Teaching philosophy and practices among chemistry faculty attending the MID project workshops: Implications for reform in chemistry

Beverly Dee Barker

University of South Florida

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Teaching Philosophy and Practices Among Chemistry Faculty Attending MID Project Workshops: Implications for Reform in Chemistry

by

Beverly Dee Barker

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy
Department of Chemistry
College of Arts and Sciences
University of South Florida

Major Professor: Jennifer Lewis, Ph.D.
Kirpal Bisht, Ph.D.
Donilene Loseke, Ph.D.
Maralee Mayberry, Ph.D.
Mike Zaworotko, Ph.D.
Dana Zeidler, Ph.D.

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Dedication

This work is dedicated to Bruce David Hougan, my husband, who helped to carry this load over the long haul.
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As happens in a project that has an interdisciplinary outlook and approach, the inspiration and completion of this work has come about through enormous assistance and advice from others. Dr. Jennifer Lewis, my advisor in Chemistry and creator of the Chemical Education program at USF, inspired her group and me by her example to think carefully about relationships of practice and thinking as they pertain to the world of chemists and chemistry. Dr. Dana Zeidler, my mentor and director of the Science Education Program in the College of Education at USF, taught me to value pedagogical content knowledge, maintain a sense of humor in the face of failure, and to value my undergraduate degree in philosophy. Dr. Jeff Kromrey, in the Educational Measurement Program in the College of Education at USF who taught me the finer points of statistical applications in education and who continued to be very open to provide much needed advice, long after I left his classroom. My gratitude to Leila Amiri, who helped organize the paperwork needed to complete my dissertation at USF when I was away in Alaska and to Dr. Mary Snyder, Dean of the College of Education at the University of Alaska, for her careful reading of the text and critique. And last but far from least, the rest of the committee who took the time to offer their perspectives and critique of this work: Dr. Mike Zaworotko, chairman of the Chemistry Department, Dr. Donileen Loseke and Dr. Maralee Mayberry, both teachers and mentors in Sociology and Dr. Kirpal Bisht, natural product chemist at USF and a willing deliberator of Chemical Education research.
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Teaching Philosophy And Practices Among Chemistry Faculty Attending Mid Project Workshops: Implications For Systemic Reform In Chemistry

Beverly Barker

ABSTRACT

Over the past decade over 600M in funding has been devoted to bringing about reform in science education, but little is known about who is implementing reform, the extent of reform implementation and how educational contexts differentially impact reform innovations. This presentation explores the results of the Multi-Initiative Dissemination Project (MID Project), a national curriculum reform program that was designed to propagate reform pedagogy among undergraduate chemistry faculty in faculty development workshops. We analyzed data from surveys, in-class observations and faculty interviews to explore the relationships between the participant faculty demographic features and their pedagogy and teaching philosophy before and following exposure to the workshops. We found interesting demographic characteristics that distinguish the participant faculty from the academic chemistry faculty responding to the ACS 2000 census. Also, our study uncovered relationships between the participants’ demographic features and their conceptions of teaching and practices that may mediate the impact of pedagogical interventions such as curriculum reform workshops. This
dissertation describes these relationships and their implications for policies supporting reform efforts.
INTRODUCTION

AN INVITATION TO ACADEMIC CHEMISTS

Reform in chemistry education holds the promise of encouraging a wider public to effectively participate in environmental, pharmaceutical, medical, and industrial chemistry choices. It holds the potential to increase public understanding and appreciation of the varied ethical perspectives that comprise the context of these choices. Through stimulating a better understanding of how science functions, the reform in chemistry education demands greater competence in the critical evaluation of chemical applications. It claims that by bringing diversity, understanding and awareness to its practices through reform, new approaches in chemical education can change not only the ‘face’ of the science, but its objectives and aspirations. Therefore it is appropriate for chemistry faculty involved in undergraduate instruction to consider their participation in the reform movement; to consider fostering its progress by learning about and understanding its history, its current direction and objectives and how to overcome obstacles to its development. Reading and thinking about these issues presented within this dissertation is an opportunity for such consideration.

This study is unique because it develops an analysis of the response to reform in undergraduate chemistry, through an investigation of teaching approaches implemented
within the context of the history of the reform movement. It includes a brief overview of reform in chemical education and reveals how conceptions about reform evolved in undergraduate chemistry education by describing key perspectives and events leading to its current state. Eminent organizations such as the National Science Foundation (NSF) and the American Chemical Society (ACS) evaluated the need for reform and the place that chemical education research has in its development. These organizations generated a discourse on themes that influenced policy on undergraduate chemistry programming. This dissertation explores these themes and reveals crucial tensions that may have unintentionally affected the development of the reform program in chemistry. Last, this work provides both a qualitative and quantitative analysis of the dissemination of the current reform movement in undergraduate chemistry through an investigation using survey and case study data collected from participants of the Multi-Initiative Dissemination Project (MID Project).

Because stimulating a change in teaching strategies is one of the primary goals of the reform in chemistry, directly exploring and understanding chemistry faculty’s practices and conceptions about teaching and learning is warranted. Hence, this study investigates the teaching practices of academic chemists after their exposure to reform pedagogy presented in the MID Project workshops. The goal of this investigation is to uncover crucial features of the dissemination process, such as how and to what extent implemented teaching practices are linked to instructors’ personal conceptions about learning and teaching chemistry. To proceed toward this goal, four specific research questions are explored in the MID Project data:
1. In what ways are chemistry faculty attending a reform workshop (such as the MIDP workshops) different or similar to the general population of academic chemists?

2. What are the ‘in-use’ and ‘espoused’ teaching conceptions (e.g. beliefs and intentions) that academic chemists attending the MIDP workshop have about reform approaches?

3. What teaching conceptions appear to have the greatest influence (impinge the most) on their observed practices and on their adoption of reform?

4. How do their specific contexts (faculty demographic characteristics and teaching environment) influence both their teaching conceptions and practices and their adoption of reform?

While chemical education research generally describes the successes or failures of particular educational projects or approaches, this study is distinctive because it is intended to complement and expand our understanding of the discourse on reform and its impact on undergraduate chemistry. Furthermore, it is unique because data from a reform dissemination program and the literature discourse are integrated together to propose a new model of reform to be developed further in future studies on reform in undergraduate chemistry. Last, interested readers of this dissertation have an opportunity to assess this model and the progress of reform in chemistry and how they might best serve its future development.

THE HISTORICAL CONTEXT

There are many ways that the history of current reform can be conveyed. The approach taken in this dissertation mirrors the discussion in the early reform policy documents, namely, ‘the problem’ of science illiteracy is described first. The section on
‘the problem’ includes a detailed presentation of a few of the policies that reformers recommended to resolve the problem of science illiteracy. The reform policy documents presented reform as a remedy but omitted available supportive data to substantiate their claims. As this historical discussion is recounted, this section reveals how this omission might have led to unintended outcomes in faculty’s perception of reform and describes data that could have been used to support reformers’ claims. Then the following section describes ‘the solution’, where the reform program that was established is presented as the reformers’ construct to resolve the problem and fulfill the recommendations of the policy papers. As such, the historical contexts of both the problem and solution are intertwined, and on occasion in this dissertation, references to reform remedies are mentioned in the discussion of the problem of science illiteracy. Risking redundancy, the following section on ‘the solution’ begins with a brief recap of the historical context of the issues as they were perceived in undergraduate chemistry. This approach was intended to help the reader establish relationships between content presented in both sections.

**THE PROBLEM: SCIENCE LITERACY**

The events that gave rise to the current programs in chemistry education occurred in the late 1980’s. Reports documented a ‘crisis’ in the US science education system that acquired the momentum of a national issue. According to this literature, the American public was “scientifically illiterate”. (1-3) One report described a survey conducted in 1988 that probed the science literacy of 2000 Americans. (1) Responses to the survey
revealed only 6% of the respondents met the criteria to be considered scientifically literate. The researchers also found that a college level science course was the “predominant, single most important predictor” of science literacy rather than a general college education or science in high school. Thus the implication of this study and other reports similar to it was that the lack of science literacy in the American public can be mitigated by enrolling the American public in college level science courses. However there was an underlying caveat: college level natural sciences courses had great difficulty attracting and keeping enough students to make a difference at the national level. (4-6)

As a consequence of reports such as the above, remedial action was taken by the National Science Board to create an administrative structure having undergraduate education as its first priority. (3) This effort led to the formation of what is now NSF’s Division for Undergraduate Education. One of the earliest actions taken by this new administration in 1988 was the funding of projects in the Undergraduate Faculty Enhancement (UFE) program to encourage faculty to adopt reform. Other reform projects or “initiatives” that were eventually funded in the late 1980’s and early 1990’s include projects in the Course and Curriculum Development (CCD) program, Research in Undergraduate Institutions (RUI), Undergraduate Research Participation (URP), Advanced Technological Education (ATE) and early reform dissemination projects, such as Comprehensive Improvement Project (CIP) and the Engineering Education Coalition (EEC).

Funding support for these programs also increased in this period. The NSF FY 1987 budget for all of undergraduate programming was $17.8M (Million). (3) By FY
1992 NSF awarded 52M to undergraduate programming and 16M for systemic reform (k-12 and post secondary).\( \text{(7)} \) From 1988-1996 NSF awarded 102M to undergraduate science course curriculum development and 46M to faculty development in undergraduate science programs.\( \text{(8, 9)} \) In 1995 NSF awarded 10M to chemistry undergraduate reform program development.\( \text{(10)} \) By 1998 NSF spent over 600M on systemic reform in science education which included 14M on chemistry undergraduate reform program development.\( \text{(11, 12)} \) Other organizations also contributed to developing reform in undergraduate science education. For example in 2003, the Howard Hughes Medical Institute awarded 20 science faculty 1M each over four years to develop new modes of science teaching.\( \text{(13)} \) In all, this substantial increase in financial support since 1988 demonstrates that educational agencies and NSF placed considerable value on the development of reform in chemistry and other sciences.

While increasing student learning was the ultimate goal of these early reform programs, program visionaries considered substantiation of student achievement to be too “distal” or affected by too many different factors to be a fruitful objective.\( \text{(14, 15)} \) Consequently, programs such as UFE approached reform by engaging faculty in activities to improve instruction with the assumption that improved instruction leads inevitably to improved student achievement. However by the mid to late 1990’s the sustained problems with science literacy and the dwindling capacity of the US to maintain science leadership at the international level called into question whether the goals and activities of the earlier reform programs served the public need.\( \text{(16-21)} \) The unresolved condition of a scientifically illiterate public and the uncertainty about the US’ future science
leadership indicate either complacency and/or a lack of understanding of how to create the change needed in the science educational system. Therefore these conditions justify a study into the complexity of reform in undergraduate science education and warrant investigating specific factors in its development using the reform in undergraduate chemistry education as a model case.

**Reflections in Chemistry**

The discussion on reform in chemistry evolved as the current reform was implemented and developed in the mid to late 1990’s. Similar to the reform developments in science education, the concern to have a public that was literate in chemistry was a central feature in the initial discussion. Reformers in chemistry sought ways to alleviate the high attrition rate among promising students. With support from national organizations, they encouraged the development and implementation of new pedagogy to increase and maintain higher enrollments and greater diversity of students in introductory chemistry courses. But over time, the focus of the discussion in chemistry education literature shifted to considerations about the role of faculty development as a means to institutionalize permanent changes in chemistry education.

ACS and NSF made several recommendations to institutionalize these changes in chemistry and the other sciences, calling for a complete reform in the educational system. These recommendations can be organized into three essential areas encouraging particular actions in undergraduate chemistry: (1) Literacy in
chemistry must be increased among diverse learners. (2) Chemistry instructors need to fully understand and engage in the integrated functions of chemical education that serves both science and society by adopting programming that produce creative, effective and conscientious scientists, teachers and technicians. (3) Chemistry instructors need to adopt practices that fulfill the reform objective of facilitating the process of learning rather than adhering to traditional practices of content transmission. The sections that follow explore these areas more fully and reveal how the development of the reform mandate triggered the sponsorship of projects such as the Multi-Initiative Dissemination (MID) Project to undertake faculty development.

(1) The problem of science literacy in chemistry

In the late 1980’s and early 1990’s the impetus to develop reform in the field of chemistry came from studies claiming a significant attrition rate in second year university students who had expressed interest and aptitude in this field. Additionally, reports from the American Chemical Society (ACS), the ACS Committee on Professional Training, as well as NSF indicated that the chemistry curriculum was neither successful in contributing to a scientifically literate work force nor able to generate broadly trained industrial and political leaders. The national concern over this decline grew because competition in the global market required the production of diverse, innovative chemical ideas and products and it appeared that the chemistry academy was unable to increase the number and variety of graduates to meet these demands. Therefore the
mandate stated in a NSF grant program announcement to encourage reform in
undergraduate chemistry was:

“This initiative was launched to enhance the learning and appreciation
of science through significant changes in chemistry instruction. Supported
projects have been designed to make fundamental changes in the role of
chemistry within the institution including better integration with curricula in
related disciplines such as biology, physics, geology, materials science and
mathematics. The included changes are expected to affect all [emphasis
added] levels of undergraduate instruction.”(25)

This quote conveys the importance given to implement reform at all levels of
instruction, to ensure a systemic reform in chemistry. This was a vision of reform that
sought to give undergraduates at all institutional levels the opportunity to acquire the
knowledge and skills necessary to allow continued learning for productive lives including
informed decision-making. Despite the drive to create systemic reform, the institutional
infrastructure was not in place for continuous improvement of curricula and teaching
methods within research/doctorial universities and undergraduate colleges.(26)

Assessment and evaluation at many institutions occurred perfunctorily, involving only
student evaluations of teachers and standardized examinations of the students at the end
of the semester.(26) Anecdotal evidence rather than rigorous systematic evaluations were
used to determine the value of teaching tools.(26) In summary, teaching and evaluation
paradigms in undergraduate chemistry were ineffective, prompting NSF to fund the
launching of sweeping reform in chemistry using wide-spread dissemination programs
such as the Multi-Initiative Dissemination (MID) Project.(12)
(2) The role of chemical education for the science and society: policy tensions and faculty perceptions

Coincident with this drive to undergo a systemic reform, and some might argue because of it, the subfield of chemical education research grew. While chemical education research had been published for over 35 years, only in 1992 was a task force called by ACS to examine and explicitly identify this research as a sub-discipline within the science of chemistry. The mandate for supporting its growth parallels that of the reform itself. The task force identified the mandate of chemical education research in the following statement:

“There was a time when the needs of chemists and society in general were well served by the small minority of citizens who studied chemistry and understood it. That is not so today. Without the understanding of how chemistry can be taught and learned that derives from research in chemistry education, the entire field of chemistry is impoverished and its contribution to humanity is reduced……chemistry education operates at the interface between chemistry and society. It helps chemists determine what knowledge society needs and investigates how chemistry is learned by chemists-to-be and society in general.” (27)

These statements expressed by the ACS Chemical Education Task Force contain claims that echo those made by the ACS Committee on Professional Training described above. The claims of both organizations together suggest that the health and economic well being of the society depends on: (1) the ability of capable workers and professionals across science fields to understand chemistry (2) the expert knowledge of chemical education researchers and (3) an educated citizenry capable of making responsible informed political and funding choices on chemistry-related issues. If these claims are true then it stands to reason that a society that is not capable of generating such a workforce requires remediation in the form of a major, systemic effort. And conjoined to
these claims is the need for a sub-discipline, in this case chemical education, which facilitates not only the trajectory of the reform effort in chemistry education but also the responsiveness of the science itself to fulfill the needs of society.

National organizations such as ACS and NSF used these claims to negotiate the institutionalization of a pedagogy that serves a broader clientele of students. To accomplish this task, they convened educational committees to identify the new clientele, the new pedagogy and how the new pedagogy could best serve the interests of this clientele. In 1993, NSF sponsored 48 educators in the field of chemical education to construct an agenda for reform in chemistry undergraduate education. A document of their findings was presented to NSF entitled “Innovation and Change in the Chemistry Curriculum”.(28) One recommendation for reform outlined in the executive summary identifies the clientele and the ‘new’ pedagogy:

“We must give all our students, whether they will become scientists or not, a sense of professionalism and involvement, an appreciation of the scientific method and how it impacts on public discourse, and an understanding of research and the excitement of exploration and discovery….We recommend that faculty open up their classrooms and laboratories to problem based instruction that allows students to participate in the kind of open-ended consideration of data that characterizes our research…We urge the National Science Foundation to support initiatives that develop means of interactive learning for students...” (28)

This quote recommends changing classroom operations so that all students are engaged, regardless of their goals in science, in ‘discovery’ learning processes characteristic of “open-ended” processes occurring in professional research. In the past, traditional teaching approaches honed the technical skills of future scientists. However the assertion in this quote refers to a clientele that is more inclusive, and specifically
recommends an orientation toward a more social learning enterprise they describe as “interactive learning”.

These views were reiterated again in a later document, “Shaping the Future”, published in 1996, describing the goal of all science education to expressly involve all undergraduate students in a discovery process of learning which they label as ‘inquiry’. (3)

“Inquiry—although there is disagreement about the meaning of the term “science literacy” and doubt about whether agreement is possible on a list of facts everyone should know, there is no disagreement that every student should be presented an opportunity to understand what science is, and is not, and to be involved in some way in scientific inquiry, not just a “hands on” experience.” (3)

Thus, “Shaping the Future” recommends both literacy, “what science is and is not” and a pedagogy that engages students in challenging roles of inquiry characteristic of professional research. Furthermore, this proposed learning experience is contrasted and elevated above “just a hands-on experience” which is described later in this document as ‘cookbook’ experiences that do no more than teach students to adhere to a set of prescribed steps.(3)

The views expressed in “Shaping the Future” had a significant impact on the direction of the reform movement in chemistry and across the sciences. (29) The production of the document itself involved interviews of 200 ‘leaders and faculty’ in the scientific and industrial community, including professional societies such as ACS and other federal agencies. It also culled the views of focus groups made up of parents, students, graduates, disciplinary faculty, institutional leaders, and executive employers of science graduates. Therefore this report was the result of an extensive process of
consultation and review taking place over a period of two years, and expressed the perspectives of a significant swath of science education leadership and stakeholders. For these reasons and because of the impact it had on educational policies supported by ACS in chemistry, it is appropriate to take a closer look at the views it expresses about the proposed reform.

Both “Shaping the Future” and “Innovation and Change in the Chemical Curriculum” reported that the previous emphasis in science education to produce scientists incurred a neglect of non-science majors. This affected an important clientele, particularly, the future teachers of the K-12 school system. Both reports accentuated the importance of a broader agenda for undergraduate science education that would provide more support to the preparation of teachers and technicians.

“But virtually every participant in the review work of this committee has expressed concern over the way the undergraduate SME&T [science, math, engineering & technology] education community is working in the preparation of teachers.” (3) (p45)

However, the language of these documents, proscribing a shift to serve a broader student clientele, juxtaposed the needs of different stakeholders and brought covert tension into the discussion about the goals of science and chemistry education. The primacy of the production of scientists and its concurrent educational practice is juxtaposed with and appears to vie for importance with the need to produce effective teachers. Consequently, the readership of these documents might interpret the proposed reform program as serving the interests of a particular clientele separate from future scientists. This is substantiated by the growth of additional introductory science courses to serve this clientele rather than a change in existing courses. (3, 21, 30)
The context for possible varied interpretations about the intent of the reform can be observed in “Shaping the Future”. This report acknowledged that the former educational practice of producing scientists developed talent among a “pre-determined class of individuals” who intended to pursue a career in science. (3) (p14) Alternatively, groups traditionally under-represented in science, such as “women, minorities and persons with disabilities”, must now be given attention and the opportunity to “learn these subjects by direct experience with the methods and processes of inquiry”. (3) (p13) While this document affirms that the former pedagogy was oriented to the production of scientists, how the reform pedagogy was expected to be different is alluded to in this quote:

“We know that the diverse communities or cultures from which our students come have different values, norms and expectations about the educational process; learning is inhibited when those culturally determined norms clash with what the instructor is doing. Research in sociology suggests that working in groups in a cooperative setting produces greater growth in achievement than striving for relative gains in a competitive environment”. (3) (p15)

In this context, reform pedagogy involving a group-oriented collaborative form of inquiry, while not defined in detail, is presumed to be capable of more inclusive sociological effects than the conventional approach. Here the emphasis on ‘group cooperative learning’ provides a more specific operational definition of the interactive learning processes described in “Innovations and Change in the Chemical Curriculum”. However in “Shaping the Future”, the discussion juxtaposes the former pedagogy with the needs of diverse students and ascribes to the former and proposed pedagogies different goals and effects. Therefore the proposed change does not entail encouraging
under-represented, non-traditional student groups into the continuing stream of education. Rather, the proposed change was to recast the machinery of education itself into a new form that serves a more diverse clientele. “We can no longer alter students to fit the abilities of educational institutions; we must alter the institutions to fit the needs of students”. However the discussion about serving a broader clientele leaves mute whether ‘group cooperative learning’ would sufficiently serve all stakeholders including science majors and whether it is sufficient to overcome hegemonic practices in chemistry and the other physical sciences.

There are indications that faculty perceive the proposed pedagogy as antithetical to educational rigor and the effective development of science majors. While NSF describes the reform pedagogy in “Shaping the Future” as one of the goals of “teaching scholarship”, apparent resistance to the reforms necessary to create this type of scholarship in chemistry and other disciplines have been reported.\textsuperscript{(3, 8, 26, 27, 31-33)} Reform researchers have proposed that the reaction to avert educational reform derives from the challenge it poses to the cultural traditions of institutions and disciplines.\textsuperscript{(34)} However, they may also be a reaction to the unintended tensions inherent in the reform policy documents. Hence, overcoming these hindrances may require the strong endorsement of senior faculty or their administration to encourage an appreciation for reform practices and to assure faculty that institutionalizing reform pedagogy serves not only science literacy but the development of science and of future scientists as well. But an argument drawing an unequivocal resolution of the covert tension implied in these documents between the two objectives of chemical education, science literacy and the
production of scientists was not presented. Neither the reform campaign documents nor contemporaneous research showing the existence of a common means for effective learning were used to resolve these tensions. Instead, reformers in “Shaping the Future” and other reform documents appeared to expect their readership to accept apriori that the proposed reform pedagogy (e.g. group-oriented cooperative inquiry) would be able to serve both goals and all students.(6)

The outlook presented in this dissertation does not expect the reader to accept apriori that the proposed reform serves interests of diversity, science literacy and the development of science and of future scientists. Rather, a brief argument based on data is presented in the next section showing how group collaborative learning can be used to progress toward both these goals when specific steps are taken to promote specific social and learning processes in the teaching practice.

(3) Promoting the process of learning: The problem of content transmission and its inherent philosophy

As described above, reformers promoted teaching approaches that emphasized processes of learning within collaborative groups and drew a corollary between these learning processes and the social processes of doing exploratory science research. In some documents these processes are described as learning operations distinctive from the acquisition of content knowledge. For example, the National Science Education Standards state:

“The responsibility of science faculty members is to develop not only the science knowledge of our students, but also their understanding of the nature of science, their ability to understand and use scientific ways
of thinking, and their ability to make connections and apply what they know to the world outside the classroom. (p. ix).”(35)

This quote suggests that meeting the goals of the national science education standards requires faculty to provide not only content knowledge but to engage students in the processes of science. However, the adherents of reform took the argument further and claimed that reform inquiry pedagogy involves processes of discovery and that both discovery and understanding must take precedence over acquiring specific content described as the ‘product of science’. (34, 36-38)

Elaborating on this argument, both “Shaping the Future” and “Innovations and Change in the Chemistry Curriculum” documents describe the proposed pedagogy as a form of inquiry linked with the “process” of science rather than the “content” of science:

“One important trend reported in the design and delivery of innovative SMET courses—one that places greater emphasis on concepts and processes…and less emphasis on facts…is generally considered to be a positive antidote to the deadening effects of rapidly and broadly covering a large range of course material” (3) (p54)

“In chemistry we test for facts and exercises….This focus robs our courses of research, inquiry, exploration, and discovery.” (28) (p6)

It will be possible to develop criteria for the better preparation of teachers if the goals of student learning and instructional innovation are defined to include more than mastery of course content. (28) (p15)

“…the Handbook of Research in Teaching has argued that content knowledge is necessary but not sufficient.” (28) (p15)

“Both groups [majors and non-majors] need an appreciation of how [emphasis added] scientific knowledge comes into existence…” (28) (p10)

“The curriculum is knowledge for advanced studies. (I might argue it is knowledge for what used to be advanced studies). And yet 90% of these students will not be chemists….The textbooks… are large collection of
facts. What I see really missing from these textbooks is the process of science.” (3)

These views have been reiterated in subsequent policy designed specifically for future chemistry scientists (e.g. chemistry majors). For example, the ACS policy document, Guidelines and Evaluation Procedures in Undergraduate Professional Education in Chemistry, states:

“Enhancing the learning of how to solve problems may lead to less emphasis on coverage of content and to greater emphasis on projects” (39)

In the context where this quote was found, the meaning of “projects” appears to coincide with collaborative-discovery based learning approaches. Embedded in their description of “problem solving” are terms such as “team work”, “undergraduate research projects” and “effective communication”. And all of these quotes, above, show a perspective that places a high value on the learning process beyond mastery of course content. Furthermore, they express a view that appears to encourage the facilitation of the inquiry process in both the lecture and lab classrooms. (30, 39-44) However, an argument presenting data that links the ‘preferred’ learning process to collaborative learning approaches with the intention of persuading chemistry faculty to adopt reform in all their classes (for majors and non majors) was not articulated in these policy documents. An argument that presents this data is given here.

The substantiation that might persuade faculty to adopt the collaborative learning process into their lecture class comes from research and theory in cognitive science. (45-50) Several of these papers were written prior to the reform policy documents. This research indicated that the model that best describes the learning process is the learning
cycle model as shown in Figure 1. The first step in the learning cycle is a phase of exploration. Students are exposed to a new situation or environment and are encouraged to explore together, through activities and exposure to new materials, ideas or concepts (which are not necessarily explicitly stated orally or in text) on their own without instructor intervention and without specific expectations on the part of the instructor. During the exploratory phase, learners incorporate the new experience into their pre-existing framework of knowledge. The second step involves concept invention or introduction. The new ideas or concepts which the students previously explored on their own are then given formal definition either via the instructor, through their own collective invention, or through their text or other medium. However, the way that the concept is introduced is crucial so that students’ learning processes are not undermined. The concept is introduced in such a way to help the student form a pattern of reasoning to map the (possibly abstract) concept to their concrete experiences. Students can then compare the new concept with their recent exploratory experiences. The final step involves applying the new knowledge. This phase increases the learner’s understanding when they apply the concept to new situations. Importantly, this phase involves both instructor and peer interactions, which reinforce what the authors call “self-regulation”—a form of self-assessment to determine for themselves whether they understand the concept and its applications.
When students undergo this sequence of learning, cognitive research indicates that understanding is greatly enhanced.\textsuperscript{(45-50)} The learning cycle is focused on the students’ learning experiences and social/educational context for learning. The teacher/instructor has a minimal role in introducing the students to the new concepts. Instead the students form, through their personal, social, active explorations, an understanding of a new concept or idea that is being introduced and they are given opportunities to apply the concept themselves to increase their understanding. The mental process promoted through this sequence creates a change in the organization of conceptions that is likened to Piaget’s notion of a paradigm shift and is described as “conceptual change” in educational theory.\textsuperscript{(36)} This approach is endorsed by
constructivist theory because it situates knowledge/understanding acquisition within the context of the students’ experience. (41)

Thus, emphasis on the learning cycle itself rather than the acquisition of content knowledge distinguishes the proposed reform practices from traditional approaches because it explicitly holds the scientific acts of discovery and understanding on equal or higher footing with the confirmatory processes that merely test content knowledge. (51) (p25-26) The results of cognitive science research suggest that using the learning cycle in undergraduate chemistry lecture classes can potentially improve learning among students whether they are preparing to be teachers or scientists. Hence data obtained from implementations that incorporate the learning cycle can be used to confirm their positive effects on student outcomes and resolve the tensions in the discourse about the goals of science (and specifically chemistry) education.

Such studies investigating the use of the learning cycle specifically in undergraduate chemistry classes were later documented by Farrel et al. (43) For example, a reform approach called, “process-oriented guided inquiry learning” (POGIL), that combines the learning cycle with group learning activities has been successfully implemented for nearly a decade in general chemistry classes. (43, 52) [Note: an example of a full activity is provided in Appendix A] Research on student achievement using POGIL found that student achievement improved with more students achieving A’s (~5% increase) and B’s (~7.5% increase) relative to a traditional lecture class taught by the same instructor.
A second investigation carried out by Lewis and Lewis in a large class setting (264 students total, 178 control and 86 experimental conditions) using peer leaders combined with POGIL substantiates the versatility of this approach in multiple settings. These authors controlled for prior schooling in chemistry and SAT scores in their analysis which served to corroborate that the improvement in student achievement can be attributed to the learning activities and not to extraneous factors relating to student background preparation.

These findings might be useful to resolve the unintended tensions of the reform policy documents and mitigate interpretations emphasizing separate pedagogies for different clientele. However, data and arguments to encourage implementation of the learning cycle may not be sufficient to establish reform. Reformers warn that instructors using reform teaching materials without understanding the philosophical principles inherent in this pedagogy might unintentionally encumber the students’ learning process. Chemistry education reformers have noted that the learning process is undermined when faculty use student assessments that emphasize the perpetuation of ‘authoritative’ or ‘normative’ content:

“Our [student assessment] examinations focus on the kinds of questions for which there is a single “correct” answer, rather than those for which the correct answer is unknown, or which have more than one correct answer. As a result, we construct an arbitrary boundary between what we do as scientists and what we ask our students to do in science courses.”

Reformers link the reliance on authoritative content to a perspective which separates learning from generating knowledge and privileges the combined authorities of teacher and text. In contrast to this outlook, the principles of the reform derive from a
student-focused perspective that values the learning process and *student-generated models* of knowledge indicative of the learning cycle. Hence, effective implementation of a practice with such a radically different focus requires a new conceptual framework. Reform-interested faculty espousing a more traditional view about teaching practices, might be revealing their reticence and need to undergo fundamental conceptual change. One of the reformers associated with POGIL, James Spencer, describes the conceptual openness to adopt the new perspective as a change in paradigms, similar to the cognitive outcomes expected of student-learners. Thus effective implementation of the reform in undergraduate chemistry requires that faculty move both philosophically and behaviorally “along a continuum” from a teacher-focused approach to a “student-focused active learning approach” (SFAL).

The overarching vision of the New Traditions Project is that we can facilitate a paradigm shift from faculty-centered teaching to student-centered learning throughout the chemistry curriculum, such that students obtain deeper learning experience, improve their understanding and ability to apply learning to new situations, enhance their critical thinking and experimental skills, and increase their enthusiasm for science and learning.

The principles of these differing philosophies (or paradigms) are contrasted in Table 1 and a description of how these principles are manifested in the classroom is presented in both Tables 2 and 3. Briefly, the learning values presented in the student-focused column in these tables are based on the learning cycle and on the constructivist theory that learners construct their own knowledge from what they already know.
Table 1. Comparison of two teaching paradigms (41)

<table>
<thead>
<tr>
<th>Positivist/Objectivist Paradigm</th>
<th>Constructivist Paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truths are independent of the context in which they are observed.</td>
<td>Knowledge is constructed.</td>
</tr>
<tr>
<td>Learner observes the order inherent in the world. Aim is to transmit knowledge experts have acquired.</td>
<td>Group work promotes the negotiation of and develops a mutually shared meaning of knowledge. Individual learner is important.</td>
</tr>
<tr>
<td>Exam questions have one correct answer.</td>
<td>The ability to answer with only one answer does not demonstrate student understanding.</td>
</tr>
</tbody>
</table>
Table 2. The role of the instructor (41)

<table>
<thead>
<tr>
<th>Traditional Teacher-focused</th>
<th>Student-focused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>Acts as a consultant for students</td>
</tr>
<tr>
<td>Explains concepts</td>
<td>Asks probing questions of students to derive concepts</td>
</tr>
<tr>
<td>Provides definitive answers</td>
<td>Elicits responses that uncover what the students know or think about the concept</td>
</tr>
<tr>
<td>Tells the students they are wrong or right</td>
<td>Provides time for students to puzzle through problems</td>
</tr>
<tr>
<td>Explains to students step-by-step how to work out a problem</td>
<td>Allows students to assess their own learning and promotes open-ended discussion</td>
</tr>
<tr>
<td></td>
<td>Refers students to the data and evidence and helps them look at trends and alternatives</td>
</tr>
<tr>
<td></td>
<td>Encourages students to explain other students' concepts and definitions in their own words</td>
</tr>
</tbody>
</table>

Table 3. The role of the student (41)

<table>
<thead>
<tr>
<th>Traditional Teacher-focused</th>
<th>Student-focused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asks for the &quot;right&quot; answer</td>
<td>Explains possible solutions or answers and tries to offer the &quot;right&quot; explanations</td>
</tr>
<tr>
<td></td>
<td>Tries alternate explanations and draws reasonable conclusions from evidence</td>
</tr>
<tr>
<td>Has little interaction with others</td>
<td>Has a margin for related questions that would encourage future investigations</td>
</tr>
<tr>
<td></td>
<td>Has a lot of interaction and discusses</td>
</tr>
</tbody>
</table>
Table 3 continued

<table>
<thead>
<tr>
<th>Traditional Teacher-focused</th>
<th>Student-focused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accepts explanation without justification</td>
<td>alternatives with other companions</td>
</tr>
<tr>
<td></td>
<td>Checks for understanding from peers</td>
</tr>
<tr>
<td>Reproduces explanation given by the teacher/book</td>
<td>Is encouraged to explain other student's explanations</td>
</tr>
<tr>
<td></td>
<td>Tests predictions and hypotheses</td>
</tr>
<tr>
<td></td>
<td>Uses previous information to ask questions, proposes solutions, makes decisions, and designs experiments</td>
</tr>
</tbody>
</table>

Conversely, the traditional role of the teacher is a transmitter of subject content (i.e. of *their* knowledge of the subject matter). This approach is considered ineffective or inoperable because, according to the constructivist view, knowledge *cannot* be transmitted. Because transmission-oriented pedagogy has long been the traditional approach in the physical sciences, its philosophical influences on practice may not be readily apparent. And it may not be obvious that difficulties in implementing reform might be linked to the hybridization of practices that belong to competing philosophies. Therefore, for an effective adoption of reform, it is essential that faculty understand the distinctions between the philosophies that underlie their current practice and that of reform. Furthermore, in order to have the ability to discern and appreciate a practice that integrates the process of learning with generating knowledge, they must be willing to expunge a perspective which values authoritative knowledge.
SUMMARY

The development of the current reform program in undergraduate chemistry was stimulated by a larger movement taking place across all the sciences in undergraduate education. Prior to development of the current reform, undergraduate science education emphasized approaches that were not successful in increasing public literacy or encouraging diverse learners or graduates in science.\(^1\), \(^2\), \(^3\), \(^{14}\), \(^{16-21}\), \(^{23}\), \(^{27}\), \(^{28}\), \(^{30}\), \(^{32}\) The current reform program is underway to change these conditions. As shown in Figure 2, a graphical synopsis of the development of the MID Project, several organizations and federal agencies took part in creating an effective reform campaign. These organizations included the National Science Foundation (NSF), the National Science Board (NSB), the National Research Council (NRC), the American Association of the Advancement of Sciences (AAAS), and the American Chemical Society (ACS). Their efforts coalesced into the formation of the Department of Undergraduate Education (DUE) sponsored by the National Science Foundation. One mandate of DUE was to propagate reform in undergraduate science education through funding initiatives. As a result, several reform programs were developed in the sciences including chemistry. Initially, five consortia of institutions teaching undergraduate chemistry were funded to create new pedagogy and materials for chemistry. After achieving this goal, the MID Project was then funded to disseminate the reform teaching approaches and materials nationally.

