they requested. It certainly kept me busy, and I did not have a lot of time to be in front of them. This bothered me, because I wanted to see more of what was going on with them. However, it also kept me out of the classroom and prevented me from leading them on to much at this critical time. (Dr. Temple's Journal, 9/19/00)

00.II.B. We are all VERY frustrated and down about this now. We have no idea how to even begin answering these questions they are asking. After Dr. Temple left the lab, we were scanning a biology book and found a life-cycle of a fern and it looks very, very similar to what we are seeing

in this 00.II.B. (continued) unknown. We are going to keep this to ourselves for a while. (Student: Connie, 9/19/00)
00.II.C. I have written twenty pages of observations, but I feel as if I have nothing concrete an I am missing something big. We brainstormed on ways to test the unknown to reach useful data. Also, Dr. Temple wants us to being designing more complex experiments. (Student: Tanya, 9/19/00)
00.II.D. He said that I wasn't clear in some areas, and I agree with him. I'll talk to him to see how I can be a clearer thinker and presenter. We also had a change to ask each other questions about the research work we reported on, by far the hardest coming from Dr. Temple...Questions like what is the control? Is the sample size sufficient? Those are really basic questions but so tough to decipher at times. (Student: Frank, 9/19/00)
00.II.E. Dr. Temple kept asking about what control and sample sizes were used in the articles. I believe this was to guide us to begin asking and forming more "in-depth" questions and hypothesis. (Student: Sam, 9/19/00)
00.II.F. We go to Dr. Temple's five questions each this week and he promised to answer them. However, we actually answered most of them together, instead of him just feeding us. I think that I really just need assurance on some of my assumptions and ideas. I am really ready to start my experiment on Monday. (Student: Connie, 10/3/00)
00.II.G. Although I did not receive the results I expected, I didn't let myself become discouraged and I thought about what this told us. It felt very good to make such a discovery. I was proud of my critical thinking abilities in conversation with the others in lab as well. I feel as if we are starting to put important pieces together. (Student: Tanya, 10/3/00)
00.II.H. This is a challenging process . . . I sometimes wish that the answers could be fed to me, but I totally feel that this process will help me in the future. I still believe that all science teachers should go through a class similar to this class. (Student: Frank, 10/3/00)
00.II.I. Dr. Temple opened the class by allowing each of us to ask five questions about the unknown. Once the questions were compiled, we answered each other's questions with a little prompting. (Student: Sam, 10/3/00)

00.II.J. In today's class I attempted to get things moving in terms of speeding up their progress in understanding what is going on by doing what I have done in the past: giving them an opportunity to write down five questions apiece. I did this at the beginning of class and then came back 20 minutes later and compiled the questions in my office. Subsequently, I returned to the classroom and discussed the questions...As in previous years, most of the questions were answered by asking the students what they knew about it. In most cases the knowledge is there, but it is not assembled or is perhaps withheld because of a hesitancy and saying something that 'might be wrong." (Dr. Temple's Journal, 10/3/00)
00.II.K. Dr. Temple is really good at challenging us and keeping us on our toes and causing us to think about the nature and history we have of this unknown. (Student: Frank, 10/10/00)
00.II.L. I've taken my final data and am ready to write my report. I can't believe the results I got! Totally opposite from the expected. I guess that's science for you. Yes, it has been frustrating at times and hard to live with, but I made it. (Student: Connie, 12/7/00)
00.II.M. We just finished our presentations. It is hard to believe that this semester is already over. I put more time into this course, especially at the beginning, than many of my other classes. . . . The course was dissimilar to all previous courses and experiences. However, I learned a lot about scientific thinking, experimental design, and the nature of science. (Student: Tanya, 12/7/00)

II. Facilitating student learning 2001 – 2002 (01/02.II.A-O)

01/02.II.A. Well knowledge, up front, I would think the traditional course is more focused on that in terms of talking specific knowledge, subject matter, ideas, events, places, information, recall—all that. And, I think, in the traditional course that's a large component of it whereas in the Do-It course, it's a relatively small component. And the testing, the assessment in traditional courses is really based on knowledge. We try to bring in things like comprehension and application and things, but the testing is really just targeted for knowledge recall. (Dr. Temple's Interview, 5/17/02)

01/02.II.B. In the traditional course, comprehension is something we want them to have and to be able to compare things and go through various levels of understanding. But, then again, that's presented more in the lecture and a lot of times it's very difficult to assess that comprehension in the traditional method. And to stick with comprehension with the Do-It type of course there's a large emphasis on comprehension, but in a different sense. It's comprehending--maybe the system that you're looking at in an experimental fashion, comprehension of the whole process of looking at things and so on...(Dr. Temple's Interview, 5/17/02)
01/02.II.C. The real application is having students able to sit down with something that is totally unfamiliar and use information and skills and thought processes that they've developed to address that new situation. And I think that's where we fail to really show (in a traditional class). I think the Do-It class pushes at that as a major thing, because I don't tell them to come in with their minds blank, I tell them to come in with all of the knowledge they have including knowledge that they can bring in through books and internet sources and so on...and in the traditional course, even though there's intent there, it's really again seldom realized. . .other than through basic problem solving--but that's a situation where we take them through a three-point test cross procedure and it's a fairly complicated logical procedure where they have to go through a thought process—more often than not they just memorize the steps and the only new application of that we have is maybe a different type of problem or a different type of organism or something but it's really the same thing. (Dr. Temple's Interview, 5/17/02)
01/02.II.D. In a traditional course, there's very little opportunity, if any at all, to come up with an original concept to combine an application or analysis and then come up with some sort of really new viewpoint or question. . .With the Do-It course, I think there's examples of that happening on a regular basis. Students last semester, for instance, by their observations of another phenomenon found that when you shined light on chloroplasts, they actually moved. When you put them in the dark, they moved some place else. So that was, for them, a totally new phenomenon that they discovered and described and actually had a very nice experiment designed to show that. Another one (student) did this wonderful thing with mealy bugs and basically their preference for surface texture and he came up with a way to combine his very crude observations with a way he could actually get a mealy bug to go through a maze. It was just a wonderful experiment. That's synthesis, that really puts things

01/02.II.D. (continued) together. What a buzz it was for the kids too! (Dr. Temple's Interview, 5/17/02)
01/02.II.E. There's little of that (evaluation) in the traditional course. To give you a really good example. . .in my traditional course, I had a small component where they students would give these presentations in the middle of the lecture period and they would be like five or ten minute presentations. I had students grading them as peer grades and with very, very few exceptions, I think we went through 50 of these, so there were 50-70 students grading 50 presentations and with very few exceptions, they gave them four out of four. It was very uncritical. (Dr. Temple's Interview, 5/17/02)
01/02.II.F. . . . in the non-traditional genetics course that I'm teaching (the Genetics and Society) I actually had a peer grading component in there. In a group within a group grading as well as peer grading, outside group grading. . . pretty complicated, they were critical (very nicely critical), it was probably the way it was structured, as well, because I had some oversight and I was actually grading their grading. It turned out that they were very critical in many of the same ways that I was of certain presentations and papers. (Dr. Temple's Interview, 5/17/02)
01/02.II.G. In the Do-It class, I encourage them to critique (and this is verbally) right at the time. . . it's not anything that's done anonymously . . .encourage them to critique other presentations, experimental designs and 01/02.II.G (continued) so on. Not one hundred percent of them, but a good number of them actually do that quite well and are critical. . . that opportunity. . .is not presented other places--to do some critical evaluation and judging. (Dr. Temple's Interview, 5/17/02)
01/02.II.H. For the Do-It course, I probably spend more time after each period sort of mentally assessing and reflecting on what had happened. That probably was preparatory for the next class. So it was sort of a reverse order preparation. How was this affecting students was a big concern and still is. Am I ruining their life and careers? Are they going to be a doctor that kills so many because they don't know something? I pretty well dismissed that because I'm pretty well convinced that if you ask this question when you are teaching in the traditional way and really ask it, then you find out you weren't doing much for the kids. So I feel like I'm not hurting them. You know, first do no harm. (Dr. Temple's Interview, 12/12/01)