At the core of this reform movement are key perspectives promoted by the catalyst organizations, which derive from a constructivist paradigm.
situates knowledge construction in the mind of the learner. Both teaching approaches and materials promoted by the reform program abide by this paradigm. The preferred teaching approaches of reform emphasize learning processes that emulate processes of doing science rather than the amount of factual subject content. They also engage students in both the learning cycle and group learning which help students to assess their understanding while exploring new concepts. But, the way that the reform goals has been described and promoted in seminal reform literature might be misinterpreted by faculty, particularly those who do not understand the constructivist paradigm. Furthermore concerns expressed in the earlier reform literature about encouraging greater participation of non-majors in science classes can be misinterpreted to mean that the new pedagogy supports mainly these learners. Therefore to encourage the implementation of reform in all undergraduate classes, it is necessary to demonstrate with data that the new pedagogy effectively helped students who were entering the discipline as well as those who were not. However, the presentation of supportive data demonstrating that reform methods improved student learning generally, was lacking in both reform policy documents, “Shaping the Future” and “Innovation and Change in the Chemistry Curriculum”. Such persuasive presentations could have been used to help convince more faculty of the merits of reform and clarify its goals. In summary, these documents claim that implementing reform is more than just applying new methods and materials in classes intended for students who are not planning to enter the discipline. Rather, implementing
Figure 2. Historical Development of the MID Project
reform entails understanding and embracing a new paradigm that is radically different from the traditional positivist paradigm, and applying methods associated with this new paradigm in core classes of the discipline.

**THE SOLUTION: PROPAGATING REFORM**

(1) The MID Project

**History:** As mentioned earlier in this account of the reform movement in chemistry, the discussions on reform in the late 1980’s and early 1990’s culminated in the propagation of large-scale reform programs in the sciences. By 1995, NSF funded the Undergraduate Education Course and Curriculum (CCD) program to develop reform pedagogy specifically for chemistry. (26) Several consortia of academic chemists employed in institutions ranging from community colleges to research/doctorial institutions designed curriculum innovations and began reform implementation. As their work became known to the wider academic community, and as the need for a concerted systemic propagation of reform became apparent, NSF funded the banding of these consortia into a unified dissemination program called the Multi-Initiative Dissemination Project. The name refers to the reform initiatives (or consortia) that had been originally and independently established and funded by NSF. The mandate of the MID Project was to propagate the innovative teaching approaches and materials of these initiatives to chemistry faculty across the nation in workshops from the years 2000-2004. (54)

The MID Project workshops presented to faculty the pedagogy and materials of four consortia who named their respective reform programs: ‘ChemConnections’,
‘Molecular Science’, ‘New Traditions’, and ‘Peer-Led Team Learning’. Each of these four consortia undertook a slightly different approach to developing innovations in the undergraduate classroom. ChemConnections (a combination of the ModularCHEM Consortium and the ChemLinks Coalition) developed new curricular materials and methods to enhance the learning and appreciation of chemistry through the use of ‘modules’. Each module consisted of a current topic of interest to promote understanding and solving of real world problems, for example, how to build an automobile airbag system or understanding the chemistry involved in global warming. Molecular Science established an online delivery of assignments and assessments in order to integrate telecommunication and technology into instruction and allow students to ‘self-teach’ instructional materials such as data, molecular models, and to engage in collaboration as well as to learn how to write about chemistry. The New Traditions project developed interactive pedagogies for the classroom with a focus on shifting the emphasis from a faculty-centered teaching approach to a student-centered learning approach. An additional focus was the development of inquiry-based labs. Last, the Peer-Led Team Learning consortium preserved the lecture format but introduced an additional weekly two-hour workshop and trained undergraduate leaders to run chemistry problem-solving discussion sessions with their peers.

**Objective:** The guiding objective of all of these initiatives was to change the teacher-centered classroom pedagogy to a student-centered pedagogy summarized in Tables 2 and 3. Their approach incorporated activities to support the learning cycle described earlier. These activities included: providing class time to allow
students to collaborate to solve problems, to engage in whole class and small group discussion and brainstorming, and to answer conceptual questions. (62)

For the most part, this pedagogy incorporated several common themes from different theories of learning. (63) In addition to using a ‘constructivist’ perspective that characterizes the acquisition of new knowledge as a process occurring within the existing knowledge base of the student, this pedagogy sets the pre-conditions for conceptual change, a process occurring in the learning cycle. (63, 64) Therefore, the learning approaches that were promoted in the MID Projected were designed to move students through a discovery and analysis process of the learning cycle in which their conceptions undergo holistic reorganization, as described in conceptual change theory. Their pedagogy also integrates Novak’s “Theory of Meaningful Learning” approach in which students develop learning skills in all domains (cognitive, social, affective and psychomotor). (36, 65, 66) Last, this approach adheres to ethical principles confirming the unlimited potential in each learner, of learner ownership and empowerment to possess knowledge of the subject matter. (67, 68)

The pedagogy also entails the use of different assessment tools which encourage higher levels of engagement with the process of learning rather than the use of rote memorization. (69) Examinations with closed-ended questions are seldom used. In active learning, assessment methods that model the assessment process for students are used to help learners develop their own capacity for self assessment using metacognition (thinking about their thinking). Student generated concept models, concept mapping, learning assessment journals, portfolios, activity sheets and peer-assessment activities are
examples of preferred assessment strategies over ‘algorithmic’ questions and answers.(63, 70-72)

The initiatives, therefore, fulfilled their objective by creating specific alternatives to the traditional form of teaching chemistry. The traditional paradigm, in which students listen to an instructor lecture, watch the instructor perform demonstrations and solve problems, and do individual homework outside the lecture setting is referred to as a teacher-focused/transmission (or passive-learning/didactic) strategy.

In order to disseminate these reform practices, the four initiatives received 1.1 million in funding together as the MID Project to co-present workshops for college chemistry faculty at colleges and universities around the country. Presentations of a 1.5 day workshop on all four of the reform initiatives were conducted during the academic year and a three day, single project immersion workshops conducted during the summer. Each workshop provided the participants with in-depth exposure to curricular materials, learning activities, research findings on teaching and learning, assessment tools, and curriculum implementation strategies. The purpose of these workshops was to give the participants sufficient experience to integrate reform learning techniques into their current teaching practices. Facilitators funded through NSF and trained by the MID Project organized and led these workshops, and the host site provided the rooms and technical facilities.

**Dissemination practices:** In order to fulfill the mandate for the dissemination of a systemic reform, the co-PI’s of the MID Project put considerable effort into soliciting and reaching as many academic chemists as possible at every designated location for a
workshop. Workshop locations were selected based upon the sites of previous workshops, the locations of current requests for workshops, the density of institutions in a given area, and the location of institutions that serve minority faculty and students. Co-PI conferences were held to strategize the appropriate workshop location and to consider accepting invitations from institutions that requested a workshop at their site. And last, if a geographical area had not been served, the co-PI’s sent requests to colleagues in that area to serve as local hosts.

Once a site had been chosen, American Chemical Society Academic Chemists’ data bases and web site data bases were used to locate community colleges, colleges, and universities. Using the American Chemical Society membership for solicitation is warranted in part because ACS represents one of the largest societies of scientists worldwide (a world wide membership of 160,000) and is the largest society of chemists in the U.S. And because of the size of its constituency, it represents a significant influence in chemical and science affairs in the U.S. And last, the ACS organization has provided several task force papers in support of reform in undergraduate chemistry.(22, 23, 73)

The region of solicitation was identified beginning in the city of choice and expanding outward to a radius of approximately 200 miles in all directions. Then using the data bases described above, e-mail addresses of chemistry faculty and chairs were gathered in that region. Approximately 400-500 faculty were invited to attend any given workshop. Each individual was sent an e-mail invitation with the goals of the workshops, information about the individual projects, a generic workshop agenda, information about the location, times, registration procedures, and contact information. Faculty were
invited to register on-line at the project web site and they were sent a confirming letter with hotel information, room and building locations, a campus map, directions to the hosting campus, and parking information.

This protocol differs somewhat from other dissemination projects such as the NSF’s Undergraduate Faculty Enhancement (UFE) program. In contrast to UFE, which involved a faculty application/selection process and provided funding to science faculty (including chemists) wishing to attend faculty enhancement workshops, the MID Project did not have an application process for individual participants and did not fund attending faculty. All chemistry faculty found in the databases within a region were contacted and invited. Using a “first come first serve” approach, all faculty who registered were admitted in the workshops until full capacity (60 faculty) was reached. As a result, the strong motivation to participate in MIDP workshops without MIDP-derived funding suggests that the attending faculty had a genuine interest in learning about MIDP or had other (external to MIDP) incentives to engage in reform oriented workshops.

Over the four years, 26 workshops were held within all levels of post-secondary institutions and several workshops in regional and national ACS meetings. Consequently, a total of approximately 15,000 faculty were directly contacted. Host-institutions were widespread and located in all of the major geographical regions in the US mainland. The majority (22/26) of the hosting institutions that met the selection criteria for central locations were institutions with graduate schools. Seventeen of the hosting institutions with graduate schools have the ‘extensive institution’ Carnegie
classification. Consequently large Ph.D. granting institutions were more highly represented as hosts relative to lower level institutions. Nevertheless, attendance at each workshop varied between 30 and 50 academics representing all institutional levels as described in more detail in the data section.

In addition to soliciting individuals, the MID Project workshops were advertised and articles describing MIDP initiatives were published in peer-reviewed ACS journals such as Chemical and Engineering News, and the Journal of Chemical Education. Last, many symposia on MIDP workshops or on the implementation of the four initiatives through MIDP, have been presented by MIDP facilitators, PI’s and faculty participants at national and regional ACS meetings and at the Biennial Conferences of Chemical Education.

In summary, the MID Project was a successful dissemination program insofar as soliciting academic chemists from all undergraduate institutional levels and promoting reform through a highly active campaign among academic chemists. The majority of the faculty attending the workshops had little or no familiarity with the MIDP materials and initiatives and thus represent interested faculty who have had no previous involvement in the project. Furthermore, reports from the participants in the earlier workshops (2000-2002) suggest that, following the workshop, participants engaged in voluntary dissemination (i.e. for which they are not paid), which is an integral component of the dissemination process for a successful project.
(2) The MID Project in a larger context: The Model of Reform Dissemination

The earlier reform projects in science education that had been launched in the early 1990’s were independent projects within isolated institutions that did not, according to the advisory committee to NSF, meet the magnitude and organization of reform needed. (17) Therefore, NSF and other federal agencies supported a subsequent reform strategy that would involve the entire network of educational organizations from preschool to post graduate work:

“The various parts of this continuum are interdependent; undergraduate SMET [science, math, engineering and technology] education depends on the students who come from grades K-12, relies on faculty coming out of the graduate programs, and prepares teachers for the K-12 system and students for graduate school. The kinds of programs offered to graduate students have significant implications for the future of undergraduate education…So these sectors have mutual obligations to each other, and the fulfillment of those obligations is essential for the health of the whole.” (3)

To meet the new goals of a broad-scale educational reform in science, several national dissemination programs were established in the late 1990’s. (75) These dissemination programs brought together isolated reform projects into collective bodies that would be propagated across all levels of academic institutions, and supported by professional organizations and the science industry. Hence, the primary objective of these national dissemination programs was to create a comprehensive change in science education described as ‘systemic reform’. These large-scale programs were designed to propagate reform pedagogy among faculty not only across institution levels, but to reinforce a more unified, responsive educational structure across disciplines, and between faculty and students in their classrooms. (18, 76)
To realize the goals of systemic reform, dissemination activity has aimed at overcoming barriers primarily at two broad organizational levels: (1) at the individual and institutional levels and (2) at regional and policy making levels. A diagram that depicts dissemination activity in a model of reform is provided in Figure 3 (below). The model shows a unidirectional flow influence in the apex of the pyramid from teachers to classrooms and then to student outcomes such as student achievement. Other factors enter into this flow such as the institutional and/or community context of the classroom and available resources such as curricular materials also have a bearing on the classroom experience. Below the apex a bidirectional flow of influence occurs between the institution and teacher level and the larger regional level of educational governance that is organized by policy and provides support to the classroom experience through funding and setting educational standards. This model predicts that significant changes in curriculum and achievement cannot be made without affecting policy. Furthermore reform researchers have found that dissemination activities that only focused on the foundation/policy levels appeared to have very little measurable effect on student achievement outcomes. Therefore, effective dissemination is a ‘two-pronged’ enterprise providing information and activities to facilitate adoption of reform at both organizational levels.
At either organizational level, dissemination activities may be generalized as having two roles: reform propagation and management. Dissemination activity at the apex entails propagation, providing faculty the resources for pedagogical change, and management, giving faculty the means to sustain reform through structural changes in their institution. Thus to achieve the objective of reform at the apex of this model, dissemination involves faculty development, offering access to the tools and skills needed to bring about pedagogical and institutional change within their educational system.(31, 82-84)
Strategies that have been successful in reform propagation mirror the very structure that they encourage. Rather than a “top-down” approach, current dissemination approaches such as those used in the MID Project promote change in teaching practices through ‘faculty development’ programs facilitated by experienced peers.\((15, 31, 82, 84-86)\) Faculty development programs may take different forms such as seminars, short-term workshops, and outreach programs between institutions.

The successful use of workshops as a mode of pedagogical dissemination in education has been well documented and is used by several dissemination programs including the MID Project for science faculty.\((82)\) However, the long-term success of workshops (or any dissemination program) is contingent upon the existence of a structure of support including administrators, colleagues and other stakeholders within and across educational organizations.\((3, 15, 30, 34, 82)\) Hence, a necessary part of the workshop content, as provided in the MIDP workshop, is discussion in how to manage and foster a supportive organizational structure and how to access funding for collaborations.\((87)\)

The content of dissemination programs also places emphasis on changes in the management of classroom social organization.\((34, 86)\) The curricular models presented in the MIDP workshops and other reform programs call for a classroom practice that regards the instructor and student as partners in the educational endeavor.\((3, 21, 31, 85, 86)\) In contrast, the traditional/normative approach in the American system places the responsibility of the educational enterprise entirely on the teacher. In the pedagogical models that the reform initiatives support, the student becomes an active agent in the learning process, and the creator of her/his knowledge, while the role and eminence of the
instructor as the holder or transmitter of knowledge is diminished. Therefore, the current model of reform provides the means for structural changes not only in the institutional structure external to the classroom but also the social structure (and interactions) within the classroom. The successful implementation of this in-class structural change is dependent on the willingness of the individual instructor and the organizational support of colleagues and administrators within a site to maintain a change in the classroom dynamic.\((15, 16, 34)\)

Regardless of how well reform is manifested in the social structure of the classroom, it cannot be effectively supported in an environment of isolated institutional sites.\((3)\) Previous (non-systemic) reform efforts have shown that in-class social structure requires a supportive structure across institutions.\((15)\) Because student learning and development requires movement of the student between levels of institutions and because accomplishment in later courses in the sciences is heavily dependent on the quality of early learning, articulation between institutional levels is crucial.\([30]\) Hence, managing structural support for reform requires a dissemination program that fosters partnerships between institution levels to build an integrated educational enterprise.\((77, 87)\)

Returning to the model of reform in Figure 3, to encourage articulation between levels of educational institutions requires dissemination activity at the regional level. Using the MID Project as an example, this can be accomplished by bringing the dissemination activities to multiple institutional sites that serves all major geographic areas in the nation. But such articulation must also be fostered through policy in the form of feedback reports generated for the sponsoring organization such as NSF. Therefore,
communication and articulation between institutional levels can be enacted through the presentation of reform experiences and practices to all interested stakeholders in regional professional conferences.

Despite the call for a systemic reform that bridges institutional levels, documented differences in cultures and structure between levels of institutions indicate that such endeavors may be difficult to achieve. On account of these historical differences, dissemination programs must inform participants to the nature of the vertical organization of the current educational system and to the extent that articulation between levels has been achieved in order to manage and sustain systemic reform.

Clarifying the influences of institutional cultures for the purposes of propagating systemic reform in chemistry requires a concerted probe into their specific social contexts. It has been pointed out in organizational learning theory that organizational learning is not simply the sum of each member’s learning, rather, organizations maintain learning systems that have a reciprocal influence on their members, that transmit organizational norms and histories to others. Thus, organizations develop world-views and ideologies: “Members come and go, and leadership changes, but organizations’ memories preserve certain behaviors, mental maps, norms and values over time.” Although an organization’s structure may play a crucial role in dissemination, research indicates that organizational culture may have an even greater role. Defined as the “overriding ideologies”, shared beliefs and norms, organizational culture is tied closely to and partially determines the strategy and direction of organizational change.
Gess-Newsome et al have derived a different model of reform shown in Figure 4. (34) This model links the specific organizational cultural context with the faculty’s teaching conceptions and reform implementation. Whereas the previous model focused on the propagation of broad-scale reform across institutional contexts, this model might be considered a representation of reform within a single context. In this regard, Gess-Newsome’s model might be construed as a ‘blow-up’ view of the faculty section of the pyramid in the previous model.

Figure 4. Gess-Newsome Model of Reform (34)
Gess-Newsome uses this model as a means to depict the relationship of teaching conceptions and dissatisfaction with reform implementation. According to conceptual change theory, dissatisfaction arising from specific learning contexts, necessarily precedes and enables conceptual change and learning. When faculty have such dissatisfaction in their teaching approaches they are no longer complacent regarding their teaching practices, they seek change whether in their environmental context, in their pedagogy or both. Therefore, in contrast to the model introduced by Zucker et al, the model that Gess-Newsome et al propose suggests that faculty’s teaching conceptions play a major role in the implementation of reform practices within the classroom. Furthermore, their findings correlate well with a substantial body of research focused on faculty conceptions and their potential influence on pedagogy that is not accounted for in the pyramid model. (Because this body of research is extensive and constitutes the rationale of this study, it will be described in greater detail in the following chapter.) The intriguing distinctions in these models and their potential overlap will be used in combination with the observations in this study to determine whether either (or neither) model or some combination of them may best describe the current status of reform as observed among the MID Project participants.

SUMMARY

The MID Project was a dissemination program with the mandate to propagate the reform pedagogy of four consortia: ‘ChemConnections’, ‘Molecular Science’, ‘New Traditions’, and ‘Peer-Led Team Learning’. MID Project workshops were conducted
from the years 2000-2004 as part of this national effort to disseminate ‘systemic’ reform—reform at all levels of instruction. To ensure such propagation, the practices of dissemination entail helping faculty to build institutional infrastructure to support reform practices and philosophy across institutional levels. Therefore the MID Project workshop participants were exposed not only to new pedagogy for the classroom but also to discussions and information on building institutional support for reform.

Because very few models of reform dissemination have been constructed in the literature on reform, it is pertinent to explore the impact of the MID Project as a component in a model of reform. While two very different models of reform have been presented in the literature, as observed in Figures 3 and 4, there has not been a discussion in the literature concerning role of the MID Project workshops in a model of reform. Therefore this dissertation will fill this gap by constructing a model that will incorporate the data obtained in this study and will be compared and contrasted with the two models given previously in the literature.
II. THE STUDY RATIONALE

PRIOR MIDP EVALUATION AND RELEVANCE OF THIS WORK

During the formation of the MID Project in year 2000, the five consortia that would comprise the MID Project were evaluated together by internal evaluators and by an external evaluator, SRI International. This work culminated in a workshop to discuss the respective evaluations as a collective endeavor and to generate a report for NSF.(26) Because the reform programs were on-going at that time, the evaluators proposed that the evaluation be considered a form of feedback to the MID Project PI’s about its progress. Given that the time required to observe long-term impact extended beyond the initiatives’ termination dates, these evaluators proposed that a future separate, ex-post evaluation of the MID Project should be conducted to explore the combined effect of these initiatives.

The intention of this study, however, is not solely to provide more feedback about the success or failure of its operations. Instead, this analysis generates a snapshot of the reform effort itself, exemplified in the MID Project within the broader context of systemic reform in chemistry, by linking the observed impact of the MID Project back to the broader social/cultural antecedents that instigated programs similar to it.

To achieve this objective, this dissertation critiques and expands the current understanding of the model of reform using constructivist and critical theory.(79, 92-97)
Using the constructivist stance, this proposed study will examine the present reform and dissemination effort within the socially constructed realities of policy makers, dissemination facilitators, faculty and students. Hence the context of reform dissemination and impact will be framed within a socially constructed context among stakeholders. To complement this approach, critical theory will be used to critique the current reform effort as observed in the MID Project context. This theory asserts that social change arises within the tensions, paradoxes, or contradictions of social relations or institutions. Such tension can be instrumental to making discoveries because it can reveal interfaces within organizations of social relations. The assumption in this view is that social reality has multiple layers and what seems immediately apparent may be superficial to a deeper structure or mechanism that with careful, directed questioning can be uncovered. (95, 98)

The justification for this theoretical approach in this study can be found in the report generated by the previous evaluators of the five initiatives of the MID Project. (26) The internal evaluators indicated that their work was influenced by the principle investigators who did not always appreciate their expertise. The evaluators claimed that this lack of appreciation narrowed the role they could play in identifying, isolating, and measuring intervening variables. These variables include factors that can potentially mediate pedagogical implementation such as faculty beliefs about teaching, or specific demographic (contextual) barriers to reform efforts. Therefore this dissertation, having greater independence to investigate these intervening variables, can provide more insight into potential solutions to the barriers of reform dissemination and implementation.
Intervening factors can be chosen that are relevant not only for the MID Project but have broader implications useful to other dissemination projects in the sciences, and to audiences within and outside the chemistry community.

The initiatives’ evaluators also discovered that participating chemistry faculty had difficulty appreciating that the desired systemic change entailed more than just curriculum development. To increase faculty participation and willingness to undergo the fundamental conceptual changes required in reform practices the evaluators suggested NSF use funding, rewards and recognition as incentives. However prior research into college science classes has shown that when controlling for institutional incentives such as funding and time for pedagogical change, intervening variables such as the instructors’ teaching conceptions mitigate the capacity to enact reform. The findings of these studies suggest that faculty must first be open to change by experiencing dissatisfaction with their practice and curriculum goals (conceptual change model). However the investigators asserted that further evidence must be obtained using a variety of methodologies and data collection tools in a variety of teaching contexts. This dissertation will fill this gap through analyzing instructors’ teaching conceptions using multiple methodologies and tools applied to faculty working in varied institutional levels and departments. Hence, this study will analyze the undergraduate chemistry instructors’ response to reform in the dynamic of their teaching conceptions as they are enacted and espoused within multiple contexts, searching for commonalities and contextualizing differences as an approach to understand educational reform. This
information is best acquired using qualitative methodology. Therefore the following section provides greater depth into the rationale for using this methodology in this study.

RATIONALE FOR THE METHODOLOGY USED IN THE CASE STUDY

In order to provide the data needed to ascertain dissemination impact beyond faculty survey reports, this investigation collected field observations of teaching practice, and triangulated this data with faculty interviews and survey data. The goal of this case study is to explore academic chemists’ conceptions (Note1) about their classroom practices and reform pedagogy in order to investigate how and to what extent their conceptions are embedded within their actual classroom practice.

The data from this case study will be richer and more informative than prior work because it explores beyond the usual limits of surveys by investigating faculty educational goals and views as they are embedded in what they do and where and who they are. If faculty perceptions and practices are shaped by the institutional organization, or by socio-economic and environmental pressures, they may not be aware or be capable of articulating the extent of these relationships. However by exploring these relationships through interviews in conjunction with in-class observations, the deeper meanings of their perceptions and practices may be revealed. Prior work has shown that surveys are too limited because the intended or implicit meanings of respondents are not always revealed.\textsuperscript{(98, 100, 102, 103)} Their interpretations of survey questions may not correspond to the interpretations of the researcher, and mutual meanings within the framework of surveys cannot be negotiated between researcher and participant because of
their separation in time and place. However, in a case study, such as that proposed here, mutual meanings can be negotiated because of the dialogic nature of face to face, semi-structured interviews and the interactive nature of in-field (e.g. within institution and in-class) observations.

**The effects of the institutional level on teaching conceptions**

The effects of institutional/organizational structures upon faculty’s perceived authority and their practice of reform pedagogy in undergraduate classrooms have not been thoroughly investigated. As a result, reform dissemination and faculty development programs emphasized academics’ instructional skills without addressing their prior perceptions or the institutional environments in which their new skills would be applied. (84, 104) Criticism has been raised within reviews of investigations on reform implementation because both the investigative evaluation and the reform program itself focused on understanding individual faculty performance, without exploring the greater context and influences from organizational, socio-economic, and environmental factors on academic’s perceptions. (104-107)

“…the educational context of a particular school or college, the goals or strategies of a university, or the stage of the university or college in its own organizational life cycle may influence the performance or perception of faculty members”. (105) (p.55)

These critics argue that because institutions of higher education are not organized by a common view of governance and curriculum, assessments of faculty perceptions and performance must probe their practices and perceptions within their *specific social contexts* in order to understand them. (84, 104, 105, 107-109) This case study will fill this
gap in prior research by exploring how faculty perceptions and practices are influenced at different levels of undergraduate institutions.

In prior investigations, surveys have been conducted to characterize the demographic distribution of faculty, however, the reported findings provide a non-specific profile of undergraduate academic chemists.\textsuperscript{(110-113)} Only a few studies have drawn correlations between university faculty (not specific to the sciences) demography and their teaching practices using survey data.\textsuperscript{(114, 115)} Their findings revealed that the capacity to adopt reform teaching strategies may differ across institutional levels, between females and males and between ethnic groups in the post-secondary academic population.\textsuperscript{(105, 110-113, 116)} For example, Kenan and Kenan found that faculty constructed their own definitions of what is required in their respective situations and the authority they believed they possessed to implement educational policies varied depending on the kind or size of their institution, their rank and sex. Similarly, another report claims that faculty in different Carnegie-based levels attach different levels of importance to different goals for undergraduate education.\textsuperscript{(117)}

This differentiation in perceptions of educational goals by institutions at the three undergraduate levels may have deeply embedded social roots. Social analysts report that K-12 schools foster and reward capacities among students that support the requirements of the social division of labor.\textsuperscript{(79, 93, 94, 106, 118-120)} Specifically, schooling must produce and reward the appropriate personal characteristics in students relevant for filling various positions in society and must encourage a perspective among students that not only accepts but supports this differentiation. Similar to the levels in the economic
hierarchy, students are categorized into various hierarchal levels: lower levels that stress rule-following and close supervision by authorities, middle levels with more independent activity and less overall supervision, or higher levels where students are expected to internalize the norms of their potential role in the economic system. This differential pattern is not perceived as coerced upon students, rather it emerges as a reflection of the educational expectations of the school administrators, parents, teachers and the students themselves. Accordingly, schooling levels reflect the values and relations relevant to the social backgrounds of both the teachers and students who populate them. The studies that substantiate this view also yield implications for undergraduate reform. They corroborated that the curriculum appears to be differentiated by institutional levels serving needs corresponding to different communities of production in society. This study will explore these issues in the data collected to determine whether they are observed among the institutions in this study.

**The effects of the discipline on teaching conceptions**

In a case study described by Gess-Newsome et al, three faculty from two disciplines co-teaching an integrated (introductory biology and physics) science course presented various degrees of reform-oriented pedagogy.(34) Interestingly, the faculty member who was most articulate at espousing reform teaching philosophy was least engaged behaviorally in reform implementation than a younger and far less pedagogically informed colleague. The authors claimed that a combination of contextual dissatisfaction (e.g. dissatisfaction with infrastructural support in their institution) and pedagogical
dissatisfaction affected the enactment of reform, as depicted in the Gess-Newsome model in Figure 4. However, the authors specifically noted that distinctions in disciplinary background may also have differentially affected reform implementation. They encouraged future studies to explore the relationship between teaching beliefs and practices by making such comparisons in a variety of environmental contexts to facilitate the building of a better reform model that will account for contextual limitations on reform. These views are echoed by other researchers cited above who encourage future studies to probe the interaction between disciplinary culture and institutional culture and their mutual effects on teaching perceptions and practices.\(^{(121, 122)}\)

Researchers, Justi and Gilbert, discovered that while teachers acknowledged the importance of giving students an understanding of the nature of science, including its reliance on models to develop and test ideas, this belief did not transfer into class practice.\(^{(123)}\) When comparing teachers from different disciplines, chemistry, physics and biology teachers, the chemistry teachers appeared to have the most difficulty implementing practices designed to fulfill the need for students to learn to generate models as part of their learning experience. Roehrig and Luft discovered that teachers with the highest degrees in chemistry used the most traditional pedagogy (didactic transmission) in their case study of 10 high school science teachers.\(^{(124)}\) While a reluctance to have students build their own models of knowledge has been reported among teachers in high school, there has not been a study that explicitly investigates the ties of a specific teaching philosophy to the chemistry discipline at the undergraduate level. Therefore, this case study will explore whether there are links between the teaching
conceptions found among chemistry faculty and the presence of a philosophy specific to
the discipline and how often students are encouraged to create their own models of
chemical phenomena.

**The effects of personal teaching conceptions on practice**

While there are a significant number of studies on K-12 teacher beliefs and their
influence on teaching practice, comparable studies at the university level are substantially
generally have not benefited from the research on school teacher beliefs. (100,
125, 126) A recent review of research conducted at the undergraduate level during the
1990’s claims that these studies “show a remarkable degree of commonality” across
three English speaking countries, (England, US, and Australia). (125) The reviewer
asserts that this commonality indicates that this research is credible and valid because the
findings were obtained independently and published in a time frame that gave the authors
little opportunity for replication. The reviewer also claims that categorizations and
meanings that these researchers used to characterize the range of teaching conceptions
also have a high degree of correspondence. (125, 127) For example, nearly all these
studies report the existence of four or five categories of teaching perspectives. These
beliefs were placed in a continuum ranging from the extreme of a didactic-transmission
perspective to a learning process facilitation (learning-cycle/conceptual change)
perspective. The extremes in this continuum have also been labeled as “teacher-oriented”
and “student-oriented” respectively. The review and the research findings alike indicate
that instructional innovations at the undergraduate level will likely have varied uptake
among faculty based on their conceptual orientation. These findings also corroborate the issue raised in the introduction of this dissertation regarding the impact of traditional teaching philosophy on faculty’s assessment of students and their acceptance of student-generated modeling that do not reflect authoritative views.

Other reviewers have a different perspective on the same research. For example in their critique Kane et al cite the plethora of terms used to describe teaching notions and claim that they do not all signify the same construct.\textsuperscript{(100)} To reduce the ambiguities of prior research, they proposed a new model to describe faculty teaching conceptions, “Espoused Theories of Action” and “Theories in Use”. This model juxtaposes teaching conceptions and practice, respectively. The title of their paper, “Telling half the story” is suggestive of their primary outlook, which is that much of prior research only partially revealed the reality of teaching practice. They claimed that the research described above examined \textit{espoused theory of action} but not \textit{theories in use}. They proposed as remedy that case studies explore both teachers’ espoused theories and their \textit{theories in use} through observations of classroom practice. All reviewers concur that the model of ‘teaching conceptions’ that the earlier research described had not had sufficient substantiation.\textsuperscript{(125, 127)} They called for case studies that would bring to light: (1) how the categories of teaching conceptions relate to each other (e.g. are they discrete or continuous with transitional conceptions?), (2) how institutional mandates can influence conceptions, (3) how the conceptions relate to observed classroom behaviors (4) how the “orientation” of departments influence the conceptions of their faculty (5) how the faculty’s conceptions influence the ‘uptake’ of alternative teaching methods.
These issues will be addressed in this study through the triangulation of the responses in the interviews with the in-class observations and by using the constant comparison method to discover patterns of conceptions that may suggest discrete or continuous categories. The emerging categories in this study will then be compared to the conceptions categories described in the research described above. If conceptions uncovered in this case study appear to match well the categories in prior research, then an exploration into how the categories relate to each other will inform that gap in prior research. Even if the categories are not well matched with the categories described in prior research, this case study can still inform the gap in prior research regarding how they differ. In addition, the other questions will be addressed such as how their conceptions relate to observed classroom behaviors, by comparing the conceptions presented in the interviews (both “espoused theories of action and theories in use”) with observed teaching practices. Last, this study will explore whether faculty’s conceptions are influenced by their environment both in the institutional and disciplinary levels and whether they affect the ‘uptake’ of reform chemistry pedagogy.