01/02.II.I. ...probably conversations with Claudia, not specifically about that (stages of change), but conversations about what are students really learning when you give them a lecture class and traditional assessment. Once you start thinking about that, give yourself this free line to really think about it and honestly say—what are we doing for these kids. That all came together and pretty much convinced me that I am doing no harm. (Dr. Temple's Interview, 5/17/02).
01/02.II.J. I am still frustrated and still dealing with it. I have a lingering fear that I have gone soft in my old age and now I have really dropped my standards...what I thought were standards relative to content. The biggest change is stepping off that level of complacency and trying to figure out if you are, in fact, accomplishing anything in your teaching and how you might do better. But I am always worried that what I am doing now is not as rigorous, is deficient in content, and not effective. I know deep down. . . I think it is effective and it goes along with everything that I get from the college of education...that there is a better way of teaching and learning. But there is this deep fear that Dr. Temple's gone soft...(Dr. Temple's Interview, 12/12/01)
01/02.II.K. I really realize now and I challenge my colleagues on this now, a lot, and we all know this but we don't say it so much. If you have a semester's worth of material that you are presenting to the students and they have to jump these things called 'test hurdles' and put what they know down (on a test), we know that two weeks after the class they don't probably have recall on more than 20% of it (just a figure to pull out of the air). The material that I presented to them was absolutely the stuff that I know they will need for the GRE and so on and so forth...and that was really hammered in well. (Dr. Temple's Interview, 12/12/01
01/02.II.L. I remember walking into this new lab at a new university, first-year doctoral student, master's in botany and this lab was working on the fern life cycle. I really wasn't quite sure what the fern life cycle was and this was after six years of undergraduate and graduate school and so it's clear, now looking back and I remember that time, going in there and fudging my way through in conversations. Then I remember another thing in undergraduate school. The experience came in graduate school again at the doctoral level. I was looking at my initial research project and it turned out to be a mutant situation. It was actually a hybrid that had some very abnormal chromosome behavior in meiosis. Well I never understood meiosis until I was analyzing that hybrid. And I still remember when I was an undergraduate, I remembered meiosis as pmat (prophase, metaphase,

01/02.II.L. (continued) anaphase...). I had to do that. It was just this little thing that you use to memorize. That just tells that that level of knowledge that I had for many, many years was a memorization trick. . . .I realized, after six years, that you really understand concepts (such as mitosis and meiosis) when you put your hands in them usually in a situation that's unfamiliar to you and you have to make sense out of it. To quote stuff that I'm reading now, it's just experiential learning. It's that precisely. (Dr. Temple's Interview, 5/17/02).
01/02.II.M. There has been some other dialogue with one of my colleagues who is now involved with the Scholars in the Schools program here at UT. We've had what you might call friendly arguments about the whole idea between content and pedagogy and what he's doing and thinks he's doing and so on. These have been some wonderful conversations, we've probably had about three to four in the last year, some of them quite loud in the main office. But he is coming across, slowly, and is now thinking more that well maybe we can drop some of the content and do other things...When I say coming across, he's not as combative in our conversations. We would have conversations like, 'well, look, our way of doing things has worked for many, many years. Look at all the Ph.D.'s and physicians we've turned out' and my question was 'what percent of (all the) students were those Ph.D.'s and physician end products and where were all the other ones (students) and do you know if you did anything effective with them?' So bringing up things like that has more than anything made him think about what he's doing and made him look at the class rather than looking at the top 10-20%...looking at it more as a group of individuals that are all going to go on and do something. Paying more attention to educating the other 80%. (Dr. Temple's Interview, 12/12/01)
01/02.II.N. And, I have frequently asked the question, 'well how do we know that we are good teachers?' And people grumble about that a little bit. Usually the response is that we get good student feedback, students like us, like the course. And then I still ask the same question—how do we know we are good teachers? . . . So there is a constant effort on my part to get some dialogue in the department going, but it's very limited. It is tough to get that dialogue going. (Dr. Temple's Interview, 5/17/02).

01/02.II.O. Oh, gosh, it is hard to teach. It is easy to lecture. You know we are all brought up in a research seminar mode and basically our teaching, I think, is largely a research seminar that is modified to a classroom situation and maybe extended to 75 minutes. But it is all based on that. So, when you change out of that lecture format and actually try to teach—I say that a little sarcastically but with some meaning behind it—it is very difficult. (Dr. Temple's Interview, 12/12/01).
01/02.II.P (In the beginning) I was definitely at point zero. This is a negative connotation for that. The awareness thing. I've always, up until this so-called change, always been a good teacher, a good lecturer, and teacher. I always thought about ways of doing lectures well and explaining materials more clearly and so on. But in terms of innovative approaches, there was no awareness. When I first talked with Claudia, I went to stage one. I think probably her passion about it was the strongest thing I took away with me. From talking with her she was very passionate about the whole idea of kids not having research experience, kids not being able to synthesize . . . and so forth. So I was at that stage, probably immediately after my first encounter or two with her, I'd like to know more about it, more information. . . . as soon as I started changing; that's (Stage) four . . . once I was trying to implement change, I was concerned about how it was affecting the kids. I probably was at least into the (change) process because I wasn't confident enough about what I was doing to really discuss it much with colleagues. That's something that probably took three years. . . .(Stage 6 of CBAM) refocusing continues (Dr. Temple's Interview, 5/17/02)