In contrast to the teaching conceptions model described above which appears to not have an explicit, explanatory theory base, some researchers have categorized teaching beliefs using the Theory of Planned Behavior.\cite{128,129} Investigators use this theoretical foundation and accompanying methods to categorize a whole belief system of the individual. In this theory, beliefs about some object are categorized by a hierarchy of levels of strength. For example Haney et al, used the theory and methods to describe the likelihood that teachers (k-12) would have a positive orientation toward Science
Education Reform in three of their studies.\textit{(130-132)} In two of these studies they triangulated their survey findings with in-class observations. They reported that their study confirmed that there is a relationship between what teachers believe and what they do in their classroom. Furthermore they found that those teachers who espouse constructivist perspectives are more likely to implement science education reform practices. Last, they assert that the environmental context is crucial to develop beliefs favorable to implementing reform practices.

These findings are helpful in illuminating possible relationships that may be found among faculty at the undergraduate level. However, this case study will fill the gap in prior research by directly investigating what faculty believe and do in undergraduate classrooms. Because prior research indicates that their environmental context may be important, this case study will explore the impact of chemistry academics’ social/institutional contexts to observe possible relationships between their contexts and faculty beliefs and practices. Also, instances where faculty espouse particular learning theories such as the constructivist learning theory, or the learning cycle, or conceptual change will be noted and will be compared to their orientations in their practice to look for consistencies or inconsistencies. However in contrast to Haney et al, my case study will not assume the importance of a particular theory of beliefs in advance of data collection and analysis to allow for the development of “data grounded” theory. Such constructed theory will be supported with the data from this case study, from prior research and with comparisons and references to established theoretical foundations. The decisions and rationale taken in the development of this theory will be
documented and explicitly reported to ensure credibility of the work. In this regard this study fills the gap in the literature because a theory about academic chemists’ propensity to implement reform pedagogy based on their beliefs and practices developed within their specific contexts has not yet been found.

**Note 1:** It is prudent to discuss the meaning of the term ‘conceptions’ that has been used interchangeably in the literature with terms such as: ‘beliefs’, ‘perceptions’, ‘perspectives’, ‘presumptions’, ‘orientations’, ‘approaches’, ‘intentions’ and ‘personal epistemology’. Despite the plethora of terms, their usage in the literature indicates they have very similar meaning (125, 127, 133) although some researchers comment that the diversity of terms causes confusion (100, 134, 135). The most common term used in a wide number of studies is the term ‘conceptions’. (125) The meaning intended here comes from Pratt (1992). (136)

“Conceptions are specific meanings attached to phenomena which then mediate our response to situations involving those phenomena. We form conceptions of virtually every aspect of our perceived world, and in so doing, use those abstract representations to delimit something from, and relate it to, other aspects of our world. In effect, we view the world through the lenses of our conceptions, interpreting and acting in accordance with our understanding of the world”. (pg.204)
III. RESEARCH QUESTIONS AND THEIR JUSTIFICATION

General Null Hypothesis: That the models of reform dissemination and reform implementation previously proposed in the literature (Figures 3 and 4) adequately describes the current reform in undergraduate chemistry as observed among the MIDP workshop participants.

1. In what ways are chemistry faculty attending a reform workshop (such as the MIDP workshops) different or similar to the general population of academic chemists? **Null hypothesis: Faculty demography of the MIDP workshop participants are similar to the general population of academic chemists represented by the ACS academic chemists census.**

2. What are the ‘in-use’ and ‘espoused’ teaching conceptions (e.g. beliefs and intentions) that academic chemists attending the MIDP workshop have about reform approaches?

3. What teaching conceptions appear to have the greatest influence (impinge the most) on their observed practices and on uptake of reform?

4. How do their specific contexts (faculty demographic characteristics and teaching environment) influence both their teaching conceptions and practices and their uptake of reform?

JUSTIFICATION FOR THE RESEARCH QUESTIONS

Justification 1

Beyond this current thrust to change teaching strategies to promote better retention of students and improved learning, some studies show that the relationship
between teaching beliefs/intentions and the strategies that teachers choose to use requires a closer examination. Prosser et al have found that instructors’ choice of teaching practices are highly dependent on their notions about learning. For example, these authors found five qualitatively different conceptions of learning associated with different teaching strategies. These learning conceptions represent a range of perspectives. At one extreme, learning is understood as an accumulation of new knowledge without a focus on how the new information relates to or is incorporated into the students’ existing knowledge framework. At the opposite extreme, learning is understood as a process that transforms the laypersons’ understanding into a more scientific view. When discussing these learning conceptions with instructors, those who saw learning as an accumulation of facts and skills used lecture techniques that transmitted this information (information transmission view or teacher-centered). In contrast, those who ascribed to changing students’ prior knowledge relied upon teaching strategies focusing on conceptual development and change (conceptual change view or student-centered).

Later studies by these researchers also found a relationship between teachers’ approaches to teaching and the students’ approaches to learning. Instructors who described their practice as one that involved transmitting knowledge had students who reported using a ‘surface approach’ to learning. This learning entailed a heavy emphasis on memorization of teacher-generated algorithms or pattern recognition as described in Appendix E. Alternatively, classrooms where instructors used approaches of conceptual change had students reporting ‘deeper’ approaches to learning, in which students are
engaged in reconstructing their knowledge (a learning process involving the learning cycle). This latter finding suggests that to encourage the implementation of the learning cycle process in classrooms, faculty may need more than a new set of pedagogical tools. Instead, they may require a change in their conception of what ‘learning’ is.

In summary, prior research suggests that if a change in the learning strategies of students is the ultimate goal of the MID Project, where students are more engaged with the material they are learning, then exploring and possibly changing the faculty’s conceptions about learning is warranted. Hence, this study will explore what teaching strategies MID Project participant faculty use after exposure to the MIDP workshop and how these strategies relate to the learning conceptions faculty convey in their teaching philosophies. This can be accomplished in part by an analysis of pre-workshop and post-workshop surveys that have been conducted with the MID Project participant faculty.

Demographic surveys are often used to characterize professional chemists in various occupations including those in academia, however the demographic categories reported are often broad and do not specify detailed characteristics of the chemistry population at the post secondary level.\(^{139}\) In contrast, there has been a considerable amount of literature reporting and exploring differences in student achievement in the physical sciences between the sexes, racial groups and economic classes. Only a few studies have drawn distinctions of this kind among faculty regarding their teaching practices.\(^{110-113}\) These studies suggest that the capacity to adopt reform teaching strategies may differ across institutional levels, between females and males and between ethnicities in the post-secondary academic population. Therefore, the surveys that have
been conducted with the MIDP participants probe what environmental or demographic characteristics (e.g. institution, classroom environment, departmental atmosphere, student evaluations, sex, and ethnicity) are associated with reported teaching philosophies and practices. It is anticipated that this data will help describe who the participant faculty are and what demographic characteristics distinguish them from non-participant faculty. In addition, this data will be used to investigate what possible relationships exist between faculty demography and environment and their reported adoption of reform teaching philosophy (e.g. the conceptual change view) and practices promoted in the MID Project workshops.

**Justification 2**

In 2002, an evaluation of the MID Project impact on faculty practices analyzed data derived from faculty surveys, faculty focus groups, faculty case study interviews, and faculty email correspondence.\(^\text{(81, 101, 140)}\) Thus all data acquired on the MID Project relied solely upon faculty reports. Evaluations of systemic reform programs in K-12 schools and reviews of evaluations have shown that teacher (or faculty) reports might reveal what faculty intend in their practice, but not necessarily what they do.\(^{\text{(14)}}\) Similarly, the 2002 evaluation of the MIDP data was unable to provide evidence that the faculty have a strong understanding of ‘process inquiry’ or other pedagogical strategies suggested in the MID Project. The evaluators of this data were hopeful that the differences in the responses in the pre and post intervention surveys suggest a change in
faculty thinking. However, the surveys were neither repeated measures in a longitudinal study nor were they constructed to discern conceptual change in the faculty. Prosser et al discovered that changing an instructor’s conception of learning and teaching from the teacher-centered information transmission view to the student-centered learning process-conceptual change view will likely be very difficult. (141) Instructors with information-transmission conceptions seemed to conceive of relations between teaching and learning in a ‘uni-instructural way’. (141) In other words, they were able to describe what they meant by teaching but had difficulty or saw no point in explaining what they meant by learning. These authors further suggest that teaching staff are unlikely to adopt approaches that reach beyond the sophistication of their conceptions. Last, they discovered that environmental conditions or demographic characteristics may lead those teachers who do have notions of conceptual change to nevertheless adopt information transmission approaches. (141)

Generally, surveys are customarily used to evaluate faculty pedagogical beliefs and understandings in reform evaluations. However, survey responses notoriously do not reveal the individual survey-taker’s interpretation as described earlier in this discussion. (98) Accordingly, what is enacted in class can not only vary from the intervention vision of reform but it may vary from the instructors’ own reported reform intentions. (34, 38, 100, 102) Therefore, rather than relying solely on faculty survey responses, this research will examine faculty understandings and practices in a case study of ten faculty entailing interviews and observations of their classroom contexts. Findings from these in-class observations will be compared with faculty survey and interview
responses to look for alignment and variances with reform teaching practices as promoted in the MID Project workshops. It is anticipated that these observations and interviews in conjunction with the surveys will provide data to answer the research questions described above. The methodology that will be used in this combined quantitative and qualitative analysis is described below.
IV. METHODOLOGY

The need to capture practices as well as beliefs requires a variety of research tools. (36) In addition to surveys, protocols that include interviews of participants and ‘field’ studies, which involve a researcher entering classrooms to observe in-class pedagogy, have been used in this work. The current understanding in science education research is that the use of surveys or standard tests have limited value as ‘stand alone’ instruments to probe reform outcomes. Rather, multiple methods must be used in conjunction and the resulting data must be integrated (referred to as ‘triangulation’) to create a picture of sufficient depth to capture the sociological practice of teaching science.

To satisfy the current quality criteria for qualitative data collection and analysis, this project follows Lincoln and Guba’s ‘naturalistic method of inquiry’.(51) The approach is called naturalistic because it is conducted within a “natural” setting, for example, the classrooms of participants in the MID Project. Relationships to relevant theory (or the materialization of new theory) and variables are expected to emerge inductively from the field data. A process referred to as “coding” the data will be used to permit description of field observations in concise content-specific units. “These units are best understood as single pieces of information that stand by themselves, that is, that
are interpretable in the absence of any additional information.”(51) (pg. 203) Coded data then will be organized into categories that will place the data within relevant theoretical contexts and/or in reference to the settings from which they were derived. Initially, the categories will be provisional until sufficient accumulation of coded data attributed to specific categories suggests some commonality or “rule” that serves as the basis for inclusion/exclusion decisions. This strategy of sorting units with “look-alike” characteristics into provisional categories is referred to as “constant comparative method”.

In conjunction with field notes of observations of classroom practice, recorded and transcribed interviews will be collected, coded, and qualitatively analyzed using the constant comparison method. Last, surveys probing faculty teaching practices, beliefs, and demography will be analyzed using conventional quantitative analysis. Relevant data will be triangulated together to create a snapshot of the current status in the reform of undergraduate chemistry as described in the introduction. The data will be referred back to theory, described in the introduction of this work, to generate an elaboration or refutation of the model of reform proposed in prior research.

**TRUSTWORTHINESS**

The trustworthiness of this research was established using the guidelines primarily from two sources.(51, 142) The criteria for trustworthiness described by Eby and Schmidt are given below in Table 4.
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<td>6. Competence in chemistry</td>
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The theory base of this investigation was presented in the introduction of this dissertation. The relevance of this work was also described in detail in two chapters (II & III) which included justification for the research questions. There are two hypotheses, one which can be answered appropriately using quantitative methods (Research Question 1) and the other is more qualitative regarding the appropriateness of an earlier model of reform (Figure 3) to adequately capture the impact of reform dissemination exemplified in the MID Project workshops’ outcomes. These hypotheses will be addressed in the Findings and Conclusions respectively. Multiple methods were used to ensure reliability.
For example, multiple instruments (surveys) were used to explore the impact of the MID Project. These surveys contained some questions in common to allow comparisons of faculty responses before and after the workshop. The questions on the surveys were constructed by a committee of chemistry faculty familiar with the issues of reform and the role and history of the MID Project or taken from other surveys previously published. Those surveys that were constructed were pilot-tested, helping toward establishing the relevance and validity of the questions. The level of significance for all quantitative tests has been reported in the findings when appropriate. In the qualitative investigation, sampling, interview and observational procedures are documented in this chapter or in the appendices. Interpretations include discussions on possible alternative interpretations if the data can support more than one inference, or no final conclusions if the data appear insufficient. Because the researcher attended the participants’ classes to observe them, and interviewed them in their offices, this approach allowed appropriate closeness to the participants. After collection, qualitative data was triangulated with the survey data when appropriate, and the findings of this analysis and implications of this investigation are presented in the final chapters of this dissertation. Last, the investigator had a graduate degree in chemistry to allow understanding of the subject matter of the participants’ classes and to allow appropriate pedagogical discussions with the faculty.

In keeping with Lincoln and Guba’s criteria, an audit trail was maintained. Documentation of the contacts with the faculty were kept on spreadsheets along with information that allowed triangulation with the surveys. Appropriate ethical treatment of the data was maintained through keeping the identity of the faculty separate from their
data. Consent forms were taken and “member-checking” was performed during the interviews to ensure participation was voluntary and corroborates the researcher’s observations of the in-class practice. Audio-files of the recorded interviews were transcribed and tabulated and their records kept together with the other qualitative and quantitative data. Documentation of the analysis performed such as coding and graphical analyses, was taken and has been presented within this dissertation.

QUANTITATIVE METHODS

INSTRUMENTS OF ASSESSMENT AND ANALYSIS METHODOLOGY

Pre-Workshop Survey

The pre-workshop survey was designed to be taken by all workshop participants, hence faculty demography and workshop attendance described in this report is based on the data from this survey. (Copies of all surveys are in Appendix B) The first evaluation team (Kathy Burke, John Gelder, Tom Greenbowe, and Jennifer Lewis) worked in consultation with the initial team of MID Principal Investigators to develop the pre-workshop survey. Over the course of the four years that workshops were conducted, this survey has been administered in two formats. The original format was a paper survey administered at the site of each workshop. After the first year of workshops, an online version was created to collect responses electronically prior to each workshop. Slightly different wording was used in the online format in questions addressing assessment techniques. Therefore, precautions have been taken to ensure appropriate construction of variables pertaining to this segment of the survey.
Two evaluation teams collected these surveys. The first team collected surveys from the years 2000-2001. The surveys from the earlier collection were handed over to the second team (Diane Bunce, Dorothy Gabel, and Jennifer Lewis). Working under the direction of Dr. Lewis, the author of this study processed and analyzed the data collected from 2000 to the spring of 2004. Therefore, this report describes the data analysis and results generated under the direction of the second evaluation team. No sampling has been performed on the pre-workshop data. All surveys submitted by respondents who participated in the workshops up to February 2004 and who gave their consent have been analyzed (N = 745). Responses to closed questions on teaching techniques and demography have been coded using HyperResearch™ software. After coding, the data was exported to Microsoft Excel software for final preparation and then imported into SPSS software, which was used for all statistical analysis.

The pre-workshop survey consisted of four main parts: (1) questions addressing the participant demography such as the race/ethnicity, sex, type of institution where they taught, type of class they taught, years of experience and tenure status; (2) open ended questions ascertaining the goals and challenges of teaching; (3) three sets of closed questions addressing the instructional techniques the faculty were currently using in their (a) lecture (b) lab and (c) assessment (these questions consisted of four response categories: ‘use’, ‘use and rank’, ‘rank but not use’, and ‘don’t know’, which include both reform and “traditional” teaching approaches); (4) questions determining how familiar the participants were with the MID Project, how they learned of the workshops and comments about the survey.
**Post-Workshop Survey**

The post-workshop survey (or “post survey”) was an online questionnaire that was developed by the second evaluation team (Diane Bunce, Dorothy Gabel, and Jennifer Lewis) and the Project Director (Eileen Lewis) in the Fall of 2002. The faculty who participated in the workshops prior to Fall 2002 (called the “first cohort,” N=289) were solicited by email in December 2002. Submission of the post workshop survey was voluntary. During January and February 2003, repeated solicitations were made and subsequently the post-survey data were electronically collected, compiled and entered into a common data spreadsheet in February 2003.

In the solicitation of the first cohort (years 2000-2001) of MID Project participants, 89 surveys were submitted, representing a 31 % (89/289) response rate. No sampling was performed and all surveys submitted have been analyzed; hence, the data from this survey likely represents those participants who have maintained interest in the project goals. All data has been analyzed using SPSS software.

The post workshop questionnaire probed reform-oriented pedagogical interests of the project using both open and closed questions. Overall, the questions in the post survey differ in format and in content from the pre-workshop survey, with only a few questions carried over. Because of this, the post workshop data cannot be treated as ‘repeated measures’ data; however, ‘within subject’ responses from both surveys may be quantitatively compared using non-parametric statistics such as ‘McNemar’ analysis and frequencies. In order to make these comparisons, certain precautions must be taken to ensure the analyses are reasonable. For example, comparisons of teaching approaches
within subjects and between groups (post survey takers and non-takers) require comparable environmental settings. Therefore, the first approach to this analysis was to evaluate the demography within subjects and between groups.

**Inventory Survey**

A second post-workshop survey, the Inventory Survey, was solicited in March/April of the year 2004 to participants who attended workshops between the years 2000 and January 1, 2004. The “Inventory Survey” was developed by the Project Director, Eileen Lewis, and one of the members of the second evaluation team, Jennifer Lewis. It was comprised of two parts. The first part entailed an “Approaches to Teaching Inventory” that assessed faculty teaching conceptions as student-oriented and/or teacher-oriented. The second part of the Inventory Survey entailed a “MID Project Workshop Inventory” that probed faculty’s perceptions about their experiences in the MIDP workshops that facilitated their use of reform pedagogy.

Stratified sampling was used to ensure that the demographic distribution of the respondents reflected the same demographic proportions found in the pre-workshop data with respect to racial identification (two categories: white/minority) and institutional level (four categories: two-year-undergraduate/four-year-undergraduate/masters-granting/doctoral-granting). The final proportions of the sample match the MID population in the targeted categories: 41% (42% pre-workshop) for participants from two-year undergraduate institutions, 61% (63% pre-workshop) for four-year undergraduate, 43% (45% pre-workshop) for masters-granting, 45% (49% pre-workshop)
for doctoral-granting, and 81% (88% pre-workshop) for minorities. The overall response rate was 56% (N_{sample} =203). Solicitation procedures entailed two e-mail requests before accepting non-response; however, all in the minority category received three e-mail requests.

An exception to this protocol involves one workshop (conducted in February 2004 and not included in the sample described above) group of attendants who received the first segment of the Inventory Survey (“Approaches to Teaching Inventory”) prior to their workshop and then were requested to take the same survey approximately one year after the workshop. This was the only repeated measurement used in the survey data. As indicated above, the “Approaches to Teaching Inventory” specifically probes faculty conceptions about teaching using 16 survey questions developed by Prosser and Twigwell.\textsuperscript{(61, 99)} The theoretical basis of these questions derives from current learning philosophy including conceptual change theory. Eight questions probe thinking that is aligned with traditional/didactic teaching approaches and eight are aligned with reform approaches and conceptual change theory.

The faculty of this workshop who retained the same email address (N=20) were solicited on three occasions to take the post workshop Approaches to Teaching Inventory. Eleven faculty responded (55% response rate). The repeated measures data will be used to probe whether these faculty indicate any changes in their teaching conceptions that might be attributable to the MID workshop intervention.

Accordingly, the data from the entire Inventory Survey and the Teaching Approaches Inventory survey received the same preparatory treatment for statistical
analysis that was performed on the pre and post surveys. For analysis, the responses to both the Inventory Survey and Teaching Approaches Inventory questions were examined with respect to demography and reported teaching practices from the pre-workshop survey.

QUALITATIVE METHODS

SAMPLE SELECTION

Purposeful stratified selection of 10 chemistry instructors who attended either one of two workshops were observed and interviewed using qualitative methodology. Therefore the sample represents an in-depth case study of two workshops chosen because of the proximity of their participants to the investigator. While the sampling was purposeful, it entailed an emergent design guided by the purposes of this study presented in the chapter on the rationale, the description of research questions and the introduction to this methodology section and should not be interpreted beyond these informational contexts. For the purposes of this study, described and supported by prior research in the rationale chapter and the text and prior research supporting the research questions, there can be no apriori specification of a sample as one might do with generalization-oriented random sampling. In such latter cases one would do a power analysis and confirm that with a desirable effect size, an appropriate-sized N was acquired. Therefore the N of the sample can be specified in advance of the study. The size of N can be determined purely by formula, once the tolerable levels of type 1 and type 2 error are specified. However this is not an appropriate approach for a naturalistic case study using purposeful
sampling, where the size of the sample is determined by informational purposes. \((51, 142)\) The appropriate number or characteristics of the sample are continuously analyzed and adjusted to the point of informational redundancy. \((51)\) This protocol was followed in this study. The factor determining redundancy used in this study was in-class teaching practices used in general chemistry courses across different contexts such as institutional levels and faculty demographic characteristics described below. All possible contexts were not exhausted, and the case study purposes and interpretations make no such claims for generalization.

The intention of the following discussion about the sampling procedure is to describe what parameters were used for choosing these participants and describing their characteristics, leaving open the possibility that they might be typical or can be confirmed as typical of the general population, should more studies be conducted to justify such claims. However, leaving open such possibilities doesn’t mean that the study cannot be used to raise questions about the population. On the contrary, observed characteristics in a case study might be the motivation for further studies to determine whether important characteristics of a case study are typical of the population.

The faculty were drawn from the University of South Florida and Florida Atlantic University workshops and their identities are kept confidential. They were chosen to best reflect the demographic distribution of the workshop participant population regarding two demographic factors, institution level and sex, following a pre-established rubric for small samples. \((143)\) In addition to the in-class observations and interviews they were
asked to submit their responses to the “Approaches to Teaching Inventory” segment of the Inventory Survey described above, after qualitative data collection began.

**Sampling Population Criteria and Population Matrix**

The selection procedure entailed the following process in the sequential order of steps as shown with emphasis on the first two steps. The rationale for steps #1 and #2 is the preference for faculty members who have been, or are in the process of being, inculcated into the chemistry academic culture and have similar responsibility and positions within the hierarchy of their institution. Rationale for #3 and #5 was to compare class environments that have students at similar academic levels and that will likely have similar subject content over the semester. The process of selection resulted in the population pool shown in Table 5.

**Selection Process—6 step criteria**

1. Selection of instructor/participants who are on chemistry faculty staff and maintaining an equal proportion as is possible of participants from both workshops, “A” and “B”. This step eliminates post docs, grad students, lab coordinators, visiting, adjunct and retired faculty and administrative staff such as deans.

2. Dimensional sampling among the potential instructor/participants (described in #1) along three levels of institutions (community colleges, 4yr undergraduate and 4 yr graduate) that teach in programs that award degrees in undergraduate chemistry. This eliminated instructors from institutions such as high schools, museums, and faculty who teach within non-chemistry programs (eg biology, physics or a program such as a nursing program that doesn't have a chemistry program).

3. When choices were available, faculty were chosen at each institutional level who teach courses out of the chemistry department at the lowest level of students, eg.
undergraduate vs. graduate; general chemistry or first year rather than 2nd year or higher.

4. When choices within any category in the above were available (eg more than one person available at an institutional level that teaches general chemistry), preference was given to those whose class schedules permit observations without conflicting the researcher’s teaching responsibilities. When conflicts necessitate greater flexibility, substitutions were arranged for the researcher’s classes, or procedure #3 was adjusted to include next higher undergrad level, if needed.

5. When class choices were available, preference was given to classes in which fundamental chemistry topics are taught (eg. molecular relationships, atomic theory etc. rather than chemistry related topics (eg. environmental science)).

6. After the above decisions have been made and if there are both females and males available for choice (eg among several who teach general chemistry at an institutional level), then preferences will be given to include both females and males in each institution category, as well as minorities and non-minorities in each institutional category.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Participant Pool Code Names Workshops “A” &amp; “B”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B-6557, B-1974, B-1215a, B-3377</td>
</tr>
<tr>
<td></td>
<td>B-1234</td>
</tr>
<tr>
<td>Community College</td>
<td>A-139</td>
</tr>
<tr>
<td></td>
<td>B-999, B-2578, B-1357, B-211, B-10</td>
</tr>
</tbody>
</table>

The case study participants were drawn from the population pool shown in Table 5. After the population matrix table was constructed it was observed that there were at
least two faculty working in the same institution at each institutional level. Because it was desirable to compare similarities and differences between faculty in the same institutional environment across institutional levels, a seventh criteria was implemented to attempt to have preferably three and at least two participants in the same institution at each level. The participants were solicited up to five times by email and three times by telephone (leaving messages) all solicitations were documented and dated. On four occasions this form of contact did not suffice to obtain the participants desired from each of the institutional levels. Therefore the next tactic used to contact faculty was to request the assistance of participating faculty to encourage a colleague to participate. On two occasions the researcher “appeared” at the office of a potential participant to request their participation and both agreed upon subsequent meetings for interviews and in-class observations. Because all of the participant faculty at the Ph.D. institution had the same tenure rank, an additional participant was solicited who did not have the same rank as the other three. During this study, there were no available “not yet tenured” MIDP participant faculty in the Ph.D. institutions. Therefore, one fulltime chemistry instructor, who had less than 5 years experience and was not on a tenure track, was solicited and participated. Consequently, there were four participants from the Ph.D.-granting institution and three in each of the undergraduate institutions making a total of 10 faculty in the case study. The participants were also chosen to obtain nearly even distribution between sexes, given the above criteria. Regarding race/ethnicity, only one minority faculty agreed to participate in this study, all others were Caucasian. The resulting demography of the case study participants is shown in Table 6.
The demography of the case study participants allowed observations at four institutions. As indicated above, four faculty were chosen at the Ph.D. university setting who attended the same MIDP workshop. These faculty were chosen based on the diversity of the first year chemistry courses that they taught (three different sections of the same general chemistry course and two chemistry courses for non-majors). Both the general chemistry and chemistry for non-majors classes were observed for comparison. Partial control of the environment was obtained by observing three faculty teaching different sections of the same course, which was coordinated to present the same curriculum to students. This allowed a greater opportunity to observe the influence of individual differences pertaining to personal conceptions and practices. The institution was located in an urban setting and served an ethnically and social-economically diverse community of students.

Three faculty at a four-year undergraduate college were chosen. All three faculty attended the same MIDP workshop and taught different sections of the same general chemistry course and general chemistry labs as well. Again, partial control of the environment allowed for observations of the contrasts and convergences of teaching practices and conceptions between individuals. The faculty had varying levels and kinds of teaching experience, tenure rank and chemistry backgrounds. All of the faculty were males. The college is a private institution located in a suburban setting, serving primarily white, middle class students and recognized for marine science education and research.

Faculty at two community colleges were observed. In one community college two faculty were observed, and each had attended a different workshop. The two faculty
were females with different backgrounds in chemistry and teaching experience. One of these instructors self-reported her ethnicity as Hispanic. These faculty taught different first year chemistry courses (general and preparatory) during this study although both taught the same general chemistry course in the semester previous to these observations. Their perspectives about the general chemistry course were probed along with their conceptions about their current courses to observe possible differences in conceptions about the same curriculum. One of the faculty formerly taught at the university of this study and provided insight into her different teaching experiences at these institutions. This community college was situated in a highly urbanized area serving a diverse ethnic and social-economic community.

One other faculty member was chosen at a rural community college. This was a male instructor chosen to provide as much diversity in sex across all institutional levels that could be attained while at the same time controlling for teaching environments. This instructor had previous teaching experience at the four year private college in this study and provided insight into his teaching experiences in these different environments. His general chemistry class took place at night, serving fulltime working students of whom several were non-traditional age but were not racially/ethnically diverse (primarily Caucasian in appearance).
### Table 6. Demography of the Case Study Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Tenure status</th>
<th>Years experience</th>
<th>Institution level</th>
<th>Class size/type</th>
<th>Specialization area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim</td>
<td>tenured</td>
<td>&gt; 10</td>
<td>Graduate</td>
<td>~ 150 1st year Gen chem</td>
<td>Chem/academic/industrial</td>
</tr>
<tr>
<td>Greg</td>
<td>tenured</td>
<td>&gt; 10</td>
<td>Graduate</td>
<td>&lt; 35 1st year Chem/gen science</td>
<td>Interdisciplinary/chem</td>
</tr>
<tr>
<td>Howard</td>
<td>tenured</td>
<td>&gt; 10</td>
<td>Graduate</td>
<td>~ 150 1st year Gen chem</td>
<td>Chem/academic/industrial</td>
</tr>
<tr>
<td>Cindy</td>
<td>not on tenure track</td>
<td>&lt; 5</td>
<td>Graduate</td>
<td>150 1st year Gen chem</td>
<td>Chem/academic</td>
</tr>
<tr>
<td>Markus</td>
<td>tenured</td>
<td>&lt; 10</td>
<td>4 year Undergraduate</td>
<td>&lt; 35; 1st year Gen chem</td>
<td>Interdisciplinary/chem</td>
</tr>
<tr>
<td>Evan</td>
<td>tenured</td>
<td>&gt; 10</td>
<td>4-year Undergraduate</td>
<td>~ 35 1st year Gen chem</td>
<td>Chem/academic/industrial</td>
</tr>
<tr>
<td>Russ</td>
<td>Not-yet tenured</td>
<td>&lt; 10</td>
<td>4-year Undergraduate</td>
<td>~ 35 1st year Gen chem</td>
<td>Chem/academic/industrial</td>
</tr>
<tr>
<td>Rita</td>
<td>Not-yet tenured</td>
<td>&lt; 10</td>
<td>Community college Undergraduate</td>
<td>&lt; 35 1st year Gen Chem</td>
<td>Interdisciplinary/chem/academic</td>
</tr>
<tr>
<td>Laura</td>
<td>Not-yet tenured</td>
<td>&gt; 10</td>
<td>Community college Undergraduate</td>
<td>&lt; 35 1st year Gen chem/ preparatory</td>
<td>Interdisciplinary/chem/academic</td>
</tr>
<tr>
<td>Vern</td>
<td>tenured</td>
<td>&gt; 10</td>
<td>Community College Undergraduate</td>
<td>&lt; 35 1st year Gen chem</td>
<td>Chem/academic/industrial</td>
</tr>
</tbody>
</table>

### INTERVIEWS

Interviews were initiated after observation of one class in all participants except for “Vern” in the rural community college. His first interview took place prior to the first
class observation based on his scheduling needs. The first interview was conducted after the first observation because prior research indicates that observations taken after interviewing might be influenced by the participants’ views. (144) Depending on availability, these interviews were conducted in the fall semester 2004 and spring 2005. In most cases these sessions varied from two to four half-hour sessions. However, on some occasions fewer (minimum of two), longer interviews, up to one hour in length were conducted based on the instructors’ scheduling needs. With the exception of Marcus (whose total interviewing time was approximately 1.5 hours), the total amount of interview time taken with each faculty member was approximately the same (2 hours). These sessions were semi-structured ethnographic interviews probing faculty reflections on their MID workshop experience, teaching and learning experiences or other informal/formal academic experiences. Questions focused on what experiences and philosophy the faculty found most meaningful or provocative regarding their previous and current teaching practices. Participants who claimed that their practice had changed were asked what factors influenced these changes the most. The rubric of questioning that was used, which combined two previously published protocols, is provided in the Appendix C. (38, 61)

One goal of these interviews was to uncover faculty understanding of reform pedagogy including equity, the learning cycle and conceptual change as components within the process learning pedagogy as described in the introduction of this work. For example, the interview probed faculty perceptions of their students’ capacity to learn in order to access their conceptions about learning. Literature indicates that faculty who
emphasize the lack of student capacity and knowledge retain philosophy focused more on transmission (inquiry as a product to be conferred) rather than process (conceptual change).(3, 28, 34, 38, 53, 58, 61, 67) This thinking has been shown to offer very little empowerment to student ownership of knowledge. Faculty were asked about what factors in their environment or previous experience helped to initiate, sustain or hinder their preferred pedagogy. They were also asked to describe what teaching techniques they consider (and/or use) are most beneficial to students and why they consider them to be the most beneficial. These responses were compared to the survey responses to look for similarities and differences.

A common perception about reform philosophy and implementation is that it fosters equity.(3, 14, 24, 28, 40, 41, 53, 67, 68, 92, 106) Therefore, evidence of equitable practices or outcomes will be explored in the interviews and observations. For example, if faculty teach more than one level of students (i.e. first year, second year, etc) they will be asked to describe the activities they use at different levels, and how they differ. Literature indicates that higher level classes cater to science majors more than lower levels and receive deferential pedagogical treatment that undermines a supportive environment and the development of a diverse student clientele at all levels.(3, 30)

Another goal of these interviews is to acquire greater depth of understanding of faculty conceptions about learning and their intentions regarding their teaching practices. These interviews were particularly important in situations where the faculty espouse reform concepts but do not enact them in their class. Interviews with this faculty were carefully constructed based upon information provided by the survey, their initial
interview and observed activities in the classroom. Hence while some questions were asked of all faculty, part of the questioning during the interviews was unique to each faculty. Because it was possible that in the course of these interviews faculty may become more aware of their discrepant acts and alter their behavior, subsequent in-class observations and notes were examined to see possible changes in their practices. The third and final interviews were used to confirm observations with faculty and to acquire their recommendations for other faculty considering reform pedagogy. Therefore, these last interviews engaged in “participant member checking” to verify the case study data and to maintain data credibility. The faculty recommendations will serve not only faculty considering implementing reform practices, but may provide another window into why these faculty have chosen their particular set of practices.

These interviews were audio-recorded and transcribed verbatim. An oral synopsis of the transcript was presented to the faculty to obtain their confirmation and/or corrections regarding their interpretation of their pedagogy. The transcripts were coded and categorized using the constant comparison methods described earlier in this methodology section. The coding rubric that was obtained through this analysis is in Appendix D. The data was then analyzed for information relevant to the research questions.

**FIELD OBSERVATIONS**

Two to four in-class observations of each of the 10 faculty were conducted and the data from these observations were used to corroborate the case study faculty’s
teaching practices reported in their surveys and in their interviews. These observations were conducted in the fall 2004 and spring 2005. In four cases the set of observed class sessions were taken from the same course given over two semesters, otherwise all of the sessions were taken of the same course in the same semester. If the faculty member taught more than one class at different levels (first year, second year students, etc) the class chosen was the lowest level. The classes were purposefully chosen to make possible comparisons of the treatment of content and instructional practices. In one case (Kim at the Ph.D. institution) observations were taken of two different courses she taught: two classes were observed in the general chemistry course and two classes were observed in a first year chemistry course for non-majors. Field notes were taken and subsequently coded and categorized. The physical setting, the number of students, their observed sex distribution and visible race/ethnicities were recorded. The number and kind (e.g. question and answer, discussion, or problem solving) of teacher-student and student-student interactions were noted. A rubric incorporating Bloom’s taxonomy, Novack’s cognitive domains, Strike and Posner’s conceptual change criteria, and Zoller’s HOC/LOC designations was used to check for reform-oriented practices. These practices might include but are not limited to: process learning strategies (described earlier), discrepant event activities (conceptual change), and collaborative learning strategies. Generally, any activity in the classroom that appeared to involve the learning cycle, in-class collaborations, discussions involving conceptual questions/problems rather than algorithmic questions/problems, and discrepant events that led to conceptual change, were considered student-oriented (and
hence reform oriented). Alternatively, transmission/didactic practices in which the faculty mainly lectured were also noted. Displays of student attitudes were noted as well as ‘off task’ behaviors. Observation practices were developed and refined during the observational period as needed. The main goal of these observations was to corroborate and obtain detail about the enacted pedagogy. After each observation a synopsis report was written and the class notes were transcribed for the purposes of coding as described above. The coding scheme that was obtained through analysis of the in-class observations is provided in Appendix D. This data was also analyzed regarding their relevance to the research questions and triangulated with the interview data and survey data to obtain an in-depth view of these instructors’ practices. The data was subsequently referred back to theory described in the introduction of this work to generate an elaboration or refutation of the proposed models of reform.
V. RESULTS AND FINDINGS

This section describes the data collected with an analysis of the data. Because the findings used to answer the research questions refer to data from both quantitative and qualitative sources, the presentation of the data is embedded within an explanation and discussion of the findings. However, tables and diagrams are presented throughout to assist in summarizing and substantiating the salient observations.

**RESEARCH QUESTION 1**

In what ways are chemistry faculty attending a reform workshop (such as the MIDP workshops) different or similar to the general population of academic chemists? **Null hypothesis: Faculty demography of the MIDP workshop participants are similar to the general population of academic chemists represented by the ACS academic chemists census.**

As mentioned in the introduction of this dissertation, this study probes the response to the call of systemic reform by comparing the composition of academics attending the MIDP workshops to the larger population of academic chemists. Because MIDP PI’s used ACS media for advertising, the ACS database for solicitations, and hosted MIDP workshops at ACS regional and national meetings, the assumption in this study is that MIDP facilitators accessed the ACS academic population. While the UFE workshops are somewhat comparable to MIDP as a dissemination program intended for physical sciences, only 10% of their workshops were held explicitly for chemists and
their reported data referred to the entire program rather than to specific disciplines. Last, because NSF census data does not provide the same rich detail in demographic data on academic chemists as ACS, this report shall refer to the ACS academic census data as a proxy for the larger population of academic chemists. Hence, the MIDP demographic data is compared primarily with ACS demographic data in this report.

All faculty attending the 1.5 day MID Project workshops submitted a “pre-workshop survey” that gathered information about the attending faculty demography and teaching practices. The first 745 submissions obtained by February 2004 were used to determine whether the attending faculty are representative of the ACS academic population or are distinguishable from the general academic chemist community profiled in the ACS census. The ACS survey was planned and analyzed by the ACS Committee on Economic and Professional Affairs (CEPA) and by its Subcommittee on Surveys. Responses to the ACS survey used in this analysis were obtained from 10,601 respondents in the year 2000. The ACS respondents were academic chemists who were employed full-time (87%), part-time (4.3%), post-docs or other fellowship (6.2%), seeking employment (1.3%) and not seeking employment (0.5%). We explored the distribution of ethnicity, the type of employing institution, years of experience, sex and tenure status by comparing the MID Project data to statistics provided by ACS and NSF census surveys.\(^{139, 146, 147}\)

In order to use the ACS census data on institution levels distribution, the ACS data were slightly modified to exclude the percentage of academic chemists working in medical schools. This was done in order to compare the ACS categories with the MIDP
survey data which did not have a category for medical schools. The last two columns in Table 7. show that, in contrast to MIDP percentages, the majority (53%) of general population of chemists in academia polled by ACS is employed in institutions with graduate schools. A comparison test, such as the $\chi^2$ (Chi-Square) “Goodness of fit” test, indicates that the distribution of MID Project faculty employed across institutional levels differs significantly from the ACS-polled academic distribution. ($\chi^2 = 188.070$, $p < 0.001$, $\alpha = 0.05$) The residuals of this test indicate that MIDP attracts proportionately fewer instructors from high school and Ph.D. granting institutions and more instructors from community colleges and four-year undergraduate institutions. Because the significance of any statistical test is heavily dependent on the sample size, a test of the effect size provides information to determine whether the significance of the $\chi^2$ is substantive. In a scale ranging from 0.10 for a small effect size to 0.50 representing a large effect, the obtained $\chi^2$ effect size was 0.50, indicating that the difference in institutional levels among MID Project participants relative to the population polled by ACS is substantive. (148)
Table 7. Institution Level Participation (%)

<table>
<thead>
<tr>
<th></th>
<th>High School</th>
<th>2-year Undergrad</th>
<th>4-year Undergrad</th>
<th>Masters-granting</th>
<th>PhD-granting</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS (2000 census)</td>
<td>7.7</td>
<td>8.25</td>
<td>26.18</td>
<td>11.3</td>
<td>46.5</td>
</tr>
<tr>
<td>UFE (1991-1997)</td>
<td>(NA)</td>
<td>23</td>
<td>28</td>
<td>33 (MS &amp;/or PhD granting)</td>
<td></td>
</tr>
<tr>
<td>MID Project</td>
<td>3.2</td>
<td>18.4</td>
<td>36.5</td>
<td>12.1</td>
<td>29.5</td>
</tr>
<tr>
<td>MID female (N=323)</td>
<td>4.3</td>
<td>19.8</td>
<td>35.3</td>
<td>10.5</td>
<td>30.0</td>
</tr>
<tr>
<td>MID male (N=422)</td>
<td>2.4</td>
<td>17.3</td>
<td>37.4</td>
<td>13.7</td>
<td>29.1</td>
</tr>
<tr>
<td>MID white</td>
<td>3.2</td>
<td>17.4</td>
<td>37.3</td>
<td>13.0</td>
<td>29.1</td>
</tr>
<tr>
<td>MID non-white</td>
<td>3.7</td>
<td>21.6</td>
<td>33.2</td>
<td>9.5</td>
<td>32.1</td>
</tr>
</tbody>
</table>

ACS N=8449 MIDP N= 745

As observed in Tables 8 and 9, MIDP workshops attracted higher female and minority faculty participation relative to the ACS academic census, the Nelson census of the “top 50 research institutions,” and UFE workshops.

Table 8. Sex Distribution (%)

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS (2000 census)</td>
<td>25.9</td>
<td>74.1</td>
</tr>
<tr>
<td>“top 50 universities”</td>
<td>10.7</td>
<td>89.3</td>
</tr>
<tr>
<td>UFE</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>MID Project</td>
<td>43.4</td>
<td>56.6</td>
</tr>
</tbody>
</table>
Table 9. Race/ethnicity Distribution (%)

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Hispanic</th>
<th>African American</th>
<th>Native American</th>
<th>Asian</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS (2000 census)</td>
<td>84.8</td>
<td>3.0</td>
<td>1.7</td>
<td>0.1</td>
<td>9.6</td>
<td>0.8</td>
</tr>
<tr>
<td>“top 50 universities”</td>
<td>91.2</td>
<td>1.3</td>
<td>1.1</td>
<td>0.2</td>
<td>6.2</td>
<td>no data</td>
</tr>
<tr>
<td>UFE</td>
<td>84</td>
<td>16 (“Minority”)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MID Project</td>
<td>81.7</td>
<td>2.7</td>
<td>5.9</td>
<td>0.5</td>
<td>7.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

In the ACS 2000 census survey, which polled academic chemists across all institutional levels throughout the nation, the proportion of female respondents was 26%, or nearly 3:1 in favor of males. The MID Project workshop population was 43% female, only 1.3 to 1 in favor of males. This difference was statistically significant, and the effect size reasonable (comparison to ACS: $\chi^2 = 118.280 \ p < 0.001 \ \alpha = 0.05; \ \text{Effect size: 0.40}$). Of course, the greatest contrast lies with the faculty of the “top 50 universities” which exhibit a ratio of approximately 10 to 1 (males to females). In light of these comparisons with national data, the MID project should be commended for attracting a large proportion of female faculty to the workshops.

As indicated in Table 9, the proportion of non-white racial/ethnic groups that attend the MID Project workshops differs significantly from the proportion of minority academic chemists responding to the ACS poll or who are employed in the “top 50 universities.” The MID Project participants report fewer white and more African American, Native American Indian and “other” relative to those reporting in the ACS poll. (Goodness of Fit $\chi^2 = 89.813 \ p<0.001 \ \alpha = 0.05 \ \text{Effect Size} = 0.35$) The ACS data do not indicate a percentage of non-responses, while among the MID Project workshop
participants 11% (85/745) did not identify their race/ethnicity. The majority (76%) of non-responders were males. In categories other than sex, the non-responders did not significantly differ demographically from either the white or non-white racial/ethnic groups.

Fewer faculty attending the MID Project workshops have tenure relative to the general population of chemists in academia polled by ACS as observed in Table 10. This difference was significant ($\chi^2 = 100.654, \alpha = 0.05$) with a medium effect size of 0.37. Comparing the same sex counterparts between the ACS and MID Project data demonstrates that smaller proportions of both male and female chemists in the MID Project workshops have tenure relative to the same sex among academic chemists polled by ACS. The difference in the distribution of tenure status among the ACS males and MID males was statistically significant ($\chi^2 = 84.580; N= 419$ MID males responded to this question; $p < 0.001$) with a substantive medium to large effect size of 0.45. The difference in the distribution of tenure status between females of each population was also significant ($\chi^2 = 17.620; p =0.001$) with a low-medium effect size of 0.24.

Tenure status was not significantly ($\chi^2 = 3.846 p = 0.279, N = 186$) different between the non-white minority groups (N=186) and the white majority. A power analysis confirms that there was sufficient power to find a low to medium effect. (This data was not available from ACS for comparison with the MID data.)
Table 10. Tenure Status-Multiple Categories (%)

<table>
<thead>
<tr>
<th>Tenure Status</th>
<th>Tenured</th>
<th>Tenure-track</th>
<th>Not Tenure-track</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS total</td>
<td>52.1</td>
<td>14.9</td>
<td>13.7</td>
<td>19.2</td>
</tr>
<tr>
<td>ACS females</td>
<td>35.8</td>
<td>19.6</td>
<td>19.2</td>
<td>25.4</td>
</tr>
<tr>
<td>ACS males</td>
<td>57.8</td>
<td>13.3</td>
<td>11.8</td>
<td>17.1</td>
</tr>
<tr>
<td>MID Project total</td>
<td>42.6</td>
<td>24.8</td>
<td>20.1</td>
<td>12.5</td>
</tr>
<tr>
<td>MID females</td>
<td>30.5</td>
<td>23.0</td>
<td>26.7</td>
<td>19.8</td>
</tr>
<tr>
<td>MID males</td>
<td>51.8</td>
<td>26.3</td>
<td>15.0</td>
<td>6.9</td>
</tr>
<tr>
<td>MID Whites</td>
<td>44.3</td>
<td>24.3</td>
<td>19.8</td>
<td>11.6</td>
</tr>
<tr>
<td>MID Minorities</td>
<td>38.2</td>
<td>26.3</td>
<td>20.4</td>
<td>15.1</td>
</tr>
</tbody>
</table>

Table 11 indicates that the majority (54%) of the MID Project participants have less than ten years experience at the time of the workshop. While no direct comparisons can be made to ACS data due to differences in measurement, the ACS census indicates that the mean age of academic chemists is 47.9 years, and that 63.5% report a minimum of 20 years since their bachelor’s degree. Even taking into consideration the amount of time required to obtain a graduate degree, the majority of the MID population appears to have less experience than the ACS average time since bachelor’s degree would suggest.

Within the MID population, a $\chi^2$ evaluation of experience demonstrates that the distribution of experience levels among females differs significantly from males. ($\chi^2 = 36.732 \ p < 0.001 \ \alpha = 0.05$, Effect size = 0.34) The majority of females (62%) has less than 10 years of experience; however, males are nearly evenly divided between those who have greater and those who have less than 10 years experience (53% and 57%
respectively). A measure of central tendency (Mann-Whitney U test) confirms that the predominant level of experience among females is lower than males (MWU z statistic = -4.153 p < 0.001 $\alpha = 0.05$). For the racial/ethnic groups, a greater proportion of the minorities (51.8% and 58.2% for “whites” and “minorities” respectively) has less than 10 years experience, which differs qualitatively from the ACS data described above.

Table 11. Teaching Experience (Years)

<table>
<thead>
<tr>
<th></th>
<th>&lt;1</th>
<th>1-5</th>
<th>6-10</th>
<th>&gt;10</th>
</tr>
</thead>
<tbody>
<tr>
<td>MID (N = 729)</td>
<td>8.5</td>
<td>25.2</td>
<td>19.8</td>
<td>46.5</td>
</tr>
<tr>
<td>Females</td>
<td>11.7</td>
<td>28.3</td>
<td>21.9</td>
<td>38.1</td>
</tr>
<tr>
<td>Males</td>
<td>6.0</td>
<td>22.8</td>
<td>18.3</td>
<td>52.9</td>
</tr>
<tr>
<td>White</td>
<td>8.1</td>
<td>26.0</td>
<td>17.7</td>
<td>48.2</td>
</tr>
<tr>
<td>Minorities</td>
<td>9.9</td>
<td>23.6</td>
<td>24.7</td>
<td>41.8</td>
</tr>
</tbody>
</table>

Table 12. Class Size (Number of Students)

<table>
<thead>
<tr>
<th></th>
<th>1-25</th>
<th>26-50</th>
<th>51-75</th>
<th>76-100</th>
<th>101-200</th>
<th>&gt;200</th>
</tr>
</thead>
<tbody>
<tr>
<td>MID (N=729)</td>
<td>27.4</td>
<td>28.8</td>
<td>12.5</td>
<td>8.4</td>
<td>11.5</td>
<td>11.4</td>
</tr>
<tr>
<td>Females</td>
<td>26.3</td>
<td>27.0</td>
<td>12.4</td>
<td>8.6</td>
<td>12.7</td>
<td>13.0</td>
</tr>
<tr>
<td>Males</td>
<td>28.3</td>
<td>30.2</td>
<td>12.6</td>
<td>8.2</td>
<td>10.6</td>
<td>10.1</td>
</tr>
<tr>
<td>White</td>
<td>29.1</td>
<td>26.6</td>
<td>11.7</td>
<td>9.8</td>
<td>10.2</td>
<td>12.6</td>
</tr>
<tr>
<td>Minorities</td>
<td>22.8</td>
<td>35.9</td>
<td>14.1</td>
<td>4.3</td>
<td>15.2</td>
<td>7.6</td>
</tr>
</tbody>
</table>

The number of students enrolled in the classes that MIDP participants teach is most often less than 50, as observed in Table 12. This observation is in concert with the predominance of faculty from undergraduate institutions: community and liberal arts colleges have a tendency to have smaller classes relative to institutions with graduate
schools. (3) There are no significant differences in the distributions of the class sizes women and men teach ($\chi^2 = 5.528, p = 0.355, \alpha = 0.05$); however, there are significant differences in the distribution of class size between racial/ethnic groups ($\chi^2 = 23.1226, p < 0.001, \alpha = 0.05$). Non-white minority groups teach fewer smaller classes (1-25 students) and more classes in the small to medium range (26-50 students) than the white majority.
## Table 13. Demographic profile summary-predominant characteristics

<table>
<thead>
<tr>
<th>Observed differences between MIDP and ACS census</th>
<th>Chi Square &amp; Significance</th>
<th>Effect Size: Med-large</th>
</tr>
</thead>
<tbody>
<tr>
<td>More undergraduate faculty in MIDP</td>
<td>$\chi^2 = 189.543$</td>
<td>0.50</td>
</tr>
<tr>
<td>More female participants in MIDP</td>
<td>$\chi^2 = 118.280$</td>
<td>0.40</td>
</tr>
<tr>
<td>More ethnic minority participants in MIDP</td>
<td>$\chi^2 = 89.813$</td>
<td>0.35</td>
</tr>
<tr>
<td>More faculty in MIDP with &lt; 10 years of experience</td>
<td>MIDP 56% &lt; 10yrs</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>ACS 63.5% &gt;20 yrs since B.S. degree</td>
<td></td>
</tr>
<tr>
<td>More untenured faculty in MIDP</td>
<td>$\chi^2 = 100.654$</td>
<td>0.37</td>
</tr>
</tbody>
</table>

### Data Summary and Implications

Survey data from 745 participants in 23 workshops form the basis of this analysis.

The direction taken in this analysis was guided by the research question described earlier,
with the first question targeting a major objective for a national dissemination effort: does the demography of the faculty attending these workshops indicate systemic involvement in the reform effort?

Based on a chi square comparison of the MIDP and ACS survey data, MIDP is reaching a diverse faculty. The population of faculty attending MIDP workshops has proportionately more women and minorities than the general academic population of chemists, represented by the ACS census. This finding holds across all institution levels. However the MIDP workshops attracted 1) proportionately fewer graduate faculty than exist in the general academic population and 2) relatively small numbers of faculty from the actual graduate host institutions. The presence of both trends suggests that this attendance pattern may be related to the geographic dispersion of graduate institutions and the relative importance of research vs. teaching at those institutions than due to recruitment practices. However, the under-representation of senior, research-institution-based tenured male Anglo faculty also suggests a social/political gulf between the powerful and reform dissemination. The portrait of those involved in reform as indicated by the demography of those participating in these workshops appear to be the relatively powerless and those who appear to be missing in this portrait appear to be the powerful within the hierarchy of academic institutions. Therefore these findings indicate the importance of making demographic comparisons: (1) to identify the social contexts of the people who are participating and (2) to ensure that the social contexts of these participants are recognized because the documents and movement for reform have previously identified these groups specifically as having been traditionally excluded from
science and (3) to recognize that such social and political separations continue well after
the institutionalization of correctives to change them.

In summary, the data indicate that the population attending the MIDP workshop
represents a population that is demographically different from the membership profile
published in the ACS census as observed in the summary Table 13. This means that
findings relating to this group may not generalize to the whole academic chemist
population. However because one of the objectives of reform is to foster a more diverse
population in the chemical field, the involvement of diverse faculty in these workshops
may indicate a positive trend so long as these groups are empowered by their
participation. Since the MIDP recruitment model worked very well for reaching women,
minorities, and undergraduate faculty, it is recommended for future projects desiring the
participation of diverse faculty.

A COUNTER PERSPECTIVE: WAS MIDP NOT EFFECTIVE IN REACHING THEIR
AUDIENCE?

The implications summarized above suggest that while the workshops were
constructed to reach the general academic chemists’ community, those who show an
interest in the workshops and/or reform (as indicated by their attendance) are a special
interest group who do not resemble the general population of academic chemists.
Because the success of an entire dissemination program cannot be gauged without
assurance that it has accessed its intended audience, the results of this study including all
the research questions cannot be fully accepted if there are indications that this
requirement has not been met. However, a counter perspective on the data described above might be that the MIDP simply was not effective in reaching the intended target audience. Therefore it is appropriate to consider as a separate issue whether there are indications that MIDP made sufficient effort to access the intended audience (i.e. ‘all’ or a general audience of academic chemists rather than a select group). The following description of the actions that the MIDP facilitators took to propagate the reform materials/philosophy to a general audience in the academic chemists’ community, are used to investigate this question.
### Table 14. Host Educational Institution and Carnegie Designation

<table>
<thead>
<tr>
<th>Department/Institution Level</th>
<th>Host Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2001 Workshops</td>
<td></td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Florida Atlanta University, Boca Raton, FL</td>
</tr>
<tr>
<td>MS/MA</td>
<td>University of Massachusetts, Dartmouth</td>
</tr>
<tr>
<td>MS/MA</td>
<td>University of Southern Colorado</td>
</tr>
<tr>
<td></td>
<td>Project Kaleidoscope Summer Institute, Snowbird</td>
</tr>
<tr>
<td>2001-2002 Workshops</td>
<td></td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Ohio State University, Columbus</td>
</tr>
<tr>
<td>2-year Undergraduate</td>
<td>Raritan Valley Community College, Somerville, NJ</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Texas A&amp;M University, College Station</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Arizona, Tucson</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of South Florida, Tampa</td>
</tr>
<tr>
<td></td>
<td>Project Kaleidoscope Summer Institute, Williamsburg, VA</td>
</tr>
<tr>
<td>2002-2003 Workshops</td>
<td></td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Central Michigan University, Mount Pleasant, MI</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>Emory University, Atlanta, GA</td>
</tr>
<tr>
<td>MS/MA</td>
<td>Northeastern Illinois University, Chicago</td>
</tr>
<tr>
<td>MS/MA</td>
<td>Tarleton State University, Stephenville, TX</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Alabama, Birmingham</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of New Hampshire</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Missouri, Columbia</td>
</tr>
<tr>
<td>MS/MA</td>
<td>University of Richmond, Richmond, VA</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Nebraska, Lincoln, NE</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Denver, Denver, CO</td>
</tr>
<tr>
<td>2004 Workshops</td>
<td></td>
</tr>
<tr>
<td>Ph.D.</td>
<td>LSU Baton Rouge, Baton Rouge LA</td>
</tr>
<tr>
<td>Ph.D.</td>
<td>University of Arkansas, Little Rock, AR</td>
</tr>
<tr>
<td>2-year Undergraduate</td>
<td>Housatonic Community College, Bridgeport, CT</td>
</tr>
<tr>
<td>4-Year Undergraduate</td>
<td>Macalester College, St. Paul, MN</td>
</tr>
<tr>
<td>2-year Undergraduate</td>
<td>Portland Community College, Portland, Oregon</td>
</tr>
<tr>
<td>4 year Ph.D.</td>
<td>North Carolina State University, Raleigh, NC</td>
</tr>
<tr>
<td>4 year Ph.D.</td>
<td>University of Tennessee, Knoxville</td>
</tr>
<tr>
<td>4 year Ph.D.</td>
<td>University of Indianapolis, IN</td>
</tr>
</tbody>
</table>
Table 15. Workshops held at National Meetings and Intensive Workshops

<table>
<thead>
<tr>
<th>Meeting and Intensive Workshops</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2000-2001</strong></td>
</tr>
<tr>
<td>University of Wisconsin, Madison: ChemConnections Intensive</td>
</tr>
<tr>
<td>California State University, Fullerton: Molecular Science Intensive</td>
</tr>
<tr>
<td>ACS National Meeting, Chicago</td>
</tr>
<tr>
<td><strong>2001-2002</strong></td>
</tr>
<tr>
<td>Western Regional ACS Meeting</td>
</tr>
<tr>
<td>2YC3 Meeting, Las Vegas</td>
</tr>
<tr>
<td>California State University, Fullerton: PLTL Intensive</td>
</tr>
<tr>
<td>Temple University, Philadelphia, PA: PLTL Intensive</td>
</tr>
<tr>
<td>Rensselaer Polytechnic Institute: ChemConnections Intensive</td>
</tr>
<tr>
<td>University of California, LA: Molecular Science/CPR</td>
</tr>
<tr>
<td>Biennial Conference on Chemical Education, Bellingham, WA</td>
</tr>
<tr>
<td>ACS National Meeting, Boston</td>
</tr>
<tr>
<td><strong>2002-2003</strong></td>
</tr>
<tr>
<td>ACS National Meeting, New Orleans</td>
</tr>
<tr>
<td>Jet Propulsion Lab, Pasadena, CA: PLTL Intensive</td>
</tr>
<tr>
<td>University of California, LA: Molecular Science/CPR Intensive</td>
</tr>
<tr>
<td>University of California, Berkeley: ChemConnections Intensive</td>
</tr>
</tbody>
</table>

Beyond the 1.5 day workshops taking place in the academic years, in total, 39 workshops (both the 1.5 day and intensive workshops) were held within all levels of post-secondary institutions and in regional and national ACS meetings as can be seen in Tables 14 and 15. For each of the 1.5-day workshops that were held in educational settings, approximately 400-500 faculty were contacted by email and sent a description of the workshop goals. Consequently, a total of approximately 15,000 faculty were directly
contacted. Each year, workshop locations were selected based upon areas that had not been served. Therefore host-institutions are widespread and all of the major geographical regions were served as shown in Figure 5. In addition, several articles describing MIDP initiatives have been published in peer-reviewed journals such as Chemical and Engineering News, and the Journal of Chemical Education. Last, many symposia on MIDP workshops or on the implementation of the four initiatives through MIDP, have been presented by MIDP facilitators, PI’s and faculty participants at national and regional ACS meetings and at the Biennial Conferences of Chemical Education.

Figure 5. Map of MIDP Workshop Locations
(Figure provided by Eileen Lewis)

- **Workshop location**

As observed in Table 16 and Figure 6, the majority of the MIDP participants prior to their workshop participation were not familiar with MIDP or the four initiatives.
associated with MIDP. This data suggests that the workshop solicitations have successfully culled interested faculty who have not had prior exposure to the MIDP program. Figure 2 demonstrates that over the course of the four years from the year 2000, that the workshops have attracted more people per workshop period who have not had previous exposure to the program materials.

Table 16. Participants Familiar with MID Pedagogy Prior to Workshop (%)

<table>
<thead>
<tr>
<th></th>
<th>Chem Connections</th>
<th>Molecular Science</th>
<th>New Traditions</th>
<th>Peer-Led Team Learning</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>not familiar</td>
<td>60.9</td>
<td>77.9</td>
<td>75.9</td>
<td>75.6</td>
<td>72.6</td>
</tr>
<tr>
<td>little familiar</td>
<td>23.6</td>
<td>13.8</td>
<td>13.7</td>
<td>9.9</td>
<td>15.3</td>
</tr>
<tr>
<td>somewhat familiar</td>
<td>11.0</td>
<td>6.0</td>
<td>7.9</td>
<td>8.6</td>
<td>8.4</td>
</tr>
<tr>
<td>very familiar</td>
<td>3.3</td>
<td>1.9</td>
<td>2</td>
<td>3.7</td>
<td>2.7</td>
</tr>
<tr>
<td>currently using</td>
<td>1.2</td>
<td>0.5</td>
<td>0.5</td>
<td>2.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>
To propagate reform, dissemination must grow beyond the workshop participant population. Hence, evidence that MIDP participant faculty are involved in such activity indicates that MIDP has achieved another of its dissemination goals. There are indications in the responses to the post-workshop surveys that MIDP workshop participants are involved in disseminating MIDP philosophy and innovations. As can be seen in Table 17, 72% of the responding MIDP workshop participants (N=89) reported in a post-workshop survey that they discussed their curricular innovations with colleagues after the workshop, while only 9% were not involved in this type of informal dissemination. The majority (47%) of this informal dissemination (discussion with colleagues) was located in community colleges. Sixteen percent of the respondents,
evenly distributed across all institutional levels, also reported that they presented their innovations to their departments. Graduate and four-year undergraduate faculty, on the other hand, appear to be more involved in a formal dissemination approach. Twenty-one percent report they present their innovations at regional or national meetings (although summing the two categories in Table 17 would yield 28%; this larger figure includes “double-counting” of responders who presented at both kinds of meetings). The majority (18%) of these presenters are employed in graduate institutions, suggesting that this group is critical for dissemination in forums that cross institutional boundaries. Ten percent of the respondents also reported that they had written a research paper and/or published a description of their innovations. This form of dissemination was reported equally by graduate and undergraduate faculty, but not by community college faculty who apparently are more involved in an informal approach as mentioned above. Because of the wide distribution of these publications and their potential for a long “half-life” of influence, it is difficult to estimate the scope of this form of dissemination. However, since this post-workshop sample appears representative of the entire MIDP population, we may anticipate that approximately 100 of such publications may be produced in the next 2-3 years.
Table 17. Post Survey (N= 89): Participant Dissemination of Innovations

<table>
<thead>
<tr>
<th>How have you communicated the success you have experienced with your innovations?</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have not told others of innovations I have tried in the past two years</td>
<td>9</td>
</tr>
<tr>
<td>I have discussed my innovations informally with a colleague</td>
<td>72</td>
</tr>
<tr>
<td>I have presented my innovations in a seminar to the dept.</td>
<td>16</td>
</tr>
<tr>
<td>I have presented my innovations at a regional professional meeting</td>
<td>11</td>
</tr>
<tr>
<td>I have presented my innovations at a state or national professional meeting</td>
<td>17</td>
</tr>
<tr>
<td>I have written a paper for publication describing my innovations</td>
<td>6</td>
</tr>
<tr>
<td>I have conducted a research experiment investigating the effects of my innovations</td>
<td>14</td>
</tr>
<tr>
<td>I have written a research paper based upon my investigation of the effects of my innovations</td>
<td>4</td>
</tr>
<tr>
<td>I have implemented innovations but have not publicized what I have done</td>
<td>19</td>
</tr>
</tbody>
</table>

**SUMMARY AND IMPLICATIONS ABOUT MIDP REACHING ITS TARGET AUDIENCE**

Through direct email contact, workshop facilitation, journal articles, symposia at national and regional meetings, and propagation through participant dissemination practices, MIDP has maintained an extensive national profile. The data analyzed in this report were collected from faculty participating in twenty-three 1.5 day workshops, and a total of twenty-eight of these workshops were conducted in a four year period (2000-2004) with an impressive geographic range. Approximately 400-500 faculty were invited to attend any given workshop, so fourteen thousand faculty have been contacted for these MIDP workshops alone. Additional workshops bring the total of directly-contacted faculty to over fifteen thousand. The majority of the faculty attending the workshops has had little or no familiarity with the MIDP materials and initiatives and thus represents
interested faculty who have had no previous involvement in the project. Data from the
first cohort suggests that, following the workshop, participants engage in voluntary
dissemination (i.e. for which they are not paid), which is an integral component of the
dissemination process for a successful project. These reported dissemination activities
are both informal, such as discussion with colleagues (community colleges) and formal,
such as presentations at meetings (graduate institutions) and publications. Therefore the
effort that MIDP facilitators and subsequently their participants put into publicizing their
innovations supports the claim that the workshops were sufficiently advertised and
accessed the intended audience. Consequently, the outcome of the demographic
constitution of the MIDP population, which reveals that it does not represent the general
academic community, likely characterizes the behavior of a group of faculty who are
taking an initiative to explore reform within the greater academic population. This means
that the null hypothesis, that the MIDP faculty resembles the greater academic chemists’
community as represented by ACS membership, is not supported in these findings.
Furthermore, it also suggests that this investigation which proposes to describe reform
interested faculty via the MID Project participants’ data as a case study, appears
acceptable.
RESEARCH QUESTION 2

What are the ‘espoused’ and ‘in-use’ teaching conceptions (e.g. beliefs and intentions) that academic chemists attending the MIDP workshop have about reform approaches?

According to prior research discussed earlier in this dissertation, survey responses generally reveal respondents’ ‘espoused’ conceptions about teaching and learning. However, there are occasions reported in the literature showing that surveys are too limiting because the intended or implicit meanings of responses are not always clear. (100, 102) The respondent’s understanding may not correspond to the interpretations of the researcher, and mutual meanings within the framework of surveys cannot be negotiated between researcher and participant because of their separation in time and place. Therefore, to probe both espoused and in-use conceptions requires multiple methods to explore this research question. Using both quantitative and qualitative sources of data can serve to either corroborate or illustrate the findings from either sources. Also, the combined data describe more fully, and with greater depth, the teaching conceptions both “used” and “espoused” that faculty have about reform innovations. The findings on the ‘pre’ and ‘post’-workshop surveys probing their espoused conceptions about the MIDP workshop intervention and their teaching practices before and after the workshops is discussed along with the case study data constituting both espoused and in-use conceptions of 10 faculty participants in Florida.