III. Becoming a reflective practitioner 1998 (98.III.A)

98.III.A. What are we doing different this year? Is the difference between this year and last year purely dependent upon the types of students that are in the course? Or are we doing something significantly different? Are the students perhaps a little bit more prepared for the concept of the course because of what Claudia has indicated to them? Did the five-minute interview help to east them into the situation? Is the absence of a video camera important? Last year, when Dr. Summer and I walked into the room there was generally a hush that came over all the students. According to the TA they had been arguing quite a bit or perhaps expressing discontent with the course, among themselves but that certainly does not seem to be the case this year. So, what are we doing differently??? (Dr. Temple's Journal, 9/3/98)

III. Becoming a reflective practitioner 1999 (99.III.A-B)

99.III.A. So, it indicated to me that he did, in fact, have a good visual recollection of what the organisms look like, but he just was not confident in his own ability to put it down on paper-without going to a textbook as a support. This is very interesting and I think as much of a learning experience for me has it was for Mark. (Dr. Temple's Journal, 11/18/99)
99.III.B. It is time for minimal interaction with me. In fact, I often feel that I'm getting in the way and should not even be in the classroom. (Dr. Temple's Journal 10/19/99)

III. Becoming a reflective practitioner 2000 (00.III.A-C)

00.III.A. In my previous life as a researcher/teacher I would definitely have classified this individual as being a student that was not capable in this subject area. Also, I would have doubts, very serious doubts, about his qualifications concerning teaching. In my "new life" as a scientist/educator I am trying to be a bit more reflective about just what the student is presenting to me. Although I am trying to be more reflective,

00.III.A. (continued) I still find myself with very strong thoughts about the student's qualifications. But, I wonder if he really should be in the classroom, ever?

So, I will continue to be patient and try to work with him and see how things develop. (Dr. Temple's Journal, 10/3/00)

00.III.B. Again, as in previous semesters, it is a very obvious that this type of experience or something similar to it is absolutely necessary for the students. I am not certain, given the results from this semester, that this particular course format is the solution to the problem. However, I feel that it is a better approach than most laboratory experiences that students get as undergraduate research participants. More fundamentals on experimental design, or original thinking, tying things together at the conceptual level, etc. etc. are absolutely needed and are typically not provided in the research laboratory setting - at least at this level. Of course, there are exceptions. (Dr. Temple's Journal, 12/13/00)

00.III.C. I have not maintained regular entries into this year's Do-It Journal. Partly that is because of the limited number of students in the class. Also, I'm teaching two courses this year and the other course (General Genetics) contains 80 students, so I have been quite busy. That aside, there are certain things that have been developing in this semester's Do-It course that concern me. (Dr. Temple's Journal, 9/29/00)

III. Becoming a reflective practitioner 2001-2002

01/02.III.A. The biggest change that I am really still struggling with is the idea that content has to be necessarily limited. The type of approach that I have taken for many, many years in teaching a course like general genetics would be to have a schedule "x" number of chapters, sometimes two (chapters) a lecture and pushing student through that material as quickly as I could. Also, with a mind to try to explain it fully and actually teach them something. But, nonetheless, it was really a content driven type of approach. And I'm still struggling with that but I am probably on a scale of 1 to 10, if I was a 1 before, I am probably about a 6 now in terms of my conscious balancing of content versus other things like understanding and dialogue in classes...

What I had done the previous time (an earlier attempt at change), and I taught this course every other year, was to take a five-ten minute break in the middle of lecture—but it was still me. I would try to change pace and talk more conversationally and get some questions going and so on. And I

01/02.III.A (continued) finally woke up one morning and said "Temple you've got to get yourself out of there to do something very different. . . not just me fast, me slow and then me fast again"(Dr. Temple's Interview, 12/12/01).