Faculty espoused conceptions as portrayed in the pre-workshop survey data (N=745) are shown in Table 18, reveal the “before workshop conceptualizations” that faculty have of their teaching practices. Faculty were asked to rank the three techniques they
thought were most effective. Of the teaching techniques used in “lecture section,” faculty report students doing problem-solving (41.3%), instructor lecturing (39.7%) and students doing collaborative learning (28.9%) as the three most effective techniques they use. This result provides an exemplar of the difficulties interpreting survey responses. Before the workshop intervention, problem solving appears to be the preferred method of teaching in lecture and in assessments. While this teaching practice can be used in active learning pedagogy, in this context, the appearance of the use of lecture as a close second suggests that the use of problem solving may be more traditional. It might mean that students are solving problems individually, perhaps as a homework assignment or the instructor may be presenting examples of solving problems as a component of their lecture. Another evaluation of this data was made to determine how many among those who use and rank lecturing as one of the three most effective techniques also indicated that they use problem solving and collaborative learning. After selecting only those who use and rank lecturing as one of three effective techniques (N= 296), 76% report using problem solving and 25% report using collaborative learning. These results suggest that the meaning of problem solving and collaborative learning intended by the respondents may not match well with the meanings intended by reformers. The meaning is even more uncertain when 23% of those who report using lecture as one of three most effective techniques also claim that collaborative learning is one of three most effective techniques. According to the concepts of learning encouraged in reform, these conceptions are considered antithetical and therefore their meanings are very likely not the same as those intended by the reformers. Therefore, acquiring an understanding that
might better reflect participants’ intentions and ideas might be served by acquiring
additional illustrations of this phenomena in the qualitative case study.

The participants in the case study are a subunit of the greater population of
workshop participants, consequently, their responses about teaching practices that they
considered effective in their pre-workshop surveys are very similar to the greater
participant population, as observed in Table 19.

Table 18. Pre-survey results about techniques used in “Lecture Section” (N=745)

<table>
<thead>
<tr>
<th>Teaching Technique “lecture section”</th>
<th>% Use and Rank as Most Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students doing in-class problem-solving</td>
<td>41.3</td>
</tr>
<tr>
<td>Instructor lecturing</td>
<td>39.7</td>
</tr>
<tr>
<td>Students doing collaborative learning</td>
<td>28.9</td>
</tr>
<tr>
<td>Instructor using conceptual questions</td>
<td>23.9</td>
</tr>
<tr>
<td>Students participating in discussion</td>
<td>22.7</td>
</tr>
<tr>
<td>Students doing an experiment/demo</td>
<td>14.5</td>
</tr>
<tr>
<td>Instructor doing an experiment/demo</td>
<td>12.9</td>
</tr>
<tr>
<td>Students working on worksheets/</td>
<td>12.3</td>
</tr>
<tr>
<td>Students following guided inquiry</td>
<td>9.5</td>
</tr>
<tr>
<td>Instructor using computer animations</td>
<td>6.2</td>
</tr>
<tr>
<td>Students working at the board or overhead</td>
<td>5.9</td>
</tr>
<tr>
<td>Students doing writing</td>
<td>5.2</td>
</tr>
</tbody>
</table>

Beyond displaying differences in pedagogical language usage, it is revealing to
observe how espoused theories revealed in surveys can be self-conflicting without faculty
awareness of these conflicts. And on the other hand it is illuminating to explore how
faculty resolve conflicting theories in use within their practice. Similar to the greater
participant population (N=745), the case study faculty provided responses on the pre-
workshop survey that would be considered self-conflicting, according to reformers’
views. But these seeming self-conflicting responses among the case study faculty survey
data are not trivial because they are consistent with the rest of the participant population observed in the survey data, evidence of a wide spread phenomena. For example as shown in Table 19, Howard, Evan and Russ rank lecturing as one of the three most effective techniques they use in their lecture class and all three rank “collaborative learning” (Howard, Evan) and/or “guided inquiry” (Russ) as one of the three most effective techniques. If these responses regarding implementation of reform approaches are taken to mean as the reformers intend, then we might assume that these faculty are already engaged in reform practices before participating in the workshop. As described above, lecturing and collaborative learning (or guided inquiry) have antithetical meanings in the reform literature presented in this dissertation. Therefore because of these potential

Table 19. Case study faculty’s pre-workshop survey “lecture” section techniques responses (Kim, Cindy & Vern gave no rankings)

<table>
<thead>
<tr>
<th>Case study faculty reporting this preference</th>
<th>Technique reported as one of three most effective they used in their lecture class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evan, Howard, Russ</td>
<td>a. Instructor lecturing</td>
</tr>
<tr>
<td>0</td>
<td>b. Students doing writing</td>
</tr>
<tr>
<td>Evan, Greg, Howard</td>
<td>c. Students doing collaborative learning</td>
</tr>
<tr>
<td>Greg, Howard, Laura, Rita</td>
<td>d. Instructor using conceptual questions</td>
</tr>
<tr>
<td>0</td>
<td>e. Instructor using computer animations</td>
</tr>
<tr>
<td>Laura</td>
<td>f. Instructor doing an experiment/demo</td>
</tr>
<tr>
<td>0</td>
<td>g. Students doing an experiment/demo</td>
</tr>
<tr>
<td>Greg, Russ</td>
<td>h. Students following guided inquiry</td>
</tr>
<tr>
<td>0</td>
<td>i. Students working on worksheets/</td>
</tr>
<tr>
<td>Evan, Laura, Marcus, Russ</td>
<td>j. Students doing in-class problem-solving</td>
</tr>
<tr>
<td>Rita</td>
<td>k. Students participating in discussion</td>
</tr>
<tr>
<td>0</td>
<td>l. Students working at the board or overhead</td>
</tr>
</tbody>
</table>
discrepancies in the intended meanings in the survey responses, it might be fruitful to explore further. The observational data might reveal information that might provide an explanation. For example, faculty might be using reform approaches hybridized with traditional practices, which might indicate that they are in an intermediate stage and progressing toward reform. If such hybridizations are observed in the case study data then we may consider the possibility that faculty do mean what they say in their responses, but don’t yet grasp entirely reform meanings. If however their practice is not some hybridized form we might explore whether they abandoned unworkable practices or alternatively, have completely different understandings of the pedagogical terms themselves.

To explore these possibilities, it is informative to present detail of what was observed in the faculty teaching approaches that can be described as non-traditional, while not definitively reform oriented, as described in reform literature. This detail can also help to explain how faculty might understand and report in their surveys that their practices contain both reform and traditional components. Table 20 below, shows an overview of the observations taken of the case study practices in first year chemistry courses. Only in one class for non-chemistry majors (Greg’s class) is group learning observed as a replacement for lecture and in one general chemistry class (Marcus’s class) collaborative learning is interspersed in regular intervals with lecture. The remaining faculty use a traditional lecture format as a regular or consistent practice.

As indicated previously in Table 19, faculty reports in the surveys do not match well with these observations. Because it is possible that faculty may have adopted reform
strategies before the workshop and then stopped or alternatively they might have entertained different meanings to the questions asked in the pre-workshop data, it is prudent to carefully consider the meanings that these faculty intend together with what is taking place in their classrooms. If faculty do understand meanings that are different from what reformers intended, then reformers need to consider two implications. One, that there may be a general lack of consensus for the use of pedagogical terminology that best describes the observed practices. And second, interpretations made on the basis of survey responses alone may not be sufficient to describe the intended meanings faculty might have in these circumstances.

Table 20: Observed Practices in the Case Study

<table>
<thead>
<tr>
<th>Practice Categorization [and practitioners]</th>
<th>Observations-Synopses</th>
</tr>
</thead>
</table>
| **Lecture**= 7                            | 1. Teacher stands in front of the class, writing on the board or writing on an overhead or pointing to PowerPoint projected slides  
   [Kim (General Chemistry Course), Cindy, Howard, Evan, Russ]  
   2. Talk is often oral repetition of written words or vocalizations of equations with occasional elaboration or an oral description of a diagram drawn or depicted model of molecular phenomena  
   3. Subject content is either problem solving or a description of a chemical model  
   4. Occasional anecdotes may be described or ‘real world’ examples used from the text |
| **Lecture Intervals**=6                    | Same as lecture above but in approximately 15 minute intervals interspersed with 1-2 minutes wait-time for students to spontaneously/voluntarily interact to obtain a solution to a problem presented by the instructor. |
Practice categorizations are coded and ascribed numerical values of a Likert Scale from 1= Collaborative learning to 7= Lectures. Seven values were chosen because statistical research indicates that seven categorizations have greater propensity for reproducibility.[98]

<table>
<thead>
<tr>
<th>Practice Categorization [and practitioners]</th>
<th>Observations-Synopses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture-Interactive=5</strong> [Rita (General Chemistry), Laura (chemistry preparatory)]</td>
<td>A lecture with frequent (every 5-7 minutes) short answer questions directed to specific students or to have students “fill in the blank” orally in a narrative about a chemistry concept. Or as the teacher solves a problem, she may stop to ask students help her complete the particular component of the solution.</td>
</tr>
<tr>
<td><strong>Lecture Intervals-collaborative learning=4</strong> [Marcus (General Chemistry), Kim (non-majors)]</td>
<td>A shorter 10 minute interval lecture component interspersed with group interactions of approximately 5-7 minutes. Students are directed to work together to solve problems that may or may not have been solved previously by the instructor and to write their answers on the board.</td>
</tr>
<tr>
<td><strong>Collaborative learning groups=1</strong> [Greg (non-majors course)]</td>
<td>Students continuously work in groups that have been previously defined. They have defined roles and are involved in problem solving requiring exploration of their own concepts, creating their own definitions or criteria for categorizations, creating their own models of chemical phenomena, and their own rubric for problem solutions.</td>
</tr>
</tbody>
</table>

In-class observations revealed that there are examples of practice that the faculty used that casually might be considered problem solving practices yet would not fit easily with reform literature conceptualizations of problem solving. For example, as shown in Table 21, many of the case study faculty were observed using questioning during the lecture period that might be described as doing problem solving work because students answer such questions after doing calculations. As discussed in the introduction, when using Bloom’s taxonomy of cognition/learning skills to categorize the observed pedagogy, the questions that the faculty typically asked did not involve the students in connecting concepts together to synthesize a conceptual framework for solutions. Rather,
the tasks predominately entailed application of procedures demonstrated in the lecture and/or the text. This type of problem solving is described as algorithmic. Students apply a rule rather than generating the rule for solving the questions asked. Also, sometimes students in the general chemistry (chemistry majors) classes were encouraged and given time to converse with their neighbor to obtain solutions to questions posed. These occasions do involve interactions between students that in casual speech would be called collaborations, but these interactions did not entail the process of learning (i.e. entailing the use of the learning cycle) meant in reform literature as described in the introduction of this dissertation.

Table 21 Questioning Practices

<table>
<thead>
<tr>
<th>Case Study Participant</th>
<th>Practice Classification: Kind of practice &amp; relative amount of time using traditional lecture-- based on observations 1-7 Low to High</th>
<th>Questioning Practice: Observed kinds of questions asked: Higher Order-Conceptual or Lower Order-Algorithmic (See Appendix E for descriptions of types of questions)</th>
<th>Approximate percentage of time students involved in answering questions (minutes Q &amp; Answer ÷ minutes of the class period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4yr Grad Greg Kim Howard Cindy</td>
<td>1 collaborative groups 6 lecture 7 lecture 6 lecture</td>
<td>High/Conceptual (80%) (non-majors) Low/Algorithmic General Chemistry Low/Algorithmic General Chemistry Low/Algorithmic General Chemistry</td>
<td>90% 8 % 5 % 8 %</td>
</tr>
</tbody>
</table>

Refer to table 20 to obtain a reference for the meanings of the Likert scale 1-7 designations.
In contrast to casual understandings, the meaning of process learning (or guided inquiry) or collaborative learning as described in reform literature, involves interactions between students in which they “brain storm” together to find solutions to problems that may not have a single solution. They may devise their own rubric or algorithm to solve a problem as required and the in-class activity brings students through a process described as a learning cycle or through conceptual change. These kinds of activities were observed consistently in Greg’s, and Kim’s class for non-majors but were infrequently observed in general chemistry classes with the exception of Marcus’ class. Typical
general chemistry classes involved posing a few algorithmic questions per class session, for example Evan and Howard used between 1-2 algorithmic questions, and Russ posed 2-3 algorithmic questions. And while students conversed with each other when questions were posed to the class, these interactions were not structured in ways that would conform to the reform meaning of collaborative learning or guided inquiry as intended in the survey questions.

As indicated in Table 21 both Rita and Laura used an exceptionally high number of oral assessment questions during class which made their classes highly interactive between students and instructor despite the traditional lecture format. This practice is evidence of a creative departure from the strictly traditional lecture pedagogy while maintaining the general structure of the lecture format. Rita and Laura also reported using guided inquiry activities approximately five occasions each semester in their general chemistry course. While these activities were not directly observed by the researcher, they presented materials and described their learning goals which corresponded to reform approaches and concepts. Based on their practices in the observational data, their reform perspective that they expressed in their pre-workshop survey data did not appear to be translated consistently into their practice. Importantly, when they were asked about their practice, both faculty reported that consistently implementing reform activities is impractical in their general chemistry courses. They specifically named several constraints, administrative and student expectations, and the scope of course content required. (These issues will be explored further in the next sections.) Therefore, their practice appears to be less reform based than what their pre-
workshop survey data might indicate, when interpreted alone. Their inquiry activities can be described appropriately as reform based practices, but their infrequent use suggests that there are persistent influences on their practice toward the traditional lecture format.

Vern’s practice represents an interesting departure from the other faculty and may represent a negative instance in the general trend in which reform-oriented conceptions are espoused but not necessarily in use. Vern’s espoused teaching conceptions in the pre-workshop data were oriented toward traditional, teacher-focused pedagogy. However, when his instruction practices were observed, he allowed students time to work on solving problems together in class. His students spontaneously shared their notes or solution procedures with each other after Vern posed a question to the class. While he did not explicitly invite students to work together, he did not inhibit their spontaneous acts to solve the question together by shortening the wait time after posing the question. This might have been construed as indication that the workshop might have influenced his practice toward reform. Interestingly, when he was asked if this questioning approach was a regular feature in his class format, he said that it wasn’t, but that the subject content covered in the day’s lecture either allowed or did not allow time for student applications of material during class. Therefore, Vern’s actual teaching approach (“in-use” teaching conception), as observed in his classes, can appear to be more reform oriented than his espoused teaching conceptions, whether on the pre-workshop data or in his interviews. But, while Vern was capable of scheduling class time around the development of student understanding of chemical concepts, he didn’t seem to plan process learning (at least according to his espoused conceptions of this class format). Rather, he appeared to
passively allow students to initiate group learning by themselves, when there was
sufficient time to allow these spontaneous student interactions.

There were other forms of questioning practices that were observed and that can
be categorized with reform orientations. For example Evan daily used ~5 minute quizzes
in his general chemistry classes that usually involved two algorithmic questions that can
be answered quickly in the given time frame. The daily use of quizzes is also featured in
reform approaches as they are intended to engage students in the class material and help
them “keep up” with the course pace. Greg, Marcus, Rita, Laura, Cindy, and Kim also
used in-class oral questioning to assess students understanding of concepts as shown in
Table 21 entitled, ‘Questioning Practices’. While these questions tended to be
algorithmic (exceptions are Greg and Marcus) all of these instructors used student
responses to determine the number of students who understood an idea or problem
solution procedure before moving on to the next topic. (See Appendix E for a full
description of types of questions) This practice is also featured in reform pedagogy.

In conclusion, some of the case study faculty were observed to have “in-use”
conceptions about reform activities that differed substantially from reform definitions as
intended in the survey questions, while others in the case study had pedagogical
conceptions that resembled reform meanings but chose not to fully implement them.
Research indicates that uptake of reform takes time for development but it is unclear how
much time or how much intervention is required to support and observe the kinds of
reform practices intended in reform literature. (14) The case study data collection took
place approximately 3-5 years after the faculty attended the MIDP workshops. Based
upon the interviews and in-class observations one important trend was observed: all of
the case study faculty indicated either that reform pedagogy was not considered either
appropriate or practical as a lecture replacement in their general chemistry courses for
majors. This finding holds across all institutional levels and class sizes and will be
discussed more fully in the following analysis.

Given these perspectives, it might be fruitful to consider whether it is best to
change faculty so that their ideas conform to the pedagogy or would it be better to modify
the pedagogy so that it is responsive to faculty interest and needs and possibilities.
According to the research on reform pedagogy described in the introduction, reform
pedagogy is sufficiently fluid that it can be adopted in different environments and levels
without compromising the kernel function: bringing students through the learning cycle
during class time in such a way to enable them to explore ideas and generate concepts
together. Greg, Kim, and Marcus provided the means and time in their classes in various
ways specific to their classes to make reform practices happen and they implemented
these practices in a wide variety of classes and class sizes. But all of the faculty appear to
have a consensus viewpoint regarding a regular or daily class practice of reform in the
general chemistry class. This is precisely where reform has been sought and where, in
the case study, it appeared not to be happening (with the important exception of Marcus).
As will be described in more detail in the next section, all case study faculty reported that
there is a problem with implementing the reform pedagogy in the general chemistry class.
And this conception is corroborated behaviorally in their practice. They supply their own
and different perceptions about what they think this problem is. These perceptions which
will be described in more detail in the next section, are very relevant. However one aspect of their understanding about what reform is (eg what inquiry is) which might be a part of the problem of why implementing reform appears prohibitive, is that there is no consensus of what it is—its meaning. This is a problem that can be interpreted to lie with the reform dissemination program itself, which is manifesting itself in the various understandings that faculty have. Thus, these findings reveal that so long as casual or substantially different meanings pertaining to reform expressions such as “guided inquiry” or “process learning” or “collaborative learning” persist, implementation of reform practices as envisioned in the reform literature will likely be difficult to achieve. Nevertheless, the case study observations also revealed that while traditional practices still dominate the general chemistry classrooms, there are indications that instructors are moving away from the traditional approach. Several faculty, Greg, Marcus, Rita, Laura and Kim espouse perspectives that are unequivocally reform oriented. However, all of the faculty who espouse reform conceptions reveal in-use conceptions in their practice suggesting a more complex process of reform uptake than described in literature as “movement along a continuum” from teacher oriented to student oriented. Therefore it is pertinent to explore what teaching conceptions might influence their practice.

**Research Question 3**

What teaching conceptions appear to have the greatest influence (impinge the most) on their observed practices?
Prior research into teaching practices have emphasized that how faculty learn (or what they report as how they learn) is different from how students learn based on Piaget’s developmental stage categorization of learning skills, constructivist learning theory, and cognitive science studies on model building and use.\textsuperscript{(41)} And, as mentioned earlier, prior research emphasized that students’ approach to learning conform to the assessment and teaching practices of their instructors. The cognitive skills required in learning general chemistry as envisioned by the transmission-oriented instructor in general chemistry involve primarily pattern recognition and problem solving rubric recall and application rather than analysis and synthesis. Thus, prior research indicated that faculty who use a teaching approach involving mainly recall, discourage the development and use of skills other than recall skills in their students.\textsuperscript{(138)} However, the importance of the relationship between faculty’s expectations of their students’ learning approach, the faculty’s preferred teaching approach and the \textit{faculty’s perceptions} about their own learning has not been emphasized in previous reports. Therefore it might be fruitful to explore these questions with the data from a survey that probed teaching and learning conceptions among the MID Project faculty.

The “Teaching Approaches Inventory” survey was conducted among a sample of 203 participants in the MID Project workshops, among 10 workshop facilitators familiar with reform pedagogy, among an additional 24 MID Project workshop participants both before and after their workshop, and among the 10 case study faculty. As mentioned in the methods section, this survey probed their espoused conceptions about their teaching strategies and intentions. The authors of the survey report that the survey probes four
dimensions of teaching conceptions: transmission-oriented strategies (1) and intentions (2), and conceptual-change strategies (3) and intentions (4). However, the observed dimensions obtained in this data were two: a conceptual change orientation (intentions and strategies together, labeled CCSF-conceptual change-student focused) and an information transmission orientation (intentions and strategies together, labeled ITTF-information transmission-teacher focused). These designations were based on prior research and the results of a Cronbach’s alpha statistical test used in this study.\(^{41}\) The Cronbach’s alpha \[\alpha = \frac{N \cdot r}{1 + (N-1) \cdot r}\] statistic indicates the extent to which items in a questionnaire are related to each other, providing an overall index of the repeatability or internal consistency of the scale as a whole. This statistic indicated that there is internal consistency among the Information transmission items (Cronbach’s \(\alpha = 0.68\); confidence interval 95%) and the Conceptual change items (\(\alpha = 0.71\)) but not among all the intentions pooled together (\(\alpha = 0.21\)) or the strategies pooled together (\(\alpha = 0.28\)). Assigning negative relationship between the Conceptual change and Information transmission intentions items, for example, did not produce a high enough consistency alpha. The Cronbach alphas of 0.68 and 0.71 are considered acceptable.\(^{149, 150}\) Therefore, the items on this questionnaire were treated as probes for two dimensions: (1) a transmission-teacher-focused orientation and (2) conceptual change-student-focused orientation.

Two samples (\(N=203\) the second cohort of participants from the years 2001-2003; and \(N=24\) (one workshop in the spring of 2004)) of MIDP workshop participants were compared statistically with the case study faculty and with the workshop facilitators. An analysis of variance (ANOVA) test was performed to test for differences between groups.
Second, a Bonferroni test was performed to control the overall error rate by setting the error rate for each test to the experiment-wise error rate divided by the total number of tests. Hence, the observed significance level for the overall test is adjusted for the fact that multiple comparisons are being made. And last, a post-hoc power analysis was performed to ensure that there were sufficient N sizes for each subgroup result that showed no significance for a statistical difference. The results of the ANOVA are shown in Table 22.

Table 22. Analysis of Variance test between case study faculty and other MIDP participants and facilitators

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITTF</td>
<td>Between Groups</td>
<td>369.962</td>
<td>3</td>
<td>123.321</td>
<td>5.251</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>5683.047</td>
<td>242</td>
<td>23.484</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6053.008</td>
<td>245</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCSF</td>
<td>Between Groups</td>
<td>377.320</td>
<td>3</td>
<td>125.773</td>
<td>4.067</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>7484.506</td>
<td>242</td>
<td>30.928</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7861.825</td>
<td>245</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The obtained significant F statistics of 5.251 and 4.067 for each scale suggest that there are significant differences between groups in both scales. The multiple comparisons Table 23 below indicate that the case study faculty scored significantly higher in the Transmission-teacher focused scale relative to the reformers’ (MIDP workshop facilitators are given this label here because of their role in reform dissemination). However the case study faculty were not significantly different from either the larger (N=203) or smaller samples (N = 24) of the MIDP workshop participants in this scale. Interestingly, the difference between the case study faculty and facilitators’
scores in the conceptual change scale was not significant, but the second cohort and spring 2004 workshop participants’ scores were significantly lower than the facilitators’ scores. Potentially, the lack of a statistical difference between the case study and the facilitators scores might be due to loss of statistical power because of the difference in the case study sample size relative to the larger cohort sample. However, a power analysis test indicated that the chance of finding a significant difference was 77%. Therefore while there is a 23% chance that a small effect might not be observable, it isn’t likely.

In sum, the data indicate that the larger gap between the teaching orientations in the facilitators’ scores had more to do with their lower transmission orientation scores rather than their higher conceptual change orientation scores relative to the respective case study faculty scores in this survey. These findings might also indicate that readiness to relinquish the transmission philosophy may be more instrumental to orient the faculty toward a student centered approach than espousal of reform conceptions. In addition, this analysis of the results of the Teaching Approaches Inventory corroborates both the pre-workshop survey analysis and case study faculty espoused perspectives expressed on their pre-workshop survey responses and in their practice described in the previous section (Research Question 2). The preference for lecture in the pre-workshop and post-workshop survey data and for ‘transmission’ of content to students in the case study data substantiates the prominence of the transmission-oriented strategies and intentions in this survey data.
### Table 23. Multiple Comparisons Table of differences between case study faculty and other MIDP participants and facilitators

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(I) QUALCASE</th>
<th>(J) QUALCASE</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second cohort N = 203</td>
<td>Second cohort</td>
<td>Case study</td>
<td>4.29</td>
<td>1.651</td>
<td>.059</td>
<td>-10</td>
</tr>
<tr>
<td>Facilitators</td>
<td>-4.35*</td>
<td>1.570</td>
<td>.036</td>
<td>-8.53</td>
<td>-.18</td>
<td></td>
</tr>
<tr>
<td>Spring 2004 workshop</td>
<td>.81</td>
<td>1.046</td>
<td>1.000</td>
<td>-1.98</td>
<td>3.59</td>
<td></td>
</tr>
<tr>
<td>Case study faculty</td>
<td>Second cohort</td>
<td>Case study</td>
<td>-4.29</td>
<td>1.651</td>
<td>.059</td>
<td>-8.68</td>
</tr>
<tr>
<td>Facilitators</td>
<td>-8.64*</td>
<td>2.227</td>
<td>.001</td>
<td>-14.57</td>
<td>-2.72</td>
<td></td>
</tr>
<tr>
<td>Spring 2004 workshop</td>
<td>-3.49</td>
<td>1.894</td>
<td>.402</td>
<td>-8.52</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Facilitators</td>
<td>8.64*</td>
<td>2.227</td>
<td>.001</td>
<td>2.72</td>
<td>14.57</td>
<td></td>
</tr>
<tr>
<td>Spring 2004 workshop</td>
<td>5.16*</td>
<td>1.824</td>
<td>.30</td>
<td>.31</td>
<td>10.01</td>
<td></td>
</tr>
<tr>
<td>Spring 2004 workshop</td>
<td>Second cohort</td>
<td>Case study</td>
<td>-8.1</td>
<td>1.046</td>
<td>1.000</td>
<td>-3.59</td>
</tr>
<tr>
<td>Facilitators</td>
<td>3.49</td>
<td>1.894</td>
<td>.402</td>
<td>-1.55</td>
<td>8.52</td>
<td></td>
</tr>
<tr>
<td>Spring 2004 workshop</td>
<td>-5.16*</td>
<td>1.824</td>
<td>.030</td>
<td>-10.01</td>
<td>-3.1</td>
<td></td>
</tr>
</tbody>
</table>

*The mean difference is significant at the .05 level.*

To further analyze the relationship between conceptions concerning their teaching orientation and their observed practice, a comparison of the Teaching Approaches Inventory survey results was taken with the in-class observations of teaching practices among the case study participants, viewed in Table 24. This comparison was taken to
explore whether there were observable relationships between these different sources of data regarding orientation and practice. The bold font is intended in this table to make easy distinctions between the survey results of faculty exhibiting high (bold) and low orientations toward lecturing.

Interesting correspondences were found between these data sources regarding teaching orientation revealed in the survey data and observed practices. For example, that Greg presents a significant orientation toward conceptual-change-student based learning while retaining some preferences for transmission-teacher focused pedagogy. In contrast to Greg, Vern shows a higher propensity toward a teacher-focused transmission pedagogy relative to the conceptual change pedagogy. An anomaly is Howard’s results which show high scores in both scales. When Howard submitted his survey, he was asked which class he based his responses. He mentioned verbally and wrote in the margin of his survey that he was making reference to his course that was conducted completely online, through the internet. To be consistent with the treatment of his survey taking conditions relative to other case study participants, he was not asked to explain his responses. Therefore, the contradiction between his survey results and what was observed in his class cannot be resolved, other than to report that they don’t reflect what he was observed doing in his class.

Several faculty obtained scores on the two scales in the Teaching Approaches Inventory survey that were sufficiently similar to indicate that the faculty were not easily categorized by either orientation singly. As observed in Table 24, these faculty are Kim,
Laura, Cindy, Rita, Evan and Russ. Among these six faculty the greatest spread between scores in each scale was six points obtained by Rita. The others were more close, and

Table 24. Comparison of the Teaching Approaches Inventory Results and In class observations among the Case Study Faculty

<table>
<thead>
<tr>
<th>Case study participant</th>
<th>Observed orientation to lecture 1-7 L to H</th>
<th>Kinds of questioning Conceptual/Algorithmic</th>
<th>Survey scores: Conceptual Change/Student Focused 40=High, 24=Med, 8=Low</th>
<th>Survey scores: Transmission /Teacher Focused 40=High, 24=Med, 8=Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greg</td>
<td>1 L</td>
<td>High/Conceptual</td>
<td>36 H</td>
<td>26 M</td>
</tr>
<tr>
<td>Kim</td>
<td>6 M-H</td>
<td>Low/Algorithmic (GenChem)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Med/Concept-Alg (Nurse/Health)</td>
<td>26M</td>
<td>29 M-H</td>
</tr>
<tr>
<td>Howard</td>
<td>7 H</td>
<td>Low/Algorithmic</td>
<td>40 H</td>
<td>34 H</td>
</tr>
<tr>
<td>Cindy</td>
<td>6 M-H</td>
<td>Low/Algorithmic</td>
<td>24 M</td>
<td>23 M</td>
</tr>
<tr>
<td>Evan</td>
<td>7 H</td>
<td>Low/Algorithmic</td>
<td>23 M</td>
<td>26 M</td>
</tr>
<tr>
<td>Russ</td>
<td>7 H</td>
<td>Low/Algorithmic</td>
<td>33 M-H</td>
<td>30 M-H</td>
</tr>
<tr>
<td>Marcus</td>
<td>4 M</td>
<td>Med-High/Algorithmic</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Rita</td>
<td>5 L-M</td>
<td>High/Conc-Alg</td>
<td>16 L</td>
<td>20 M</td>
</tr>
<tr>
<td>Laura</td>
<td>5 L-M</td>
<td>High/Conc-Alg</td>
<td>25 M</td>
<td>24 M</td>
</tr>
<tr>
<td>Vern</td>
<td>6 M-H</td>
<td>Low-Med/Algorithmic</td>
<td>19 L</td>
<td>35 H</td>
</tr>
</tbody>
</table>

in some instances, their practice shows similar orientations. For example, both Rita and Laura are close in teaching orientations and their observed approach to teaching appears to be a hybrid of interactive lecturing. Kim’s scores are close and her practice appears to be a combination of approaches that are separable by contexts. Revealing a more complex correspondence, two faculty (Evan and Russ) were observed to have more traditional practices of lecturing corresponding to one of their scales. But these two faculty also had relatively close scores between both orientations which corresponds to
their choices in their pre-workshop surveys but less so to their practice. Therefore, with the exception of Howard who reported that he responded to the survey based on his web-based class, the survey results generally appeared to corroborate approaches observed in their classes.

A detailed comparison of the case study faculty survey responses to the nine MID Project faculty facilitators also might serve to illustrate the orientation of the case study faculty relative to the MIDP faculty who would be considered reform implementers. Table 25 below shows a comparison between these two groups. The faculty who displayed a high orientation to traditional lecture in their general chemistry classes are shown in bold. On average, when the case study faculty scored higher on the conceptual change scale, the average increase of their student oriented scale above their teacher-oriented scale was 4 points. The average increase in the student-oriented scale above the teacher oriented scale among the ‘reformers’ was 13 points. As mentioned previously in the discussion on the ANOVA test, the significant statistical difference between these groups was their preference for the transmission orientation, there were no statistical differences between these groups in the student-oriented (or conceptual change-oriented) scale. Therefore the distinction between these groups regarding the gap between their teaching conceptions and orientations appears to be the degree that the faculty maintain the transmission orientation rather than the degree they hold to the conceptual change orientation.
Table 25. Comparison Between Case Study Faculty and MIDP workshop Facilitators on Teaching Approaches Inventory Survey

<table>
<thead>
<tr>
<th>Case study participant</th>
<th>Case study Survey scores: Conceptual Change/Student Focused 40=High, 24=Med, 8=Low</th>
<th>Case study Survey scores: Transmission/Teacher Focused 40=High, 24=Med, 8=Low</th>
<th>9 MIDP facilitators’ survey scores Conceptual Change-student focused</th>
<th>9 MIDP facilitators’ survey scores Information transmission-teacher focused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greg</td>
<td>36 H</td>
<td>26 M</td>
<td>(1) 40 H</td>
<td>17 L</td>
</tr>
<tr>
<td>Kim</td>
<td>26 M</td>
<td>29 M-H</td>
<td>(2) 37 H</td>
<td>19 L</td>
</tr>
<tr>
<td>Howard</td>
<td>40 H</td>
<td>34 H</td>
<td>(3) 25 M</td>
<td>21 M-L</td>
</tr>
<tr>
<td>Cindy</td>
<td>24 M</td>
<td>23 M</td>
<td>(4) 30 M-H</td>
<td>27 M</td>
</tr>
<tr>
<td>Evan</td>
<td>23 M</td>
<td>26 M</td>
<td>(5) 33 M-H</td>
<td>19 L</td>
</tr>
<tr>
<td>Russ</td>
<td>33 M-H</td>
<td>30 M-H</td>
<td>(6) 31 M-H</td>
<td>18 L</td>
</tr>
<tr>
<td>Marcus</td>
<td>NA</td>
<td>NA</td>
<td>(7) 25 M</td>
<td>21 M-L</td>
</tr>
<tr>
<td>Rita</td>
<td>16 L</td>
<td>20 M</td>
<td>(8) 39 H</td>
<td>12 L</td>
</tr>
<tr>
<td>Laura</td>
<td>25 M</td>
<td>24 M</td>
<td>(9) 31 H</td>
<td>19 L</td>
</tr>
<tr>
<td>Vern</td>
<td>19 L</td>
<td>35 H</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The discussion in this section has focused on the survey results and a comparison of those results to in-class observations. In addition to such comparisons it is pertinent to explore what conceptions faculty report in their interviews that might bring more awareness and understanding of the relationship between their survey derived teaching orientation and their practice. As described in the previous section on Research Question 2, Laura, Rita, Kim, Greg, and Marcus all use some reform-based activities in their classrooms or labs. Laura and Rita use these activities periodically in their chemistry courses of 35 students. Kim uses these activities periodically in her chemistry class for non-majors in a class size of 90. And Greg uses these activities consistently in his non-majors class of 35 students. Both Greg and Kim teach at a PhD granting university while Laura and Rita teach at a community college. Thus a wide variety of contexts are
represented and corroborate the position held by reformers that reform is sufficiently fluid and that it can be implemented in all contexts.

Despite the observation that the case study faculty all used some reform-based activities in different class sizes and institutional levels, however, they all indicated in their interviews that they shared an important teaching conception. They all expressed the viewpoint that reform could not be a consistent practice in the general chemistry course as a lecture replacement due to the feature of normative content in the general chemistry course (their quotes are shown in Appendix F). While this espoused concept about normative content was corroborated in how the general chemistry classes were conducted, it did not provide an explanation as to why normative content required normative practice using the traditional lecture. Even faculty who used some reform activities in their general chemistry class, indicated that lecture was a better vehicle to deliver normative content. When asked why some general chemistry topics were not left for the students to “cover” on their own, allowing time for in-class learning, some faculty expressed the view that students were not capable or could not be trusted to learn new topics on their own. And conversely, some of the faculty expressed the view that they do not expect their general chemistry students to learn the topics during class time, therefore requiring students to learn the topics on their own. These conflicting views about students’ capacity for learning in the classroom suggested that there might be yet another conception that might be linked to using a normative practice in the general chemistry course.
The case study data was analyzed further to determine whether there was an “in-use” conception that might correlate to their practice. As mentioned earlier, prior research indicates that faculty’s notions of teaching are closely aligned with their conceptions of what learning is. Therefore if faculty appear to have a notion that there is a normative way to teach general chemistry, they might have a conception that there is a normative way to learn general chemistry. To probe this possible perspective the faculty were asked how they best learned chemistry. The faculty conveyed in their response to this question that they considered how they learned to be a normative scheme of learning chemistry. This conception varied with their in-class practice in a way that might provide more explanation for the lack of full use of reform pedagogy in the general chemistry course. The relationship between this in-use concept and their practice is shown in Table 26 below.
Table 26. Case Study Participant Learning Concept and Practice Comparison

<table>
<thead>
<tr>
<th>Case Study Participant</th>
<th>Practice Classification: Kind of practice relative to traditional lecture 1-7 Low to High</th>
<th>Questioning Practice: Frequency/Observed kinds of questions asked: Higher Order-Conceptual or Lower Order-Algorithmic</th>
<th>Partial quotes describing how they learned chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>4yr Grad Greg</td>
<td>1 collaborative groups High/Conceptual (80%) (non-majors)</td>
<td>making <strong>connections</strong> to multiple things</td>
<td></td>
</tr>
<tr>
<td>Kim</td>
<td>6 lecture Low/Algorithmic (GenChem)</td>
<td>reading, <strong>doing problems</strong>, thinking, having an interest</td>
<td></td>
</tr>
<tr>
<td>Howard</td>
<td>7 lecture Low/Algorithmic</td>
<td>reading and <strong>doing problems</strong></td>
<td></td>
</tr>
<tr>
<td>Cindy</td>
<td>6 lecture Low/Algorithmic</td>
<td><strong>drill</strong> (practicing problems)</td>
<td></td>
</tr>
<tr>
<td>4yr College Evan</td>
<td>7 lecture Low/Algorithmic</td>
<td><strong>doing end of chapter problems</strong></td>
<td></td>
</tr>
<tr>
<td>Russ</td>
<td>7 lecture Low/Algorithmic</td>
<td>“<strong>working at it</strong>” &amp; getting help</td>
<td></td>
</tr>
<tr>
<td>Marcus</td>
<td>4 lecture intervals &amp; collaborative Med-High/Conceptual (1-5%) Algorithmic (95%)</td>
<td><strong>discovery process</strong>, seeing how things work</td>
<td></td>
</tr>
<tr>
<td>2yr College Rita</td>
<td>5 lecture-interactive High/Conceptual (2%)–Algorithmic (95%)</td>
<td>practicing problems, <strong>connecting concepts</strong></td>
<td></td>
</tr>
<tr>
<td>Laura</td>
<td>5 lecture-interactive High/Conceptual (2%)–Algorithmic (95%) (prep)</td>
<td>practicing problems, making <strong>connections</strong></td>
<td></td>
</tr>
<tr>
<td>Vern</td>
<td>6 lecture intervals Low-Medium/Algorithmic</td>
<td>reading and <strong>doing problems</strong></td>
<td></td>
</tr>
</tbody>
</table>

(Note: bold font in the partial quotes highlight terms that appear to distinguish types of learning described below)
Several faculty mentioned that the way they learned chemistry is by “doing problems” but did not distinguish which kinds of problems such as algorithmic or conceptual problems were important to the learning process. While several faculty did not directly mention differences between algorithmic problems and conceptual problems, a few of the faculty appeared to have a tacit understanding of the distinction. (Refer to Appendix E for detailed descriptions of types of learning under Bloom’s Taxonomy) Based on faculty discourse and practice in this study and in the literature on cognitive science, the cognitive skills implied in “doing problems” can be separated from those entailed in “making connections”. “Making connections” connotes synthesizing and analysis, while “doing problems” connotes recall, comprehension and application of problem solving strategies. One of the distinctions between these conceptions is whether the problem solving strategies students apply are their own creation or a prefabricated strategy provided by the text or teacher. To create a problem strategy on their own and apply it requires making connections between concepts whereas applying a ‘provided’ problem solving strategy involves recall and “knowing when” (pattern recognition) to apply the strategy.

The participants in this case study appear to hold either one of these conceptions and two appear to hold both. Those who only mention “doing problems”, or drill, with reading, conveyed that learning chemistry involved learning facts and relied heavily on a traditional lecturing strategy. These perspectives and approaches correspond to those views that project science as a product—a body of received knowledge, described earlier in the introduction to this dissertation. This view contrasts with the view of science as a
process, which emphasizes discovery, synthesis and analysis. They also conveyed that learning chemistry involves a vertical process of “building up” rather than creating a network of connections. This conceptualization conveys a view of science knowledge as amassing sequential or hierarchal layers where learning is building with static blocks of information rather than a fluid, integrating and continuous process.

Interestingly, the two faculty who reported that they used both learning strategies (doing problems and making connections) also had the highest frequency of teacher-student questioning during their traditional lecture. They exhibit a conceptualization of their own learning that appears to be a hybrid of two strands of orientation and their practice appears to exhibit a similar hybridization. These findings suggest that faculty perceptions about how they learned chemistry might have an important influence on their practice in their general chemistry class. Their perception that their learning is a normative way to learn chemistry might be more closely tied to either their actual history of learning in chemistry or their perception of that history, rather than to other constraints. These results highlight the potential importance of faculty conceptions about their own learning patterns and history relative to findings of earlier studies which have focused mainly on faculty conceptions about learning among their students.

The two faculty who referred to only connections or discovery in their learning conceptions used collaborative learning processes in their classrooms. One (Greg) used collaborative strategies exclusively in a course for non-majors. Despite his obvious commitment to reform pedagogy, he voiced a concern that reform pedagogy may not be amenable to general chemistry because of the amount of content required in that course.
Greg’s espoused conception about teaching general chemistry is unusual relative to other case study faculty because while he perceived his learning as “making connections” he did not expect such learning approaches from his students. In contrast to other faculty, Greg did not see his way of learning chemistry as normative. Rather, he believed that making connections was the learning strategy of the “expert learner” not necessarily of the novice learner, who lacked the knowledge base to make connections. Instead, he believed that students needed to be helped or taught to make their own connections and the teaching strategies he used, such as encouraging “student reflections” during class time and in homework assignments, were designed for this purpose. Here Greg distinguishes various levels of capacity for students to engage with the practices of making connections. This view is supported by cognitive learning theory. Furthermore, he presents his reasoning that because students need help to make connections then there is a distinction between what he is able to accomplish in his class for non-majors relative to what other faculty are able to do in the general chemistry course. The main distinction he points to is the difference in the amount of general chemistry content which he believes is normative and prohibitive to implementing these kinds of activities. As described earlier, this viewpoint was expressed by several case study faculty.

The argument that the content of the general chemistry course must have a large array of topics was also discussed in the reform literature, as described in the introduction of this dissertation. However, the discussion on reform in chemistry also included and supported alternative views of what would constitute appropriate content in the general chemistry course. While it might be inevitable that faculty would have varying views on
what topics to emphasize, not all topics can be covered, hence decisions need to be made to determine sufficient content at the introductory level. The contention that the reform literature raises concerning general chemistry course content is this: that these decisions are inevitably made based on criteria which traditionally views science as a product or as a body of knowledge. Because of this view and because of the bulk of the product that they desire to deliver, they consider that the product-content is better delivered didactically. Consequently, a wide array of topics becomes the normative product delivered. Equally pertinent and arguably viable, but less traditional criteria that views science as a process, are not considered. Thus these are the reasons that reform documents have encouraged the propagation of reform perspectives, in part, so that the uptake of reform perspectives would lead to different decisions about appropriate content.

If the amount of content in the general chemistry course is the main teaching conception (excluding for the moment important external constraints such as administrative support or class size) that faculty have for not implementing reform then they may find it difficult to accept or understand the rationale for the reform objectives described in the introduction. And perhaps related to this issue about normative content, faculty decisions about what approaches best facilitate students to learn this content might be related to their perceptions about their own learning histories. They appear to believe that their learning histories are normative. Thus the reform objective to help students be more successful learners might be misinterpreted by faculty to mean that faculty ought to reproduce their learning experience in students—a conception which is unsupported by cognitive learning theory and research.
Summary

The findings from the post-workshop Teaching Approaches Inventory survey analysis of the second cohort (N=203) corroborates the case study findings regarding a preference for using lecture. The prevalent teaching conceptions, both strategies and intentions, are oriented toward transmission which is the didactic approach traditionally used in lecture. Furthermore, the case study data along with both the pre-workshop data and the post workshop data revealed that these conceptions include the idea that the practice of using transmission best conveys the content that students are given to learn in the general chemistry course. The observations in case study revealed that instructors’ perceptions about their own learning appear to be more strongly connected to the transmission orientation. In contrast, their strategies and intentions toward the conceptual change-student orientation appear to be less strongly related to their perceptions about their own learning through processes of making connections. These distinctions in the case study data are observed to be greatest in the context of the general chemistry course, where reform dissemination objectives have been most heavily directed. If this differential correspondence between faculty’s perceptions about their learning and their practice extends beyond the case study faculty, then encouraging faculty to recognize that their own processes of learning entail a learning cycle (of discovery, making connections and applications) may not be sufficient to orient them toward a conceptual change—student-focused approach. Thus the survey data and the case study exhibit a complex movement toward reform that does not corroborate the expected smooth movement.
“along a continuum” as described in the reform literature. Some faculty in the case study exhibit both hybridized practice and conceptions while others exhibit a practice that conflict with their reported conceptions and a few exhibit reform practices but have a moderate engagement in reform conceptually.

In addition to these conceptions that influence their practice in their general chemistry course, the case study observations and interviews revealed that additional factors, such as organizational influences, might mediate the differential implementation of reform in chemistry classes between non-majors and majors. They mentioned that there were ‘impracticalities’ to fully implement reform approaches because of curriculum objectives stipulated by their administrations. Alternatively, rather than having inhibitions related to their conceptions such as those about normative content or normative learning experiences, the difficulty for some faculty may be limited only to physical or structural constraints of class size, particularly in the PhD granting institution where classes often range above 100 students. Therefore this discussion leads us to the fourth research question of what external factors or contexts might be helpful to encourage faculty to adopt reform thinking and practice.

**Research Question 4**

How do their specific contexts (faculty demographic characteristics and teaching environment) influence both their teaching conceptions and practices and on their uptake of reform?

Based on the case study observations and the teaching approaches inventory survey data it is pertinent to question whether the workshop was instrumental in helping
people move toward reform pedagogy and whether this movement is a general trend in the whole participant population. The post workshop surveys suggest possible success. For example, the post-survey of the first cohort [participants from the year 2000 to 2002] contained responses from 15 people who reported on the pre-workshop survey that they were currently using in-class problem solving but not collaborative learning. After the workshop, 60% of these people had moved to group problem solving at least 1-2 times per semester if not more frequently. Among the post-survey respondents, 96% reported using lecture in their pre-workshop surveys. The post-survey asked whether respondents lectured most of the period and believed that this was an effective practice. The McNemar test was applied to probe changes in their responses between the pre and post surveys regarding their lecture practices and the possible impact of the MIDP intervention on lecture use. Table 27 shows that after MIDP intervention, 18% (15/85, lower left square of the table) of the faculty who indicated that they used lecture in the pre-survey reported on the post-survey that they did not lecture most of the period. In other words, the percentage of reported lecture users in this group decreased from 96% to 79%. In a two-tailed test of significance, this proportion of change was significant with an intermediate, small/medium effect size ($w = 0.15$).
In fact, as Table 28 shows, the majority of the first cohort responders had cited their attendance at the MID workshop as having had direct influence on changes in their assessment methods. Collectively, the implication of these results from the first cohort is that MIDP has a positive impact on faculty who had favored traditional techniques such as lecturing and can influence their teaching conceptions away from lecture and toward reform pedagogical approaches.

Table 28. Post Survey (N = 89): MIDP Influence on Assessment Practices

<table>
<thead>
<tr>
<th>What factors influenced change in your assessment practices?</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance at MID workshop</td>
<td>56</td>
</tr>
<tr>
<td>Dissatisfaction with previous methods</td>
<td>39</td>
</tr>
<tr>
<td>Attendance at another workshop/presentation</td>
<td>30</td>
</tr>
<tr>
<td>Implementation of one or more of the 4 MID projects</td>
<td>29</td>
</tr>
<tr>
<td>Difference in skill level of current students</td>
<td>16</td>
</tr>
<tr>
<td>Policy change within department or institution</td>
<td>7</td>
</tr>
<tr>
<td>New testing materials provided by publisher</td>
<td>1</td>
</tr>
</tbody>
</table>

In addition, the Inventory Survey administered near the end of the dissemination period, directly inquired whether workshop participants had made changes in their courses that they would attribute to MID workshop attendance. The responses of the
faculty showing change away from lecturing in the post-survey (the fifteen people described above) were triangulated with their responses to a question from the Inventory Survey (Table 20) that directly asked what changes had been implemented as a result of attending the workshop. This comparison reveals that 60% (9/15) of those people who indicate change away from lecture in the post survey also report using collaborative learning as a result of attending MIDP workshops in the Inventory Survey. In addition, these ‘switchers’ indicate that 67% place a greater focus on ‘active learning’ (or process learning) in class, 47% use materials from one or more of the MIDP initiatives, and 80% report changing their assessment practices.

Another point of reference is provided by MID’s consistent performance across different surveys with respect to its influence on assessment. As observed in Table 30, the majority (56%) of the participants responding to the post-survey of the first cohort reported that MIDP influenced a change in their assessment techniques. This finding is corroborated in the Inventory Survey in Table 29, which shows again that a reasonable proportion (22.8%) report MIDP influencing changes in assessment practices. Table 29 demonstrates their additional belief that, not only was the workshop generally beneficial, but it actually helped them to make changes. The majority (68%) indicate that MIDP intervention brought about a greater focus on active learning (or process learning). MIDP also was cited as an influence on the use of group problem solving (53%) and the use of questions (53%). Notably, only 4% of the respondents are unwilling to ascribe any actual pedagogical changes to their experience at the workshop. In light of the findings on the case study faculty’s orientation toward transmission approaches described in the previous
section, these results suggest the possibility that the espoused influence of MIDP workshops to encourage faculty toward student-centered approaches might have occurred in the absence of or reduced influence of the traditional teaching orientation/philosophy among these respondents.

Table 29. Inventory Survey: Changes in Teaching Strategies Ascribed to MID

<table>
<thead>
<tr>
<th>What changes have you implemented in your class(es) as a result of attending the workshop? (Please select all that apply)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater focus on active learning in class</td>
<td>68.0</td>
</tr>
<tr>
<td>Have students do more problem solving in groups</td>
<td>53.4</td>
</tr>
<tr>
<td>Use questions to introduce new concepts</td>
<td>52.9</td>
</tr>
<tr>
<td>Use collaborative learning in class</td>
<td>48.5</td>
</tr>
<tr>
<td>Use real world questions to drive the learning of concepts</td>
<td>44.7</td>
</tr>
<tr>
<td>Ask questions to elicit student ideas</td>
<td>41.7</td>
</tr>
<tr>
<td>Use materials from one or more of the projects</td>
<td>41.3</td>
</tr>
<tr>
<td>Implemented my own version of more active learning</td>
<td>41.3</td>
</tr>
<tr>
<td>Use common student misconceptions to structure in-class discussions</td>
<td>35.4</td>
</tr>
<tr>
<td>Base instructional decision on student responses to questions</td>
<td>29.2</td>
</tr>
<tr>
<td>Lecture less and do more &quot;just in time&quot; teaching</td>
<td>27.0</td>
</tr>
<tr>
<td>Changed my assessments</td>
<td>22.8</td>
</tr>
<tr>
<td>Other</td>
<td>7.7</td>
</tr>
<tr>
<td>No change</td>
<td>4.3</td>
</tr>
</tbody>
</table>

The inventory survey included a specific question regarding the perception of the usefulness of MID workshops: “What did the MID Project workshop provide that was helpful to you?” As can be seen in Table 30, most respondents (82%) to the inventory survey report they benefited from the information MIDP provided them on teaching and learning research. The second highest proportion of faculty (75%) benefited from the curricular materials that MIDP provided from the four initiatives. The remaining options are listed in the table according to decreasing frequency. Note that respondents were
explicitly offered the option “nothing” as a potential answer to the question, and 0.5% of the sample did choose this response. The low number indicates that, in general, the MID workshops were reported to be beneficial.

Table 30. Inventory Survey Reported Benefits (N= 207)

<table>
<thead>
<tr>
<th>What did the MID Project workshop provide that was helpful to you? (Please select all that apply)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information on teaching and learning research</td>
<td>82.2</td>
</tr>
<tr>
<td>Specific materials from the projects that I could use or adapt</td>
<td>74.5</td>
</tr>
<tr>
<td>The opportunity to work with colleagues who shared my vision of teaching and learning</td>
<td>66.3</td>
</tr>
<tr>
<td>Ideas about how to implement what I wanted</td>
<td>56.7</td>
</tr>
<tr>
<td>Seeing that so many people were involved in changing how we teach</td>
<td>45.7</td>
</tr>
<tr>
<td>The opportunity to experience my own learning processes</td>
<td>39.4</td>
</tr>
<tr>
<td>Information on changing assessments</td>
<td>39.4</td>
</tr>
<tr>
<td>Reinforcement of what I already knew</td>
<td>37.0</td>
</tr>
<tr>
<td>Experiencing ideas I'd heard before</td>
<td>32.7</td>
</tr>
<tr>
<td>Nothing</td>
<td>0.5</td>
</tr>
</tbody>
</table>

While the survey results seem very positive about the influences of MIDP workshop, contrary arguments can be made because research indicates that faculty report their espoused conceptions rather than their in-use conceptions or may exhibit reactivity (demand characteristics)—answering what the researcher wanted in their responses. Therefore it is appropriate to triangulate the survey results with the case study faculty data.
When the case study faculty were asked what they may have gained from the MIDP workshops, a range of responses indicate interesting and varied perspectives (see Appendix F for quotes from transcriptions). There are a combination of responses both positive and less positive about what the workshop offered and what the faculty felt they could implement. Thus, these responses add greater variety and depth to the survey results provided by the greater participant population concerning the reaction to the reform approaches presented in the workshops. These varied response also indicate that changing pedagogy is a complex process involving not only changing teaching philosophies but changing the traditional class environment into an environment with which they have had little or no experience. Therefore exploring what influences faculty thinking may not be sufficient. In addition to exploring faculty thinking, it may be important to explore whether faculty have gained sufficient confidence to implement approaches which may or may not have full departmental support.

Several faculty indicate that collegial support is necessary to maintain continuity in a course which may be taught by different teachers or by a first time teacher. Therefore changing the pedagogy in one class involves not only changing one faculty member’s philosophy but requires philosophical changes among several colleagues which in turn, involves organizational mechanisms for change. Also, several faculty insist that time (or lacking time) is a critical factor in their use of the reform pedagogy. Therefore according to their view, using reform approaches entails additional time for preparation for a new approach, in order to make such change functional both inside and outside of class.
The case study data indicate that environment appears to be important to these faculty. Therefore it may be prudent to explore the extent of the influences that these faculty mention in this investigation. For example, the environment or context appears to have an influence how chemistry is taught and learned in the general chemistry course. In the case study, the community college faculty indicated that they did not have autonomy in curriculum and pedagogical decisions in contrast to one of the faculty in the four year college and one faculty in the PhD institution who reported that they did. Two of the faculty, both Rita and Laura, expressed the desire to do more reform oriented pedagogy but felt they did not have the support of their institution. Vern also expressed that his administration expected him to “stand up and lecture”. Despite these reported influences, Rita and Laura exhibited more frequent student questioning activities during their lecture relative to faculty in the four year college or PhD institution in the general chemistry course.

Vern presented an interesting variation to the trend among faculty in the case study. This variation involved the interaction of his teaching strategy with the teaching environment. During his interviews he expressed a fairly traditional outlook to teaching and learning that might have easily accommodated his administration’s expectations to just “stand up and lecture”, except for the student activity that occurred whenever he allowed enough wait time after a question. Similar to the other teachers in the general chemistry, Vern presented problems and solutions as part of the class lecture. But in contrast to other faculty’s classes, his students spontaneously broke out into quiet collaborative problem solving whenever he paused. In one of his interviews, Vern was
questioned about his pauses during class time to determine whether or not he intended
collaborative learning. He claimed that he preferred and often went faster in his delivery
but happened not to on the occasions of my visit. His response implied that he may have
unintentionally supported collaborative learning by increasing his wait time and he may
also diminish it by increasing the pace of his delivery. These findings suggest that the
class environment, which included a greater number of mature students, the physical
setting of tables rather than individual desks, and wait time may have contributed
together to the collaborative problem solving behavior observed in his students.

The potential of the environment to influence teaching practices was also probed
using a post workshop survey submitted to 89 MIDP participants. The results of this
survey were used to triangulate the case study observations. There is agreement between
the survey data and the case study data suggesting that one of the reform oriented
approaches, questioning students about their understanding and basing curriculum
decisions on students’ responses, has been incorporated into the traditional lecture
format.

Similar to the case study observations, the post workshop survey responses
indicate that environmental or demographic contexts do have an impact. As shown in
Table 31 below, females more than males use questioning techniques to determine
whether their students have understood a topic. The survey responses also indicate that
questioning techniques are used more in lower level institutions and by faculty having
lower level tenure status.
There are four questioning techniques that obtained significant demographic associations in the Post-workshop survey data (N=89):

- **a** “I use student responses to determine whether a topic has been understood,” [82%]
- **b** “I base instructional decisions on students’ responses to questions,” [39%]
- **c** “I use questions to introduce new topics,” [67%]
- **d** “I use common misunderstandings to structure class discussions.” [46%]

In all of these practices (a, b, c & d), females reported higher frequencies than males (p <0.05). Two of these practices, (a and d) are associated with institution level (Spearman correlation (-.241) p=0.014) and tenure status (L.R. p=0.015) respectively. Technique (a) is valued more in undergraduate institutions and community colleges rather than in higher degree granting universities. Technique (d) is valued more by those who are on tenure track than those who are tenured. The case study data confirm these results: Females were observed using questioning techniques in the manner described above more often than males—particularly the females at the community college level.

The agreement with the case study data regarding the use of questioning techniques suggests that the survey results for these techniques may be considered valid. Consequently, the implications are that there is a high percentage of faculty who may be using the questioning techniques throughout the entire MIDP participant population. The adoption of these techniques may represent an early stage toward reform that these faculty found was amenable to their traditional lecture approach.
SUMMARY

The workshop participants report in their surveys that MIDP has influenced change in their knowledge, skills and behavior. Faculty report that they come to workshops for the purpose of acquiring the necessary skills for making change, such as implementing new assessment methods. After their workshop experience, they report using the methods they have attained through their attendance to MIDP workshops. Furthermore, even faculty who report satisfaction in traditional methods in the pre-workshop survey, indicate that they have acquired experiences through MIDP to influence change in their teaching approaches. These findings suggest that dissatisfaction with traditional techniques prior to the MIDP workshop experience may not be a necessary pre-condition for the uptake of reform pedagogy. This is corroborated in the case study where faculty implement reform pedagogy in non-major classes while retaining a traditional approach in the general chemistry class. Finally, in terms of the reported experiences of the workshop participants, the MID workshops were influential in supporting actual pedagogical change.

The data from the case study and the pre and post workshop surveys have provided four key findings. (1) Because faculty from all educational institutional levels are attending the MIDP workshops, it appears that there is systemic interest in reform. However, the MIDP participants’ demography are different from the ACS census. This finding suggests that those who show an interest in reform by their attendance to a faculty development workshop, are not representative of the general academic chemist population. Therefore, the MIDP data may not be generalizable to the entire academic
field. (2) Faculty conceptions about how they learned chemistry appear to have an impact on how receptive they are to implement reform pedagogy in the general chemistry course. Courses for non-majors and possibly higher level chemistry courses are not as affected by these conceptions. Because lecturing is still used extensively in the general chemistry course across all settings, future reform dissemination programs must address this course specifically, the conceptions faculty have regarding their own learning experiences as being normative, and the perception that the course content is normative. (3) Faculty report differentially about the influence of administrative control on their teaching at the lower level institutions. Some of these faculty attempt to meet the administrations’ objectives while attempting to incorporate a higher level of student questioning. Future dissemination programs need to solicit and address administration participation to support the reform effort. (4) The uptake of some reform practices appear to be happening among lower ranking faculty. Because this group does not have job security, it is recommended that administrations wishing to support reform in their institution, give clear indications for reward and tenure considerations for implementing reform pedagogy.
VI. SYNTHESIS

A MODEL OF REFORM

This work began with a description of the history of reform and two models of reform presented by different authors. Here a model of reform is developed based on the data gathered in this investigation which will be compared and contrasted with the earlier models.

At the core of the reform movement are key perspectives promoted by the catalyst organizations described in the Introduction. Below are a few of these perspectives, recapped:

Knowledge is constructed in the mind of the learner
The learner’s prior knowledge and learner contexts affect what is learned
The learner contexts include the wider community in which the learner lives
Both the learner and the wider community determine meaningful subject content
Understanding occurs through a cognitive process called the “learning cycle”
Reform teaching approaches intentionally engage the learning cycle
Promoting the learning process takes priority over amount of subject content
Learning is exhibited by conceptual change in subject content rather than a capacity to apply algorithmic rubrics
Teaching approaches that involve process-oriented guided inquiry-based group learning best approaches the realization of all of the above.

The foundational premises of these perspectives belong to a constructivist or 'non-positivist' paradigm which has been given various labels in the literature including a "student-focused" or conceptual change paradigm. Part of the thrust in science reform educational literature has been to present arguments in support of the non-positivist paradigm. Data demonstrating the insufficient capacity of higher education to overcome misconceptions in 'core' or 'fundamental' science concepts have been attributed to influences of the positivist paradigm on teaching methods. The foundation premises of the positivist paradigm argue for the authority of the 'universal reality' depicted in science texts and in the lectures of teachers. There have also been various labels given to this paradigm which include "a teacher-focused paradigm". Arguments in favor of either one or the other paradigms will not be presented here because they have been made elsewhere and will detract from the work at hand. From the onset of this work, the merit of reform and its supporting paradigm is assumed, and readers interested in a discussion giving more depth to these arguments are referred to literature on this topic.

The research in this work seeks to determine, in part, what teaching conceptions participants in a reform workshop have and whether there is evidence for the possible influence of their teaching conceptions on their observed teaching approaches. It may seem likely that if their teaching conceptions are infused with one or the other paradigms, positivist or non-positivist, that their teaching approach might reflect such orientation in
favor of or against reform implementation. However, as indicated earlier in the
discussion on prior literature, several factors might also mitigate such influences.
Therefore evidence provided by the data to construct a model of how teaching
conceptions relate to practice would be helpful in our understanding of the contexts of
successful reform implementation.

This discussion will focus first on the distinctions of the case study participants
from the other workshop participants and the workshop facilitators who promoted reform.
The sample (N=203) of MID Project workshop participants who participated in the
Teaching Approaches Inventory Survey submitted responses that were distinctively less
oriented toward a conceptual change orientation (a reform orientation) relative to the
facilitators. This might be understandable insofar that they might still be assimilating the
reform paradigm. However this assumption is questionable in light of the case study
data. The case study faculty had some members who attended the earlier workshop and
whom might have had more time to adopt reform perspectives. However in both scales
the case study faculty did not differ significantly from the larger sample of survey takers.
Yet, the case study faculty submitted responses that were not significantly different from
the facilitators on the conceptual change scale and only differed in their responses to
information transmission scale. This result suggests that moving faculty “along a
continuum from a teacher-focused paradigm to a student-focused paradigm” is not what it
was anticipated to be. Rather than one ‘continuum’ there appears to be two operating
simultaneously. Furthermore it calls into question the notion of a transition from one
paradigm to the other because it appears possible to have conceptions of one paradigm
‘nestled’ within conceptions of another. Examples of this are seen in faculty who retain the reform paradigm for particular circumstances (courses for non-majors) and insist on the ill suitability of reform approaches in others (the general chemistry course) regardless of the suitability of those circumstances for reform approaches as seen by reformers.

Similar behavior regarding the adoption of a new paradigm (in cognitive literature paradigms are described as belief systems) has been described before in cognitive science literature on how learners adopt ideas which refute the validity of previously held conceptions.\(^{(34, 38)}\) If the previously held conceptions belonged to a ‘peripheral’ set of beliefs which are not held as strongly as ‘core’ beliefs, then the learner may exhibit more readiness to adopt the new concepts. On the other hand, should the new concepts be antithetical to the learner’s ‘core’ beliefs, the learner might engage in creative ways to adopt the new ideas while retaining the older concepts. To accomplish this, the learner finds ways to create a “boundary” between the closely held core beliefs and the new concepts. It may be possible that the behavior observed in the case study faculty regarding their perceptions about implementing reform in their general chemistry courses, is an example of this phenomenon.

If the case study faculty hold conceptual boundaries between competing conceptions, then the boundaries might be found in the explanations they give to justify why the general chemistry course, but not necessarily other courses, lacked “appropriateness” for the application of reform approaches. Several explanations were given that followed a similar theme. Namely, the numerous topics that constitute the subject content of the general chemistry course and the ways that the faculty have
successfully learned it, indicate to them a need for and the success of the traditional lecture approach. This is an approach which they likely experienced themselves as students in general chemistry, and according to their reports, is still widely practiced and considered appropriate among their colleagues and importantly, their administrations. This rationale might seem valid if research confirmed that students learn effectively and understand the subject content in the lecture-based class. But data from research on student outcomes in lecture classes do not support this view.\textsuperscript{(151)} Therefore the presentation of these arguments might indicate a conceptual ‘boundary’ as described by cognitive scientists between their core concepts about teaching science and the reform perspectives.

Alternatively, some of the case study faculty whose practice varied somewhat from a traditional lecture also mentioned their inhibitions to fully implement reform approaches because of a lack of departmental or administrative support. These explanations might be indicating the presence of more than a conceptual boundary but a social boundary either between the faculty and their administrations or colleagues, or to reform practices or both.\textsuperscript{(92, 93, 94,95)} While differences in job security (e.g. tenure status) might make obvious social boundaries, propensities to express reform oriented thinking, whether in behavior or speech did not appear to correlate to tenure status in the case study, but to personal histories.

The Statewide Systemic Initiatives model indicated that reform dissemination influenced both sectors, administration and faculty and that administrations supported the preferred outcomes for students. The pyramid structure in this model had no obvious role
for teaching conceptions and faculty histories in reform uptake. Therefore, the model of reform proposed here varies considerably from the model proposed by Zucker et al, evaluators of the Statewide Systemic Initiatives (Figure 3) because the faculty conceptions have a prominent role in the proposed model.

Similar to the model that Gess-Newsome et al proposed, the model depicted in Figure 7 emphasizes the importance of personal histories in teaching practice. The entire model in Figure 7 might appropriately fit in the Gess-Newsome model, in the box framing personal practical theories and knowledge and beliefs. However the variation proposed here from Figure 4 is not trivial. Gess-Newsome proposed that critical intervention, pedagogical dissatisfaction and contextual dissatisfaction were critical features that contributed to the development of reform practices. And as mentioned earlier, faculty dissatisfaction in their teaching approaches has been well documented in conceptual change theory and research as a necessary precondition to pedagogical change. However in the observations in this work, the close relationship between dissatisfaction and pedagogical change appears less clear. Pedagogical dissatisfaction was described by faculty in the case study who did make the greatest strides in reform practices, generally. But this dissatisfaction did not appear to influence their perspectives or practice regarding the purported normative content of the general chemistry course. Greg, and Kim made significant strides toward practicing reform in their respective non-major classes, but neither Kim Greg or Marcus considered conducting a reform approach in general chemistry feasible pedagogically or appropriate for learners of general chemistry content. Therefore the findings of this study would suggest that modifications
to both models of reform are necessary and a combination of both models appears to be required to depict the observed behaviors and ‘theories in use’. But the role of dissatisfaction has been left out of this proposed model because it doesn’t appear to be a factor that strongly influences change in the general chemistry course in either the field observations or in the survey data.