IV. Scientist-Professor observes student behaviors as related to learning 1997 (97.IV.A-E)

97.IV.A. It also became clear during the period that the students knew some information about C-Fern. Apparently, they had seen the C-Fern information on the Botany bulletin board. Melody went to the internet and pulled up the C-Fern webpage. She read some information on the introduction pages, but did not really get very much information. At any rate, the students did learn that it, the C-Fern, was an aquatic plant and obviously that it was a fern. I don't really think that they learned much more than that, however. An interesting point was that they attempted as a group to keep their knowledge of the C-Fern a secret. For some reason they did not want us to know that they, in fact, knew something from another source. We will try to bring this out next Tuesday in class. (Dr. Temple's Journal, 9/18/97).
97.IV.B. We tried to push them some in terms of their understanding. It does not seem that they have a very firm grasp on things. It was interesting that there were two general biology books in the lab that they had brought in themselves. They, some of them, were consulting these books and were looking at fern life cycles. There were pictures of gametophytes and terminology, etc., but it was interesting that the students really didn't analyze what was in the book deeply and relate it to what they were seeing under the microscope. For instance, there was a photograph of a gametophyte with many archegonia. The students didn't look for comparable structures in their own living material. We're very perplexed about this?? (Dr. Temple's Journal, 10/2/97)
97.IV.C. Today we spent the majority of class in a "lab meeting" atmosphere. Melody and I volunteered to go first. I wish we wouldn't have. Dr. Summer and Dr. Temple really drilled us with questions. We didn't think our discussion would have to be so in depth. I don't know about Melody, but I felt really stupid. I'm pretty sure that she felt the same way. They were asking us to explain what we meant by growth and how we would explain it to Dr. _______ in Russia who couldn't speak English. In a way this is good but I think it would be better for a research oriented class rather than an education one. Maybe if I had more experience dealing with science from his angle, I would feel more comfortable. I also am having a hard time relating to how this all ties into teaching a high

97.IV.C. (continued) school level class. I don't remember ever learning in this way. (Student: Lucy, 10/2/97)
97.IV.D. There were some more very uncomfortable (for all of us!) silent periods during this class. They need some extra encouragement next class!! (Dr. Temple's Journal, 9/2/97)
97.IV.E. Some of the things have sprouted and I suspect that they are some type of plants. Anyway, sometimes I feel totally lost in this class. After so many years of structured classes, to be involved in this just makes me feel lost. I really don't know which way to go. I guess the main problem is initiation for all of us. It seems no one knows what to do and when someone comes up with an idea everybody likes it. I guess it is because no one has a clue. We accept ideas even though they may not be useful. At this point in time though any idea is welcomed to start the class. (Student: Bill, 9/2/97)

IV. Scientist-Professor observes student behaviors as related to learning 1998 (98.IV.A-D)

98.IV.A. We tried to relate this to the concept of eggs and sperm but they didn't grab a hold of the idea and this sort of dropped away in the conversation. This was very curious. (Dr. Temple's Journal, 9/15/98)
98.IV.B. The notable things about anything that we might call a deficiency in them as a whole are the following: a hesitancy to come up with formal experimental designs, their failure to recognize the very simple but appropriate questions that they're asking, their hesitancy to initiate experiments with an adequate number of replicas and backup dishes. Also, they are generally not well-versed, at least in a practical sense, in the idea defining how they were going to measure something, how they were going to represent (data), and essentially how they were going to generate data sets. (Dr. Temple's Journal, 9/15/98)
98.IV.C. The presentation by Ian was a shock! He began by handing out a relatively long paper that was basically a review of some of the literature that Dr. Summer and I have generated on C-Fern. This was a pure violation of the initial instructions. . .but he didn't seem to realize it. He also had intermixed with this some of his own "experiments," although they really aren't very much of experiments. He handed out this paper to everyone and as I was glancing through it decided that the best thing to do was to end his presentation. (Dr. Temple's Journal, 10/27/98)

98.IV.D (continued) A variety of questions were asked and the responses were generally quite good. They have come to a partial and certainly incomplete understanding of the organisms at this point, but it seemed that most of their observations were well taken. They are in fact making some very keen observations such as the organism does not appear to need a carbon source in the medium and therefore seems to be photosynthetic. (Dr. Temple's Journal, 9/10/98)

IV. Scientist-Professor observes student behaviors as related to learning 1999 (98.IV.A)

99.IV.A. At this point, they still seem to be wary that they may be going off in false direction, and I wanted to be sure that they understood that I would not give them incorrect information nor would I let them go hopelessly down a dead end of an investigation. (Dr. Temple's Journal, 10/5/99)

IV. Scientist-Professor observes student behaviors as related to learning 2000 (00.IV.A-C)

00.IV.A. Also, it is interesting (and not surprising) that the boys set up a single petri plate and a single pot of soil and to do their "experiment." Let's hope that there are really dramatic changes in what they are doing by the time they get finished with the course and before they get into the classroom. (Dr. Temple's Journal, 8/24/00)