Figure 7. Model of Reform

The model proposed here depicts in the lower quadrant, influences of broad contexts such as administrative constraints and/or controlling influences of senior colleagues mentioned by all of the case study faculty with the exception of Howard and
Evan. This context is a common experience for both reform interested faculty composing the left side of the model as well as the greater academic community composing the right side of the model. The models proposed by both Zucker et al and Gess-Newsome and literature cited in the rationale chapters of this dissertation also referenced the influences of broad contexts common to teaching environments. Therefore the model proposed here does not differ from the others regarding the importance of mutual institutional contexts.

Because this model represents an explanation specific for academic chemists rather than a general model for all academic science faculty or academics generally, the structure within the model reflects specific relationships that might not be found in the earlier models. For example, the bifurcation of academic chemists into two different groups makes this model distinct from the earlier models. The proposed distinction between ‘sides’ of teaching practice lies in the influence of personal history derived from learning experiences, personal demography and teaching experiences that appear to have a combined effect to encourage reform-oriented teaching conceptions in chemistry.

Neither this study nor any other has explored the teaching conceptions and practices of those who populate the right side of the model, thus the model shows a proposed relation that those who are not visibly involved in reform oriented functions will likely have teaching practices that reflect “traditional approaches”. The model conveys that the chemists on the right side represent the academic chemists documented demographically by the ACS census. The major demographic features that characterize the ACS community (predominately male, white, senior faculty) described earlier have not changed across the decades that the census has been taken. Such stable characteristics
suggest that there exist factors in broad institutional contexts that influence and support this stability, but they have not been explored here beyond representing a community that contrasts demographically with the participants on the left side. The faculty on the right side of the model are older and more experienced faculty, representing fewer women and ethnically less diverse faculty than those who participate in faculty development workshops, practice reform pedagogy, and who are depicted on the left side of the model.

But whatever factors that might be at the root of these distinctions between groups among academic chemists, they do not appear to create a linear behavioral transition toward reform on the left side. Furthermore, even when reform-oriented conceptions are articulated or observed behaviorally, they appear to be sequestered behaviorally in ways that do not challenge the continued implementation of positivist orientations in classes that prepare students for continued studies within the chemistry discipline. The differential behavior appears to support different pedagogies for different students populating different classes. Thus this model depicts different practices for different groups of students among the faculty populating the left side of the model. Majors within the discipline are treated similarly by faculty on both sides of the model, yet the faculty on the left side hold reform values and perspectives that do not always translate to their practice based on their perception of student needs within the discipline. While these behaviors and perspectives are not unique, and they might not appear problematic to the greater community of academic chemists, they do not contribute to systemic reform within the discipline. Researchers have called attention to the limitations of a “functional” science literacy taken from a technocratic perspective which gives scant
support to the epistemological and intellectual development of future scientists and teachers of science. Therefore this model depicts that non-major students who experience the reform pedagogy will likely have different outcomes pertaining to their learning experiences that will distinguish them from majors who do not. This model does not account for the importance of these issues insofar as it only reflects and categorizes observations in this study and not the desired goals of reform.

**Implications and Future Studies**

Based on the observations in this study, several trends have been observed that provoke further questions and more study. One question regarding the faculty’s perspectives entails the constraints in general chemistry content: How wide spread are the views presented in this study concerning the normative content of general chemistry and the consequential outlook that a larger repertoire of teaching approaches cannot service this course better than lecture? Given how convinced these participants were in their interviews, especially those who were engaged in reform practices for non-majors, there appears to be indications that this phenomena is wide spread and entrenched but not typically apparent in survey data. Thus this investigation indicates that future work is needed to expand the qualitative approach used in this research to study more in-class instruction of more participants in reform dissemination projects to conclude whether this phenomenon is generalizable to the greater academic chemists’ community.

A critical feature that differentiates this study from the Gess-Newsome study was the impact of dissatisfaction on developing teaching approaches. Both studies revealed
that a favorable disposition toward reform practices as a necessary precondition for adopting reform practices. Both studies also revealed the presence of pedagogical dissatisfaction as a component of adopting non-lecture based practices. However faculty in the case study partitioned their adoption of reform to upper level classes for majors and for non-majors at the introductory level. These faculty hold to a common personal theory about the immutability of the general chemistry course for majors that appears to be linked to their own learning and their practices in their general chemistry courses. Therefore determining whether and to what degree this phenomenon persists throughout the whole academic chemistry community might lead to finding new ways to amplify their dissatisfaction with their general chemistry course practices, leading to systemic reform in undergraduate chemistry.

It is unclear whether the practice of sequestering reform pedagogy to higher academic levels and to non-majors is linked solely to participants’ histories. Many of the participants claimed that they were influenced by both senior faculty and their administrations. Therefore, future studies should focus on triangulating participant conceptions and practices with administrative members’ conceptions and their influence on faculty practices. Careful interviews with members of their administrations appear to be warranted. The literature review given in the introduction of this work indicates that such study of organizational influences would provide greater depth to in-class observations and personal histories in teaching experiences.

Distinctions in practices performed across different institutional levels were observed in this study. However, these observations indicated that faculty appeared to be
influenced more by class size and scale of course organization and coordination rather than by institutional cultures. In contrast to these observations however, some of the faculty admitted in their interviews the existence of organizational influences that were not related to issues of scale. (Note: some of these comments appear in Appendix F.) Therefore future work should explore these findings, specifically whether faculty views about organizational culture compare with observations regarding scale, to determine whether both faculty views and observed distinctions are common. A study that specifically investigates and triangulates faculty views and class characteristics with institutional social-organizational characteristics will help to clarify how these contexts mitigate faculty practice as described by the case study faculty in this investigation.

Since this study revealed that the dominant group comprising academic chemists in the ACS census is not represented in the MIDP workshops, future studies should be directed toward establishing the extent of systemic reform in undergraduate chemistry among this group. Other dissemination projects should compare their demographic results with those presented here to determine what degree the community documented in the ACS census participates in and promotes systemic reform. Given that ACS, as a scientific and scholarly society, purports to support and publishes documents to promote systemic reform, there appears to be an unusual phenomenon that its dominant academic constituent does not.

As mentioned in the last section preceding this chapter, faculty conceptions about how they learned chemistry appear to have an impact on how receptive they are to implement reform pedagogy in the general chemistry course. If this is confirmed by
future research, several actions are recommended. Future reform dissemination programs must address the general chemistry course specifically and the conception that faculty appear to have regarding their own learning experiences as being normative. Constructivist learning theory must be explained to faculty and documentation supporting learning outcomes from the application of process oriented teaching approaches need to be disseminated. The perception that the general chemistry course content must be normative should be approached with diplomacy and with research indicating that this perception is unfounded. Research results that show improved student post-implementation performance both at upper divisions and across different professional examinations, must be published and disseminated.

Chemistry academics have a tendency to value their personal views of their learning experience in general chemistry above consensual data, when considering and valuing teaching approaches. Therefore, faculty also need to be encouraged to distinguish their personal views about their personal experience and personal preferences from those supported by cognitive research and research conducted by chemical education researchers across contexts and people. As scientists, they should be encouraged to value data from the field of chemical educational research that might not coincide with their perception of their personal history of learning chemistry.

Last, administrations should “put money where their mouth is”, that is provide time and additional income to those learning to implement new pedagogy. Rewarding systemic reform monetarily and with time is a clear message of institutional support. Therefore, funding agencies such as NSF, NIH and ACS should continue to solicit and
fund institutions that consistently maintain reform practices in undergraduate chemistry. Furthermore, the case study data in this research has shown that “self reports”—survey data—are insufficient alone to confirm consistent and systemic practice. Thus reports need to be substantiated by funded evaluation field research and evaluation programs conducted by trained researchers in chemical education. Perhaps these are the “institutional factors” that will help to bring about a systemic change of practice in undergraduate chemistry, among the faculty who are the dominant academic constituency of ACS and among the faculty who are not.
REFERENCES

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52. POGIL. *Process Oriented Guided Inquiry Learning*. [cited; Available from: http://www.pogil.org/].


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APPENDICES
APPENDIX A: CHEMICAL THINKING ACTIVITY

Chemical Thinking

Why?
We have been applying fundamental concepts of chemical thinking from the earliest known times in human history. Archaeologists report that our understanding and use of fermentation extends beyond thousands of years. We have purified chemicals such as oils and ointments for medicinal, cosmetic and culinary purposes. Coatings of particular chemicals such as salts, spices, fats and resins have been used for weatherproofing, curing, and general protection from infestation of animals, insects and bacteria. While this knowledge has been acquired over thousands of years, the discipline of chemistry as a science is more recent. We define chemistry as the study of matter and the changes it undergoes. But before we begin to study matter, it is helpful to consider and define what matter is and how to differentiate matter into different kinds of substances.

Learning Objectives
Identify and define matter
Identify pure substances, mixtures, elements and compounds

Success Criteria
Quickly identify kinds of substances such as mixtures, elements and compounds, identify and define matter

New Concepts
Element, compound, pure substance, mixture, physical properties, chemical properties

Vocabulary
macroscopic, nanoscopic, composition, subscript, superscript, mass, weight

Definitions
In your own words, write definitions of matter, atoms and molecules
Model 1: Classification of phenomena
Below is a list of different kinds of phenomena. Create two lists to separate what you might label as matter from what you would not label as matter. Add five more terms to each list of ‘matter’ and ‘not matter’.

Dust
Air
Steam
Electricity
Chirp
Rust
Sunlight
Idea
Pudding
Pain

Key questions
1. What is your criteria, in other words how were you able to distinguish between phenomena falling into these categories of matter and not matter?

2. What is the difference between mass and weight?

3. How would you find the mass of air?
Model 2: Classification of Matter
The table and diagram below show a few definitions of kinds of matter and their relationships. Study this table and diagram and then using this information classify from the list below which is a pure substance and which is a mixture.

### Classification of Matter

<table>
<thead>
<tr>
<th>Pure Substances</th>
<th>Macro Scale</th>
<th>Nano Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
<td>Cannot be broken down into simpler units</td>
<td>Only one kind of atom</td>
</tr>
<tr>
<td>Compound</td>
<td>Fixed composition but capable of being broken down into elements</td>
<td>Two or more elements in fixed combination</td>
</tr>
<tr>
<td>Mixtures</td>
<td>Variable composition of Elements and/or Compounds</td>
<td>Variable assortment of atoms and/or molecules</td>
</tr>
</tbody>
</table>

### Kinds of Matter Relationships

```
HOMOGENEOUS (SOLUTIONS, ALLOYS)

MIXTURES

HETEROGENEOUS

Matter in the Universe

PURE SUBSTANCES

Break down

Two or More

Elements

Compounds

Two or more
```
**List of Substances:**

<table>
<thead>
<tr>
<th>White sugar</th>
<th>Baking Soda</th>
<th>Charcoal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown sugar</td>
<td>Wood</td>
<td>Diamond</td>
</tr>
<tr>
<td>metallic bracelet</td>
<td>Gold</td>
<td>Pencil lead</td>
</tr>
<tr>
<td>metallic earrings</td>
<td>Beer</td>
<td></td>
</tr>
</tbody>
</table>

**Classify these substances into mixtures and pure substances**

**Key Question**
How do you know when something you see is a mixture or pure substance?

**Model 3: Atomic symbolism**

Sometimes it is hard to identify a pure substance from a mixture at the macroscopic level but it can be easier if we tried to identify them at the nanoscopic level. For example below are dots which represent atoms which are the smallest part of an element. One dot is one atom and another similar dot is a different atom of the same element and two dots touching each other represents a molecule where two atoms are chemically bonded.

![Diagram of atoms and molecules](image)

**Atoms of one element**

**Molecules**

**Draw a compound with 3 atoms**
Is this a compound? Why or why not? If it is not a compound how many substances are there?

Properties and Changes in Properties
Definition: Any characteristic that can be used to describe or identify matter is called a property: eg size, amount odor, color, temperature
Properties can also be classified as either physical or chemical depending on whether the property involves a change in the chemical makeup** of a substance.

- **Physical properties** are characteristics that do not involve a change in chemical makeup
- **Chemical properties** are characteristics that do involve a change in chemical makeup

(**A chemical makeup is the composition and combination of atoms in a substance)
Which of the phenomena & items below represent chemical or physical properties?

Gasoline is flammable
Electrically conductive wire
Magnet sticks to fridge
Density of water
Baking soda mixed with vinegar makes bubbles
Sugar tastes sweet
Soap makes bubbles in water

**Exercises:**
1. Classify each of the following as a C (for compound), E (element) and M (mixture)

<table>
<thead>
<tr>
<th>Water</th>
<th>Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>Steel</td>
</tr>
<tr>
<td>Diamond</td>
<td>Pancake syrup</td>
</tr>
<tr>
<td>Milk shake</td>
<td>Gasoline</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Concrete</td>
</tr>
<tr>
<td>Chicken soup</td>
<td>Iron</td>
</tr>
<tr>
<td>Table salt</td>
<td>Candy bar</td>
</tr>
<tr>
<td>Sugar</td>
<td>Chocolate cake</td>
</tr>
<tr>
<td>Ice cube</td>
<td>Lemon</td>
</tr>
<tr>
<td>Diet coke</td>
<td>Wood</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Gold</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Laundry detergent</td>
</tr>
<tr>
<td>Liquid nitrogen</td>
<td>Baking soda</td>
</tr>
</tbody>
</table>

2. Underline each of the following which is not an example of matter.

<table>
<thead>
<tr>
<th>Air</th>
<th>Light</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>heat</td>
<td>Water vapor</td>
<td>Table salt</td>
</tr>
<tr>
<td>paper</td>
<td>Sand</td>
<td>Wood</td>
</tr>
<tr>
<td>dirt</td>
<td>concepts</td>
<td>Soap</td>
</tr>
<tr>
<td>gasoline</td>
<td>sound</td>
<td>sugar</td>
</tr>
</tbody>
</table>
APPENDIX A (continued)

3. Write a C before each of the following statements that describes a chemical property and P before each that describes a physical property.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Chemical Property</th>
<th>Physical Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium metal melts at 64 degrees Celsius</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Sodium metal is soft and shiny</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Water is colorless</td>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Copper sulfate (root killer) is blue</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Ethanol is flammable</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Bromine is liquid at room temperature</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>The density of water is 1 gram per milliliter at room temperature</td>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Magnesium reacts with oxygen</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Lemon juice tastes sour</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Diamonds are hard</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Silver will not react with hydrochloric acid</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Sodium metal can be easily cut with a knife</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Sugar dissolves in hot tea</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Sulfur burns in air forming sulfur dioxide, which is a precursor to acid rain</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

4. A sample of matter that contains only one kind of atom is: (Circle)
   - A solution
   - A homogeneous mixture
   - An element
   - An alloy
   - A compound

5. Write a C before each of the following statements that describes a chemical change and a P before each statement that describes a physical change

<table>
<thead>
<tr>
<th>Statement</th>
<th>Chemical Change</th>
<th>Physical Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit decays</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>A window is broken</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Cream is separated from milk</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Photographic film is developed</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Gasoline is burned in an automobile engine</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Silverware tarnishes</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>An electric iron is heated</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>A potato is cooked in a microwave oven</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>A pen writes</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Dry ice is changed from a solid to a gas</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Hydrogen is burned in air</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Baking soda reacts with acetic acid to produce carbon dioxide &amp; water</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Dew forms on grass</td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>Classified documents are shredded into small pieces of paper</td>
<td>C</td>
<td>P</td>
</tr>
</tbody>
</table>
6. How would you classify these substances according to the table and diagram of kinds of matter?
APPENDIX B: SURVEYS

Surveys pasted into dissertation starting next page.
Multi-Initiative Dissemination Project
Pre-workshop Survey

Please complete the following pre-workshop survey. The information that you provide project evaluators via this survey will be treated as confidential. The information will be compiled and used to create a general picture of MID Project Workshop Attendees. No specific identifying information will be made available to anyone outside the evaluation staff. Direct quotations used for any purpose will remain completely anonymous, that is, there will be no reference to identity or institution of respondents. Thank you for completing this survey.

Important do not press the enter key or the return key while you are answering these questions. Your Browser will interpret either key the same as clicking the mouse on the Submit button. So BE CAREFUL and use the TAB key to move between the fields!

What workshop will you be attending: ____________________________

1a. Your Name: ____________________________

1b. Your ID code is: __________

2. What is your gender?
   Choose…
   Male
   Female

3. What is your ethnic group?

4. In what type of institution do you teach?
   Choose…
   2 Year
   4 Year Undergrad
   4 Year Masters
   4 Year PhD
   High School

5. How long have you been teaching at one college level? (For HS teachers only, how long have you taught HS science?)
   Choose…
   < 1 Year
   1 – 5 Years
   6 – 10 Years
   > Ten Years
4. What is your tenure status?

Choose…

<table>
<thead>
<tr>
<th>Tenured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not yet Tenured</td>
</tr>
<tr>
<td>Not on Tenure Track</td>
</tr>
<tr>
<td>Other (see below)</td>
</tr>
</tbody>
</table>

If you selected other in Question 6, please explain:

7a. What courses do you teach? (please mark all which apply)

- Preparatory
- Chem for liberal arts or nonscience students
- Chem For nursing, allied health, applied biology, etc.
- Science, engineering, pre-professional majors
- Soph., Jr., and Sr. undergrad courses
- Other (please explain)

7b. Please select ONE of the courses that you teach and base the answers to the questions on the rest of this form on that ONE course. Please select one of the following categories that best identifies the course you will be describing.

- Preparatory
- Chem for liberal arts or nonscience students
- Chem for nursing, allied health, applied biology, etc
- Science, engineering, pre-professional majors
- Soph., Jr., and Sr. undergrad courses
- Other (please explain)
7c. What is the approximate enrollment in this course per semester?

Choose…

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 25</td>
<td></td>
</tr>
<tr>
<td>26 - 50</td>
<td></td>
</tr>
<tr>
<td>51 - 75</td>
<td></td>
</tr>
<tr>
<td>75 - 100</td>
<td></td>
</tr>
<tr>
<td>101 - 200</td>
<td></td>
</tr>
<tr>
<td>&gt; 200</td>
<td></td>
</tr>
</tbody>
</table>

8. What would you describe as the most important goal(s) of your chemistry class?


9. What are the most serious challenges you face when instructing your students?


10. How would you describe the climate in your department in terms of faculty engaging in instructional reform?


APPENDIX B (continued)

11. Which of the following teaching techniques do you use to teach in your lecture section? Please click on the appropriate box. Please select the three techniques you think are most effective.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>I use this technique</th>
<th>Three most effective techniques</th>
<th>I don’t know what this is</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Instructor lecturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Students doing writing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Students doing collaborative learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Instructor using conceptual questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Instructor using computer animations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Instructor doing an experiment/demo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Students doing an experiment/demo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. Students following guided inquiry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Students working on worksheets/tutorials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j. Students doing in-class problem-solving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k. Students participating in discussion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>l. Students working at the board or overhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m. Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. If you have recitation/discussion sections associated with your course, are they run by a TA or by you, the instructor?

Choose… ▼

- Run by TA
- Run by Instructor
- We have no recitation discussion sections
- Workshops run by peer facilitators

13. Do you have undergraduate peer facilitators (students who help tutor other undergraduate students)?

Choose… ▼

- Yes
- No
APPENDIX B (continued)

14. Which of the following teaching techniques do you use to teach in your laboratory section? Please select the appropriate box. Also, please rank which three techniques you think are most effective.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>I use this technique</th>
<th>Three most effective techniques</th>
<th>I don’t know what this is</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Students doing pre-lab assignments</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>b. Instructors doing pre-lab instruction</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>c. Students designing an experiment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>d. Students doing verification laboratories</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>e. Students doing demonstrations</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>f. Students doing guided inquiry</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>g. Students doing discovery lab work</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>h. Students preparing a lab notebook</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>i. Students doing multi-week experiments</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>j. Instructors presenting/students doing lessons on laboratory safety</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>K. Other</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

15. Describe any teaching techniques used in your classroom that have not been mentioned.

16. What methods do you currently use to assess student learning? Please click on the checkbox(s) of the choice(s) that best describes your current practices.

a. Examinations

<table>
<thead>
<tr>
<th></th>
<th>I use this technique</th>
<th>Three most effective techniques</th>
<th>I don’t know what this is</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ACS exams</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Multiple choice questions (not ACS)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. Essay or short answer questions</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. ’Show your work’ problems</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
APPENDIX B (continued)

b. Other Activities

| 1. Group assignments, quizzes, or exams | I use this technique | Three most effective techniques | I don’t know what this is |
| 2. Short writing assignments | | | |
| 3. Debates | | | |
| 4. Poster presentations | | | |
| 5. Defense of a position using data | | | |
| 6. Expert group activities (jigsaw) | | | |
| 7. Portfolios | | | |

c. Laboratory Activities

| 1. Group assignments, quizzes, or exams | I use this technique | Three most effective techniques | I don’t know what this is |
| 2. Lab reports | | | |
| 3. Pre-lab quizzes | | | |
| 4. Lab practical exams | | | |
| 5. Expert group activities (jigsaw) | | | |
| 6. Oral examinations | | | |
| 7. Student design and conducting of experiments | | | |

d. Please describe any additional assessment practices you use:


17. Do you use “conceptual questions” or “conceptual understanding questions” in your assessment practices? If no, please go to Question eighteen. If yes, please describe how you characterize a conceptual question:


18. Please rank your familiarity with each of the MID projects before attending this MID workshop by selecting the appropriate boxes.

a. ChemConnections (Chemlinks and MC^2):

<table>
<thead>
<tr>
<th>Choose… ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Familiar</td>
</tr>
<tr>
<td>A Little Familiar</td>
</tr>
<tr>
<td>Somewhat Familiar</td>
</tr>
<tr>
<td>Very Familiar</td>
</tr>
<tr>
<td>Currently Using</td>
</tr>
</tbody>
</table>

b. Molecular Science:

<table>
<thead>
<tr>
<th>Choose… ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Familiar</td>
</tr>
<tr>
<td>A Little Familiar</td>
</tr>
<tr>
<td>Somewhat Familiar</td>
</tr>
<tr>
<td>Very Familiar</td>
</tr>
<tr>
<td>Currently Using</td>
</tr>
</tbody>
</table>

c. New Traditions:

<table>
<thead>
<tr>
<th>Choose… ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Familiar</td>
</tr>
<tr>
<td>A Little Familiar</td>
</tr>
<tr>
<td>Somewhat Familiar</td>
</tr>
<tr>
<td>Very Familiar</td>
</tr>
<tr>
<td>Currently Using</td>
</tr>
</tbody>
</table>

d. PLTL:

<table>
<thead>
<tr>
<th>Choose… ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Familiar</td>
</tr>
<tr>
<td>A Little Familiar</td>
</tr>
<tr>
<td>Somewhat Familiar</td>
</tr>
<tr>
<td>Very Familiar</td>
</tr>
<tr>
<td>Currently Using</td>
</tr>
</tbody>
</table>
APPENDIX B (continued)

19. How did you find out about the MID projects? Please select all boxes that apply.

<table>
<thead>
<tr>
<th></th>
<th>Web site</th>
<th>JCE article</th>
<th>ACS or Gordon Conf.</th>
<th>Colleague</th>
<th>E-mail notice</th>
<th>U.S. mail notice</th>
<th>ACS local notice</th>
<th>Other (please explain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ChemConnections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Chemlinks and MC²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Molecular Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. New Traditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. PLTL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you selected other, please explain below:

________________________________________________________________________________________

20. With which of the MID projects do you wish to become more familiar? (Please select all that apply.)

- ☐ All of them
- ☐ ChemConnections
- ☐ Molecular Science
- ☐ New Traditions
- ☐ PLTL
- ☐ Don’t know – Not familiar enough with them

21. Do we need to change the registration process for the workshop and if so, how?

________________________________________________________________________________________

Submit Form  Start Over
APPENDIX B (continued)

**MIDP Evaluation Form**

**Section 1: Demographics** (Questions 2a – 6c of 32)

2a. Which workshop did you attend? Select all the workshop/presentations you attended.
- Project Kaleidoscope Summer Institute, Snowbird, UT July 22-25, 2001
- Florida Atlantic University Feb 23-24, 2001
- University of Massachusetts at Dartmouth March 23-24 2001
- University of Southern Colorado April 27-28 2001
- Raritan Valley Community College Nov 16-17, 2001
- Project Kaleidoscope Summer Institute, Williamsburg, VA June 2-5, 2002
- TxCEPT, Texas A&M Jan 25-26, 2002
- University of South Florida Feb 22-23, 2002
- The Ohio State University, Columbus March 22-23, 2002
- University of Arizona, Tucson April 26-27, 2002
- University of New Hampshire, Durham, NH Sept 27-28, 2002
- University of Alabama-Birmingham Oct 11-12, 2002
- University of Wisconsin, Madison June 7-9, 2001 (Chem Connections only)
- CSU-Fullerton, June 28-30, 2001 (Molecular Science only)
- Other (not listed) 

2b. Which of the following have you implemented? Check if you have:
- Used project development materials
- Authored your own materials

<table>
<thead>
<tr>
<th>Which of the following have you implemented?</th>
<th>Used project development materials</th>
<th>Authored your own materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibrated Peer Review</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Molecular Science</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Guided Inquiry (GI) Labs</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>GI Chem Activity Worksheets</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Concept Tests</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Peer-Led-Team-Learning</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>ChemConnection Modules</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>A hybrid of the Above</td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>
APPENDIX B (continued)

2c. In how many courses have you used the above teaching strategies?

Choose:…

1

2

3

More than 3

2d. Where have you implemented the above?

- In class/lecture
- In lab
- In recitation
- As homework

3. In what type of institution do you teach?

Choose:…

2 year

4 year undergraduate

4 year Masters

4 year Ph.D.

High school
APPENDIX B (continued)

4. How long have you been teaching? (For HS teachers only: How long have you taught HS science?)

Choose:

- Less than one year
- 1 – 5 yrs.
- 6 – 10 yrs.
- > 10 yrs.

5. What is your tenure status?

Choose:

- Tenured
- Not yet tenured
- Not on tenure track
- Other

6a. Please select one of the courses you teach and base your answers to the rest of this survey on that one course.

- Preparatory
- Chemistry for liberal arts or non-science students
- Chemistry for nursing, allied health, applied biology, etc.
- Chemistry for science, engineering, pre-professional majors.
- Sophomore, Junior, or Senior undergraduate chemistry courses
- Other (Please write in what course is):
6b. What is the approximate enrollment in this course per semester?

Choose:…

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 25</td>
<td></td>
</tr>
<tr>
<td>26 - 50</td>
<td></td>
</tr>
<tr>
<td>51 - 75</td>
<td></td>
</tr>
<tr>
<td>75 - 100</td>
<td></td>
</tr>
<tr>
<td>101 - 200</td>
<td></td>
</tr>
<tr>
<td>&gt; 200</td>
<td></td>
</tr>
</tbody>
</table>

6c. If you have a recitation/discussion section associated with your course, indicate by choosing the appropriate box.

Choose:…

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>There are no recitation sessions</td>
<td></td>
</tr>
<tr>
<td>The instructor is a teaching assistant</td>
<td></td>
</tr>
<tr>
<td>I am the instructor</td>
<td></td>
</tr>
<tr>
<td>Another faculty member is the instructor</td>
<td></td>
</tr>
<tr>
<td>Peer facilitators are used</td>
<td></td>
</tr>
</tbody>
</table>
Section 2: Goals

7. List the most important goals you hope to accomplish in your chemistry class. Place a (1) after the goal of highest priority, a (2) after the second highest, etc.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
</tr>
</tbody>
</table>

Section 3: Innovation within the Institution

8. Innovative teaching is a high priority at my institution among the following: (Check all that apply)
   - Myself
   - Higher administration
   - My dean
   - My chair
   - A majority of my colleagues
   - Support staff
   - Teaching assistants
   - None of the above
   - Other: ____________________________

9. Support for innovative teaching at my institution is shown by the following: (Check all that apply)
   - Availability of internal grants
   - Availability of released time for curriculum development
   - Availability of professional development workshops on campus
   - Availability of travel support for faculty development
APPENDIX B (continued)

- Importance in tenure and promotion considerations
- Importance in yearly evaluations and salary considerations
- None of the above
- Other: 

10. How interested are your colleagues in trying innovative teaching methods? (Check all that apply.)
- One or more of my colleagues are interested
- No one appears to be interested
- One or more of my colleagues are hostile to new teaching methods
- My colleagues are neutral about new teaching methods
- Comments: 

---

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Section 4: Teaching Practices

11. Questioning Techniques

<table>
<thead>
<tr>
<th>In my course:</th>
<th>I use this technique:</th>
<th>I believe this technique to be:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily</td>
<td>Weekly</td>
</tr>
<tr>
<td>1. I ask questions during class in which a response is expected of each student</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. I record students responses to questions in some manner</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. I use student responses to determine whether a topic has been understood</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4. I use student responses to questions to introduce new topics</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>5. I base instructional decisions on student responses to questions</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>6. I have students discuss the questions with each other</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>7. I use questions to introduce new topics</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>8. I use common student misunderstandings to structure in-class discussion</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
### 12a. Group work

<table>
<thead>
<tr>
<th>In my course, group work occurs:</th>
<th>Daily</th>
<th>Weekly</th>
<th>2 times or more per semester</th>
<th>Never</th>
<th>Very effective</th>
<th>Somewhat effective</th>
<th>Not effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. In lecture</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. In lab</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. In recitation / discussion</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

### 12b.

<table>
<thead>
<tr>
<th>When I use groups....</th>
<th>The groups have peer leaders</th>
<th>The peer leaders trained</th>
<th>The group members have assigned roles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1. In lecture</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. In lab</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. In recitation / discussion</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4. Via computer</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

### 12c. If students work in groups, please indicate your typical group size.

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3-4</th>
<th>5-6</th>
<th>7-8</th>
<th>&gt;8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. In lecture</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. In laboratory</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. In recitation / discussion</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4. Via computer</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
## 13. Real world applications

<table>
<thead>
<tr>
<th>In my class:</th>
<th>I use this technique:</th>
<th>I believe this technique to be:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily</td>
<td>Weekly</td>
</tr>
<tr>
<td>1. I introduce concepts using real world examples</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. I use real world examples as extensions after teaching a concept</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. I use real world questions to drive the chemistry course concepts</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

## 14. In a non-testing situation, I use writing assignments…

<table>
<thead>
<tr>
<th>I use this technique:</th>
<th>I believe this technique to be:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily</td>
</tr>
<tr>
<td>1. To give a factual answer or definition</td>
<td>□</td>
</tr>
<tr>
<td>2. To have students compare and contrast concepts</td>
<td>□</td>
</tr>
<tr>
<td>3. To explain the logic behind an answer</td>
<td>□</td>
</tr>
<tr>
<td>4. To have students explain the chemistry in a real world application</td>
<td>□</td>
</tr>
</tbody>
</table>
(Question 14 Continued)

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. To help students organize what they know</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. To have students explain what they don’t understand (example: one minute paper)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. To have students explain or share knowledge with their peers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For other reasons:
## 15. Teaching Techniques

<table>
<thead>
<tr>
<th>I use this technique:</th>
<th>Daily</th>
<th>Weekly</th>
<th>2 times or more per semester</th>
<th>Never</th>
<th>I believe this technique to be:</th>
<th>Very effective</th>
<th>Somewhat effective</th>
<th>Not effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I lecture most of the period</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. I give brief mini lectures as needed</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. I have teacher led demonstrations</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. I have student led demonstrations</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. I use computer animations</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. I have students solving problems individually in class</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. I have students solving problems in groups in class</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
### 16. Laboratory practices

<table>
<thead>
<tr>
<th>In my course...</th>
<th>I use this technique:</th>
<th>Daily</th>
<th>Weekly</th>
<th>2 times or more per semester</th>
<th>Never</th>
<th>I believe this technique to be:</th>
<th>Very effective</th>
<th>Somewhat effective</th>
<th>Not effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Laboratory experiments introduce or develop a concept rather than confirm it.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Laboratory experiments lead students to develop data-handling analytical skills or investigative strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Laboratory experiments lead students to develop an understanding of the scientific method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The outcome of laboratory experiments is unknown to students before they gather the data.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5. Laboratory experiments require students to pool data in order to see the desired pattern/outcome</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Section 5: Assessment

17. Which of the following methods do you currently use for assessing student learning? Check whether the assessment occurs on an individual basis or on a group basis or both, and check all that apply. Also, please mark with an ‘x’ the three methods you think are the most effective, whether on an individual basis or on a group basis.

<table>
<thead>
<tr>
<th>Method</th>
<th>Individual Use</th>
<th>Best 3?</th>
<th>Group Use</th>
<th>Best 3?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple choice questions on exams / quizzes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Multiple choice questions on exams/ quizzes for which students explain their choices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Essay or short answer questions on exams / quizzes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Conceptual questions on exams / quizzes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. “Show your work” problems on exams / quizzes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. ACS standardized exams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Short writing experiences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Oral presentations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Poster presentations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Debates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Guided Inquiry ChemActivity worksheets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Participation in Peer-led team-learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18. Please use this space to describe more fully any other assessment practices you use to assess student learning.
APPENDIX B (continued)

19. Have your assessment practices changed in the past two years since attending the MID workshop? If so, please comment on how they have changed.