00.IV.B. I do not think George is equipped to teach in the classroom. He has serious deficiencies both in terms of content as well as in his conceptual understanding of the subject material at a basic level. Added to this, his complete lack of any ability to really ask questions and design effective experiments to answer them, makes him highly deficient in terms of ever teaching in an inquiry based setting. For his final research paper on C-Fern, we went through approximately five drafts of the paper. In the final draft, I awarded him 10 of 20. It was very thin both grammatically as well as in its overall structure. Very, very frustrating! (Dr. Temple's Journal, 12/13/00)

00.IV.C. So, I congratulated them on a series of good observations and encouraged them to be sure that they wrote things down. I also pointed out in our general conversations any instances where they suggested

00.IV.C. (continued) experiments and had it least a glimmer of some type of hypothesis. This seems to be quite necessary at this point. The students are not sophisticated enough or comfortable enough in they're dealing with open-ended research to know when in fact they do have a particular hypothesis or when they have observations that should be made note of. (Dr. Temple's Journal, 8/29/00)

Bloom's Taxonomy

Benjamin Bloom created this taxonomy for categorizing level of abstraction of questions that commonly occur in educational settings. The taxonomy provides a useful structure in which to categorize test questions, since professors will characteristically ask questions within particular levels, and if you can determine the levels of questions that will appear on your exams, you will be able to study using appropriate strategies.

Competence	Skills Demonstrated
Knowledge	• observation and recall of information • knowledge of dates, events, places • knowledge of major ideas • mastery of subject matter • *Question Cues:* list, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.
Comprehension	• understanding information • grasp meaning • translate knowledge into new context • interpret facts, compare, contrast • order, group, infer causes • predict consequences • *Question Cues:* summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
Application	• use information • use methods, concepts, theories in new situations • solve problems using required skills or knowledge • *Questions Cues:* apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover

Analysis	• seeing patterns • organization of parts • recognition of hidden meanings • identification of components • *Question Cues:* analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer
Synthesis	• use old ideas to create new ones • generalize from given facts • relate knowledge from several areas • predict, draw conclusions • *Question Cues:* combine, integrate, modify, rearrange, substitute, plan, create, design, invent, what if?, compose, formulate, prepare, generalize, rewrite
Evaluation	• compare and discriminate between ideas • assess value of theories, presentations • make choices based on reasoned argument • verify value of evidence • recognize subjectivity • *Question Cues* assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize

Adapted from: Bloom, B.S. (Ed.) (1956) Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain. New York ; Toronto: Longmans, Green.

Stages of Concern
Typical Expressions of Concern about the Innovation

Stages of Concern	Expressions of Concern
6 Refocusing	I have some ideas about something that would work even better.
5 Collaboration	I am concerned about relating what I am doing with what other instructors are doing.
4 Consequence	How is my use affecting kids?
3 Management	I seem to be spending all my time getting materials ready.
2 Personal	How will using it affect me?
1 Informational	I would like to know more about it
0 Awareness	I am not concerned about it (the innovation).

VITA

Terry L. Hester (Lashley) was born in Cushing, Oklahoma, on August 14, 1946. At an early age, her family relocated to Houston, Texas, where she attended grades 1-3. In 1955, the family once again relocated to Bemidji, Minnesota, where she attended grades 4-8. In 1960, the family moved (farther north!) to Clearbrook, Minnesota where she graduated from high school.

Lashley graduated from Wisconsin State University in Superior (now the University of Wisconsin, Superior) in 1971 with a B.S. in Biology and Secondary Science and a minor in Psychology. Lashley later attended the University of Tennessee (UT) where she earned an M.S. in Curriculum and Instruction in 1993. She received her doctoral degree from UT is 2002.

Lashley has taught in Missouri and Tennessee. She taught biology and AP biology at Fayette High School, Fayette, Missouri, from 1971-1973. Lashley taught earth science and gifted science at Cedar Bluff Middle School and, later, biology at The Center School in Knoxville, Tennessee, from 1977-1990. Between 1990 and 1997, she was employed as the Precollege Program Administrator and Team Leader at the Oak Ridge National Laboratory's Office of University and Science Education. Since 1997, she has worked at her present position at the University of Tennessee with a National Science Foundation Rural Systemic Initiative.