20. What factors have influenced this change? Please check all that apply and mark with an ‘X’ the top three factors in terms of their importance to you.

<table>
<thead>
<tr>
<th>Use</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Attendance at MID workshop</td>
<td></td>
</tr>
<tr>
<td>2. Implementation of one or more of the 4 MID projects</td>
<td></td>
</tr>
<tr>
<td>3. Attendance at another workshop/presentation</td>
<td></td>
</tr>
<tr>
<td>4. Dissatisfaction with previous methods</td>
<td></td>
</tr>
<tr>
<td>5. Difference in skill level of current students.</td>
<td></td>
</tr>
<tr>
<td>6. Policy change within department or institution</td>
<td></td>
</tr>
<tr>
<td>7. New testing materials provided by publisher</td>
<td></td>
</tr>
</tbody>
</table>

Section 6: Barriers to Implementation (Questions 22 – 29 of 32)

22. Curricular materials

<table>
<thead>
<tr>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project materials that I am interested in do not exist for the course I am teaching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The materials are too expensive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The publisher doesn’t have the materials I am requesting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 23. Scheduling and staffing issues

<table>
<thead>
<tr>
<th>Problem</th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. There is insufficient support staff</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2. I am unable to schedule computer facilities</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3. The setup of available rooms/labs does not support the project I am interested in</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4. There is insufficient financial support at my institution</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

### 24. Facilities

<table>
<thead>
<tr>
<th>Problem</th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The available computer facilities are not adequate</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

### 25. Time

<table>
<thead>
<tr>
<th>Problem</th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Too much time is required to get project started</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2. Too much time is required to use project on a regular basis</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3. I would be required to teach course beyond my standard teaching load</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
### APPENDIX B (continued)

#### 26. Established Curriculum

<table>
<thead>
<tr>
<th>Implementing a project requires that .....</th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I eliminate content that I want to include</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2. I eliminate content that is expected to be covered in the course</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3. I modify project materials which are too difficult for my students</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4. I modify project materials which are too easy for my students</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>5. I convince other faculty members who oppose the project and who teach the same course</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

#### 27. Student Response

<table>
<thead>
<tr>
<th>To implement the project...</th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I <em>anticipated</em> significant student resistance to change</td>
<td>□</td>
<td>□</td>
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<tr>
<td>2. I <em>experienced</em> significant student resistance to innovative teaching</td>
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<tr>
<td>3. I anticipated negative student response on course evaluations</td>
<td>□</td>
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<td>4. I didn’t expect significant student response one way or the other</td>
<td>□</td>
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### 28. Support

<table>
<thead>
<tr>
<th></th>
<th>Major Problem, prevents innovation</th>
<th>Major Problem, but surmountable</th>
<th>Minor Problem / No Problem</th>
<th>Not Applicable</th>
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</thead>
<tbody>
<tr>
<td>1. I lacked sufficient knowledge concerning the project of interest</td>
<td>□</td>
<td>□</td>
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<tr>
<td>2. I lack access to colleagues implementing similar projects</td>
<td>□</td>
<td>□</td>
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<tr>
<td>3. I lack continuing access to project leaders/presenters</td>
<td>□</td>
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<tr>
<td>4. Colleagues and/or administrators lack sufficient understanding of the project</td>
<td>□</td>
<td>□</td>
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<tr>
<td>5. Innovative teaching is not valued in promotion and tenure decisions</td>
<td>□</td>
<td>□</td>
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</table>

### 29. Are there any additional barriers that discourage you from implementing innovative teaching practices at your institution? Please explain what you have encountered.

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**APPENDIX B (continued)**

### Section 7: Dissemination
(Questions 30 – 32 of 32)

30. Do you plan to continue with the innovations you have implemented and if so, what additional help do you need for this additional implementation?

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Continue?</th>
<th>Help needed</th>
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<tbody>
<tr>
<td>1.</td>
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<td>2.</td>
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<tr>
<td>3.</td>
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<tr>
<td>4.</td>
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</table>

31. How have you communicated the success you have experienced with your innovations?
- I have not told others of innovations I have tried in the past two years
- I have discussed my innovations informally with a colleague
- I have presented my innovations in a seminar to the department
- I have presented my innovations at a regional professional meeting
- I have presented my innovations at a state or national professional meeting
- I have written a paper for publication describing my innovations
- I have conducted a research experiment investigating the effects of my innovations
- I have written a research paper based upon my investigation of the effects of my innovations
- I have implemented innovations but have not publicized what I have done
- Other: 

32. Please describe any other ways attending the MID workshop has influenced your thinking or practice as a teacher.
Online Survey System

MID Project Follow-Up Survey

Participant Identification
Please enter your name below. (Your name will be removed from the file once it has been matched with your assigned identification number)
First name: ___________________________ Last name: ___________________________

Section 1: Approaches to Teaching Inventory (Questions 1a – 2 of 4)
This inventory is designed to explore the way that academics go about teaching in a specific context and/or subject. This may mean that your responses to these items may be different to the responses you might make on your teaching in other contexts or subjects.

1a. Please select one of the courses you teach and base your answers to these questions on that one course.

- Preparatory.
- Chemistry for liberal arts or nonscience students.
- Chemistry for nursing, allied health, applied biology, etc.
- Chemistry for science, engineering, preprofessional majors.
- Sophomore, Junior, or Senior undergraduate chemistry courses.
- Other (Please write in what course is) ___________________________

1b. What is the approximate class size in this course?

<table>
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<tr>
<th>Choose…</th>
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<tr>
<td>1 - 25</td>
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<td>26 - 50</td>
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<td>51 - 75</td>
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<td>75 - 100</td>
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<tr>
<td>101 - 200</td>
<td></td>
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<td>&gt; 200</td>
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</table>
APPENDIX B (continued)

2. For each item please select one of the numbers (1 – 5). The numbers stand for the following responses:

1. this item was only rarely true for me in this subject.
2. this item was sometimes true for me in this subject.
3. this item was true for me about half the time in this subject.
4. this item was frequently true for me in this subject.
5. this item was almost always true for me in this subject.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>1. I design my teaching in this subject with the assumption that</td>
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<td>most of the students have very little useful knowledge of the</td>
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<td>topics to be covered.</td>
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<td>2. I feel it is important that this subject should be completely</td>
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<td>described in terms of specific objectives relating to what</td>
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<td>students have to know for formal assessment items.</td>
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<td>3. In my interactions with students in this subject I try to</td>
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<td>develop a conversation with them about the topics we are</td>
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<td>studying.</td>
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<td>4. I feel it is important to present a lot of facts to students</td>
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<td>that they know what they have to learn for this subject.</td>
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<td>5. I feel that the assessment in this subject should be an</td>
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<td>opportunity for students to reveal their changed conceptual</td>
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<td>understanding of the subject.</td>
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<tr>
<td>6. I set aside some teaching time so that the students can</td>
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<td>discuss, among themselves, the difficulties that they</td>
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<td>encounter studying this subject.</td>
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<td>7. In this subject I concentrate on covering the information</td>
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<td>that might be available from a good textbook.</td>
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<td>8. I encourage students to restructure their existing knowledge</td>
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<td>in terms of the new way of thinking about the subject that</td>
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<td>they will develop.</td>
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<td>9. In teaching sessions for this subject, I use difficult or</td>
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<td>undefined examples to provoke debate.</td>
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<td>10. I structure this subject to help students to pass the</td>
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<td>formal assessment items.</td>
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<td>11. I think an important reason for running teaching sessions</td>
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<td>in this subject is to give students a good set of notes.</td>
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<td>12. In this subject, I only provide the students with the</td>
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<td>information they will need to pass the formal assessments.</td>
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<td>13. I feel that I should know the answers to any questions that</td>
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<td>students may put to me during this subject.</td>
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<tr>
<td>14. I make available opportunities for students in this subject</td>
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<td>to discuss their changing understanding of the subject.</td>
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<td>15. I feel that it is better for students in this subject to</td>
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<td>generate their own notes rather than always copy mine.</td>
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<tr>
<td>16. I feel a lot of teaching time in this subject should be</td>
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<td>used to question students’ ideas.</td>
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</table>
Section 2: MID Project Workshop Inventory

3. What did the MID Project workshop provide that was helpful to you? (Please select all that apply)
   - The opportunity to work with colleagues who shared my vision of teaching and learning.
   - The opportunity to experience my own learning processes
   - Information on teaching and learning research
   - Information on changing assessments
   - Specific materials from the projects that I could use or adapt
   - Ideas about how to implement what I wanted
   - Experiencing ideas I'd heard before
   - Reinforcement of what I already knew
   - Seeing that so many people were involving in changing how we teach
   - Nothing
   - Other: 

4. What changes have you implemented in your class(es) as a result of attending the workshop? (Please select all that apply)
   - Use collaborative learning in class
   - Greater focus on active learning in class
   - Use materials from one or more of the projects
   - Base instructional decision on student responses to questions
   - Use questions to introduce new concepts
   - Use common student misconceptions to structure in-class discussions
   - Use real world questions to drive the learning of concepts
   - Lecture less and do more "just in time" teaching
   - Have students do more problem solving in groups
   - Changed my assessments
   - Implemented my own version of more active learning
   - No change
   - Other: 
   - Ask questions to elicit student ideas

[Submit Survey]
APPENDIX C: RUBRIC OF INTERVIEW QUESTIONS-SEMI STRUCTURED

How would you describe yourself as a Chemistry teacher
What role model do you have for yourself as a chemistry teacher?
When you have your classroom running the way you like, what do you see happening?
How long did it take to develop this model of teaching?
What principles of teaching chemistry do you think are important?
How do you learn chemistry best?
How do you know when you have learned chemistry?
What are characteristics of a good learner?
Do you think other places where you have taught before been an influence on your current teaching practices?
How are chemistry models arrived at?
What are models in chemistry?
What is chemistry?
How is chemistry different or similar to learning mathematics or biology or history (or physics)?
What do you think students will take out of their general chemistry classroom?
What was your best teaching experience?
How do you decide what to teach or not teach?
How do you decide when to move from one concept to another?
Are there any things happening locally in this institution that affect your teaching?
How do you overcome these constraints?

How do you know when your students understand a concept?
How do you believe your students best learn chemistry?
In what ways do you manipulate the educational environment to maximize student understanding?
What chemistry concepts are important for your students to learn?

What are your main strengths as a teacher?
When did you realize that you were having a positive effect on your students and satisfied that you were doing the right thing?

How would you slice up a pie chart to indicate the amount of influence your undergraduate training vs your graduate training vs your on the job experience had on your teaching practices?

What have been the greatest influences on your teaching approach in (general) chemistry?
Were your undergraduate course experiences beneficial to you when you began teaching?
What changes would you make to your chemistry text book?
What criteria do you use to choose chemistry textbooks?
APPENDIX D: CODING RUBRIC AND DEVELOPMENT OF CODING PRACTICES

These broad themes of codes were developed sequentially order over time and represent a sample of the coding schemes used to categorize the qualitative data. The ‘first categorization’ of data was the first attempt to categorize data early in the collection phase. Few categorizations were generated and those that were generated were very broad until trends began to be observed. These trends became more observable as data was collected, and subsequently, the application of the in-class protocol adapted to gain more detail. The second categorization took place after several faculty had been observed and detailed data was collected and organized into categorizations. Greater refinement was achieved in the third level or ‘third categorization’, which was the level of categorization conducted later in the collection and analysis phase. For example, records of numbers of questions faculty asked were taken and categorized under “Lecture-interactive”. The broad category of learning was refined to observations and categorizations of specific kinds of learning, such as undergoing parts of the learning cycle. This was determined by the amount of time students spent in the processes of discovery or concept building. The rationale for this approach is described more fully in the rationale and methods section.
First Categorization
1: Pedagogy
2: Nature of Science
3: MIDP content
4: Teaching Rationale
5: Learning
6: Teacher Characteristics
7: Learner Characteristics

Second Categorization
Code 1 Perception of their pedagogy relative to MIDP promoted pedagogy
Code 2 Perspective of MIDP pedagogy
Code 3 Pedagogical knowledge
Code 4 Content knowledge
Code 5 Pedagogical Content knowledge
Code 6 Implemented pedagogy
Code 7 Nature of Science
Code 8 Learning
Code 9 Rationale for instruction
Code 10 Conceptions of teaching science
Code 11 Learner characteristics
Code 12 Preferred instructional techniques
Code 13 Metaphor use
Code 14 Student-student interactions
Code 15 Teacher-student interactions
Code 16: Learner actions
Code 17: Questioning Practices

Third Level Categorization
Code 17: Kinds of Questions Asked
   Teacher/transmission oriented
   Algorithmic
   Low Cognitive Skills questions
   Student/Conceptual Change-oriented
   High Cognitive Skills questions

Code 8: Learning
   Analysis Critical Thinking
   Process learning-Learning cycle
   Surface-memorizing
   Applying given rubric
   Devising rubric

Code 11: Learner characteristics
APPENDIX D (continued)

Ethnicity
Sex
Temperament
On task

Code 6: Implemented pedagogy
Lecture
Lecture intervals
Lecture intervals-collaborative learning
Lecture-Interactive
Collaborative learning groups

The following provides an example of how the coding rubric was applied to qualitative data. First the collection of qualitative data is described then examples of data are provided.

A general protocol was followed that entailed first writing notes that captured details of the physical aspects of the room, followed by physical characteristics of the students (number, sex and visible ethnicity and age), where they sat and how they positioned themselves to each other and to the teacher. The researcher’s perspective might be different depending on their position in the classroom therefore the position of the researcher varied on each class observed but not during the class. Next, notes were taken on the acoustics in the room and the noise-behavior of the students as the class began. Teacher appearance, behavior, voice modulation, gestures and apparent emotional tone were noted. If questions were asked and answered, teacher and student behavioral interactions including voice qualities and tone were noted, whether they conveyed enthusiasm or uncertainty. Notes were taken of class content that were written or projected on the board or overhead or screen. If demonstrations were used they were fully described in the notes. If particular students dominated questioning or the classroom
setting they were also described more fully including details of how they related to the teacher. Before or after class, the researcher might speak briefly to the teacher. These brief conversations were also included in the notes. Depending on the day’s schedule, “brain dumping”—any information that can be remembered that wasn’t captured in the moment during class was written down as soon after class as possible. A class synopsis was generated usually as part of the brain dumping procedure that summarized the notes. Occasionally the synopsis also had a commentary on what took place in the classroom, explaining the researchers’ perspectives on what took place in the classroom.

One of the earliest data collected were in Greg’s class. His class was the most complicated to record because it entailed group learning and many different “micro” situations occurred simultaneously in response to Greg’s facilitation. The description of the first class recorded includes a description of the conversation in which the researcher solicited him to participate in the study.

**************************************************************************Data Begins**************************************************************************

10/10/04

Initial Solicitation and Talk

This is the description of the discussion that took place with Greg just after the solicitation for him to participate in the study which he immediately accepted. Notes were written down immediately after our talk.
Greg initially asked what the study was about. I mentioned that I wanted to learn about MID Project participants’ teaching philosophy and practices in the classroom.

Greg stated that he wasn’t sure that his class would tell me anything because it wasn’t exemplary of the kind of things promoted in the MID Project. I responded that his perspective was similar to other MIDP participants that I have spoken to however what he thinks and how he has or has not used the MIDP materials was important information to help dissemination programs learn what is helpful and what isn’t and that this information needs to get out.

He mentioned that he felt that he didn’t learn very much from the MIDP workshop other than the peer-leading group method of learning. This was because he had already learned quite a lot from earlier experiences of implementing new methodologies. He said that he tried “something” ten years ago however the students weren’t ready for the methodology (I believe it was group learning) and they complained. Greg mentioned that “you have to eat what you do” and that “you’re trying to feed an entire family” therefore the “ramifications can be very extensive”. Therefore he reasoned that one cannot startup some methodology without considering the ramifications. He mentioned that students need to have familiarity with the methodology before they come to the university level. By having the methodology in the K-12 learning experience, they would be better prepared to enter into group learning at the university level without all the difficulties they had in their previous experiences. At this time (and without earlier experiences of the methodology in the K-12 schooling), he felt that “students aren’t ready for that stuff”.

I said to Greg that I hoped one result of this study would be to communicate his experience and thoughts to others, for example in the K-12 school systems in order to encourage better preparation of students for the university level learning experience. At the end of this talk Greg said that he was looking forward to our future talks.

10/11/04

I arrived five minutes late for Greg’s class. Students are seated at tables, 4-5 students per table. Greg is speaking to the class:

What is your dew point?

Students appear to be working in teams and discussing. Students are being directed to explain why they are doing what they are doing to answer the question. There is writing already on the board, a list of terms:

Condensation
Evaporation
Heat capacity
Humidity
Pressure
Density

Greg is asking students:
“What temperature are you looking for?” He is going around tables students are freely asking him questions as he comes around and he appears to be asking them questions in response to their questions. The two people at the table immediate to the left of me appear to be off task and are talking about what they did last weekend.

There is a lot of talking and I hear Greg’s voice intermittently above the students’ voices: “Sixteen point five grams per cubic centimeter”. Then as he sees different numbers obtained in different groups he asks the class: “How come we are getting different numbers?”… “Estimate…what do you do to estimate?”… “Do you have to use a scale?...Describe how to use the graph.”

Greg appears to be a little frustrated he pacing around and his voice is a little louder. Twenty grams of water is in the air, at what temperature will air hold twenty grams of water? A team of students call out “77” and students at a table near them ask, “how did you get that?” After that they are back to discussing their numbers.

Greg admonishes one team who appear not to be discussing the problem. He asks them how come they’re not engaged. But the students protest, they say they are engaged. Then Greg asks the class what are you going to see at this temperature? Rain or Dew?” Greg calls on specific students by name. Then Greg asks the class to “tie the ideas together”. A student asks Greg a question and he repeats it aloud saying this is a good question. The question is does the graph they are using involve pressure. He answers that the curve in the graph involves pressure but that pressure is not explicitly written on the graph they’re using.

Greg is using the overhead to connect the ideas. The overhead is a graph which the students appear to have hard copies in their materials. He points to the graph and assigns teams to explain the parts of the graph. The handout is a graph on weather showing how air circulates over the surface of the earth, goes up into the sky forming clouds. Cooler air causes precipitation, hot air makes the moister rise.

Teams are combined (some students move to join other groups) the two students to the left of me get up to move elsewhere but they pause and seem not to want to join any group. Both of these students, a male and female (“James and Cindy”), seem to be ethnic minorities in appearance (and may possibly be the same ethnicity) and were the students
who were off task described previously. After hesitating, the female asks Greg, “do we have to join another group, there’s no room”. Greg doesn’t force them to join.

The students’ task are to describe the relationships on the graph and what the words mean regarding the physical properties written on the board and in the physical properties content in their handout. Students are given 4 minutes.

At the table directly in front of me all of the students appear to be white in ethnicity. One male and four females and the male appears to be explaining to the females the physical dynamics of the weather system.

At the table to my left James and Cindy are comparing ID card pictures.

At the table to the front right are four students (all females) who appear to be a mixture of ethnicities and who have spent almost the entire time reading silently their handouts. Now nearing the end of their time to come to some consensus they are beginning to discuss but are reading aloud.

Greg asks the group at a table furthest from me at the opposite side of the room “How are you doing?” he is asked a question and he is talking but I hear only part of his answer “……depending on how much water…..”

James and Cindy are talking about their weekend.

Greg asks the class: “Ok how are we doing?” There is no general response. At a table near Greg are three students who ask a question I cannot hear them. At a table behind James and Cindy are three students, also ethnic minorities in appearance and all males. One of the students (Tom) at this table asks, “what are we supposed to do?”

Greg answers, “Real weather versus what we see in this little cartoon…What does this figure represent?” Then Greg asks the table with the one male and four females to answer they look a little surprised and attempt an answer but it is apparently wrong. A couple of females at this point quietly giggle. Then Greg asks a question and pauses for a moment and then answers it himself: What are we talking about? [with emphasis in his voice lowered in tone] Thunderstorms! Then Greg asks Tom, “What happens when the sun hits the surface?” Tom answers that the water rises (“water rises” is written on the graph on the overhead) Greg asks Tom again “what’s going on?” and Tom answers “the water is rising up”. Greg responds, “like the ten commandments?” Students at several tables laugh and then they respond, “the water evaporates”.

Greg asks, “what’s involved in evaporation?…make a connection with the terminology.” The male at the table with four females attempts an answer but it is wrong, the same two
females at that table are silently giggling again. Greg provides a scenario to the class, “there are couples on a dance floor...what happens when it gets hot?...what happens between the dancers? The dancers are spreading out, when they are moving more energetically, they need more space.”.... “Now what happens to the density when you heat air?...How does this relate to pressure?”

The male at the table with four females asks the females, “do we know what pressure is guys?” Greg asks this table for the definition of density. They respond “concentration of a substance in another substance”

Then Greg addresses the other teams: “what do the other teams think about this?” The students at the table across and at the opposite side of the room have a dictionary open and respond, “amount of material per unit space” Greg interjects, “in this case volume”. Greg continues, “mass over volume, what does it mean in terms of the compounds in the atmosphere?” Students at various tables respond, “lower pressure means less density”. Then Greg asks, “what about high pressure in the atmosphere?” Students don’t respond. Greg writes the same question on the board and then states, “let’s think about heat, remember the example with the dancers on the dance floor?...you have the same volume but the number {‘of dancers’ ? (but not stated in my notes)} increases”.

Greg writes on the board: 100/500 100/1000 and then states “Do the math...math is good...what is the number...I want a number...which has the higher density?” The students get out their calculators and are pressing buttons. Greg gives two answers 0.2 g/cc and 0.1 g/cc respectively written on the board, then he states, “therefore the first one is the more dense...therefore if we heat molecules density will decrease. {but I have written in my notes that he said increase and I don’t know if this is my mistake or Greg’s} Then Greg continues, “think of a hot air balloon...hot air rises...and as part of the air is hot moisture.”.... “Ok, what things are going to affect pressure?...Students are not responding and Greg makes a decision, “Do this as your homework...what affects pressure and explain why...that way you will be more engaged with the process.” Students appear not to want the work as homework and appear to be discussing among themselves possible responses.

I left at this point approximately 5 minutes before the end of class. Total in-class time was 40 minutes out of a 50 minute class. I noted that there were 28 students in all in the class and 8 of the 28 were visible minorities.
APPENDIX D (continued)

Interpretation of the class activities: (synopsis)

There appears to be some reluctance in the class for the minorities to sit with non-minorities.

Students appear to be seated where they want to sit and the “teams” appear to be informal. Therefore this pedagogy may have some resemblance to group learning but not necessarily to the pedagogy presented in the MID Project workshops. I think that this activity might have resembled process (discovery and understanding) inquiry more if the students had not been confused with the intention of the activity.

In the table nearest front (one male and four females): while the male appears to be “taking charge” he also appears not to have a strong understanding of the material. While at least a couple of the females appear to have some humor about this situation they still appear to be ready to defer to his answers. On one occasion Greg asked one of the females a question and she immediately looked to the male student for help.

Males generally appear to be more willing to speak out, however the student who read out of the dictionary the definition of density was female.

James and Cindy were off task for the entire period and they were not called on or asked to become more “engaged”.

Generally, students appear to have been more confused rather than “not engaged”. In the numerical example that Greg used to demonstrate density, he varied the volume to show differences in density. However, the non-numerical model did not match (and hence did not reiterate) the numerical model because in the scenario he gave, the volume (the dance floor) was constant but the number of dancers were varied.

While students were told to make links between the terms and the process depicted in the diagram, they indicated that they did not understand what was expected of them. On several occasions they offered their ideas but had difficulty drawing the relationships between terms and the process depicted in the diagram. Instead, when asked to describe what they saw in the diagram they used words written in the diagram itself rather than cross link with a separate list of terms. Perhaps more explicit instructions such as “instead of using the terms written in the diagrams I would like you to use the terms written on the list to describe the processes depicted on the diagram. Or “Use your knowledge of the terms in the list to help you describe the processes in the diagram.” However this task may still be difficult for the students to achieve without scaffolding by using examples and questions that would lead the students to make the links.
APPENDIX D (continued)

The analogy, “rising like the ten commandments”, confounded me, however the students appeared to know what Greg wanted for a response. The use of the ‘ten commandments’ appeared to have a more immediate positive effect to obtain the desired student responses than the dance floor analogy (when discussing evaporation). This difference may be related to the differences in meaning of the dance floor analogy to the students and Greg. When I have seen people of the students age dancing on a dance floor, they are often dancing very closely (constantly touching and bumping) and energetically. The sort of dance that Greg described sounded more like the popular dance of an older generation (e.g. “swing dancing”), where dancing “energetically” required “more space” for the dancers to move.

The relationship I believe that Greg wanted to link was between density and pressure. Hot air has hot “energetic” molecules (e.g. hot water molecules) that require “more space” therefore involve a decrease in density and an increase in pressure. The decrease in density suggests that the less dense air will rise. The hot moisture in the air will accumulate and eventually will fall back to the earth when there is sufficient amount of moisture in the air (increase in density and lower pressure). However the analogies used, dance floor and hot air balloon, involved relatively constant volumes (e.g. closed systems). Students may have been experiencing difficulty making the links with the analogies to the diagram depicting an open system such as the atmosphere.

Four days after observing this class Greg mentioned that I should have come to the subsequent class (on a later occasion) because the class “went much better”. I couldn’t tell from this statement whether he meant he was better or the students or both. Greg seems a little concerned that I didn’t see a better example of his teaching so I reassured him that I was going to come on more occasions.

Initially, as part of the process of transforming the raw data to data used for analysis and triangulation, a color coding scheme was used to color the text. Below is an example of the color scheme used. The scheme was used initially when the study was still underway and the majority of the data was yet to be collected. Later the color scheme was abandoned and code words or numbers were used within the synopsis itself when it was written shortly after class.
Coding Colors

**Broad Code/Schemes:**
- C/S 1: Pedagogy
- C/S 2: Nature of Science
- C/S 3: MIDP content
- C/S 4: Teaching Rationale
- C/S 5: Learning
- C/S 6: Teacher Characteristics
- C/S 7: Learner Characteristics

**Specific Codes:**
- Code 1 Perception of their pedagogy relative to MIDP promoted pedagogy
- Code 2: Perspective of MIDP pedagogy
- Code 3 Pedagogical knowledge
- Code 4 Content knowledge
- Code 5 Pedagogical Content knowledge
- Code 6 Implemented pedagogy
- Code 7 Nature of Science
- Code 8 Learning
- Code 9 Rationale for instruction
- Code 10 Conceptions of teaching science
- Code 11 Learner characteristics
- Code 12 Preferred instructional techniques
- Code 13 Metaphor use
- Code 14 Student-student interactions
- Code 15 Teacher-student interactions
APPENDIX D (continued)

Below is the text of Greg’s class that had been partially coded using the color scheme. The example shown here depicts how the solicitation and class activities were coded. ‘Pedagogy’, ‘learning’, ‘MID Project content’, ‘teacher rationale’, ‘learner characteristics’ and ‘pedagogical content knowledge’ were color coded in this example.

10/10/04
Initial Solicitation and Talk

This is the description of the discussion that took place with Greg just after the solicitation for him to participate in the study which he immediately accepted. Notes were written down immediately after our talk.

Greg initially asked what the study was about. I mentioned that I wanted to learn about MID Project participants’ teaching philosophy and practices in the classroom.

Greg stated that he wasn’t sure that his class would tell me anything because it wasn’t exemplary of the kind of things promoted in the MID Project. I responded that his perspective was similar to other MIDP participants that I have spoken to however what he thinks and how he has or has not used the MIDP materials was important information to help dissemination programs learn what is helpful and what isn’t and that this information needs to get out.

He mentioned that he felt that he didn’t learn very much from the MIDP workshop other than the peer-leading group method of learning. This was because he had already learned quite a lot from earlier experiences of implementing new methodologies. He said that he tried “something” ten years ago however the students weren’t ready for the methodology (I believe it was group learning) and they complained. Greg mentioned that “you have to eat what you do” and that “you’re trying to feed an entire family” therefore the “ramifications can be very extensive”. Therefore he reasoned that one cannot startup some methodology without considering the ramifications. He mentioned that students need to have familiarity with the methodology before they come to the university level. By having the methodology in the K-12 learning experience, they would be better prepared to enter into group learning at the university level without all the difficulties they had in their previous experiences. At this time (and without earlier
APPENDIX D (continued)

experiences of the methodology in the K-12 schooling), he felt that “students aren’t ready for that stuff”.

I said to Greg that I hoped one result of this study would be to communicate his experience and thoughts to others, for example in the K-12 school systems in order to encourage better preparation of students for the university level learning experience. At the end of this talk Greg said that he was looking forward to our future talks.

10/11/04 Greg’s Class

I arrived five minutes late for Greg’s class. Students are seated at tables, 4-5 students per table. Greg is speaking to the class:

What is your dew point?

Students appear to be working in teams and discussing. Students are being directed to explain why they are doing what they are doing to answer the question. There is writing already on the board, a list of terms:

Condensation
Evaporation
Heat capacity
Humidity
Pressure
Density

Greg is asking students: “What temperature are you looking for?” He is going around tables students are freely asking him questions as he comes around and he appears to be asking them questions in response to their questions. The two people at the table immediate to the left of me appear to be off task and are talking about what they did last weekend.

There is a lot of talking and I hear Greg’s voice intermittently above the students’ voices: “Sixteen point five grams per cubic centimeter”. Then as he sees different numbers obtained in different groups he asks the class: “How come we are getting different numbers?”… “Estimate…what do you do to estimate?”… “Do you have to use a scale?...Describe how to use the graph.”

Greg appears to be a little frustrated he pacing around and his voice is a little louder. Twenty grams of water is in the air, at what temperature will air hold twenty grams of water? A team of students call out “77” and students at a table near them ask, “how did you get that?” After that they are back to discussing their numbers.
Greg admonishes one team who appear not to be discussing the problem. He asks them how come they’re not engaged. But the students protest, they say they are engaged. Then Greg asks the class what are you going to see at this temperature? Rain or Dew?” Greg calls on specific students by name. Then Greg asks the class to “tie the ideas together”. A student asks Greg a question and he repeats it aloud saying this is a good question. The question is does the graph they are using involve pressure. He answers that the curve in the graph involves pressure but that pressure is not explicitly written on the graph they’re using.

Greg is using the overhead to connect the ideas. The overhead is a graph which the students appear to have hard copies in their materials. He points to the graph and assigns teams to explain the parts of the graph. The handout is a graph on weather showing how air circulates over the surface of the earth, goes up into the sky forming clouds. Cooler air causes precipitation, hot air makes the moister rise.

Teams are combined (some students move to join other groups) the two students to the left of me get up to move elsewhere but they pause and seem not to want to join any group. Both of these students, a male and female (“James and Cindy”), seem to be ethnic minorities in appearance (and may possibly be the same ethnicity) and were the students who were off task described previously. After hesitating, the female asks Greg, “do we have to join another group, there’s no room”. Greg doesn’t force them to join.

The students’ task are to describe the relationships on the graph and what the words mean regarding the physical properties written on the board and in the physical properties content in their handout. Students are given 4 minutes.

At the table directly in front of me all of the students appear to be white in ethnicity. One male and four females and the male appears to be explaining to the females the physical dynamics of the weather system.

At the table to my left James and Cindy are comparing ID card pictures.

At the table to the front right are four students (all females) who appear to be a mixture of ethnicities and who have spent almost the entire time reading silently their handouts. Now nearing the end of their time to come to some consensus they are beginning to discuss but are reading aloud.

Greg asks the group at a table furthest from me at the opposite side of the room “How are you doing?” he is asked a question and he is talking but I hear only part of his answer “……depending on how much water…..”
APPENDIX D (continued)

James and Cindy are talking about their weekend.

Greg asks the class: “Ok how are we doing?” There is no general response. At a table near Greg are three students who ask a question I cannot hear them. At a table behind James and Cindy are three students, also ethnic minorities in appearance and all males. One of the students (Tom) at this table asks, “what are we supposed to do?”

Greg answers, “Real weather versus what we see in this little cartoon...What does this figure represent?” Then Greg asks the table with the one male and four females to answer they look a little surprised and attempt an answer but it is apparently wrong. A couple of females at this point quietly giggle. Then Greg asks a question and pauses for a moment and then answers it himself: What are we talking about? [with emphasis in his voice lowered in tone] Thunderstorms! Then Greg asks Tom, “What happens when the sun hits the surface?” Tom answers that the water rises (“water rises” is written on the graph on the overhead) Greg asks Tom again “what’s going on?” and Tom answers “the water is rising up”. Greg responds, “like the ten commandments?” Students at several tables laugh and then they respond, “the water evaporates”.

Greg asks, “what’s involved in evaporation?...make a connection with the terminology.” The male at the table with four females attempts an answer but it is wrong, the same two females at that table are silently giggling again. Greg provides a scenario to the class, “there are couples on a dance floor...what happens when it gets hot?....what happens between the dancers? The dancers are spreading out, when they are moving more energetically, they need more space.”.... “Now what happens to the density when you heat air?...How does this relate to pressure?”

The male at the table with four females asks the females, “do we know what pressure is guys?” Greg asks this table for the definition of density. They respond “concentration of a substance in another substance”

***************************Data Coding Example Ends****************

Coloring the initial transcription of the class data was changed in favor of using written codes with examples in the synopsis that was written shortly after class. These were ‘marked’ for greater ease of reference using colored tabs that stuck to the page.

Below are observations transcribed and written in synopsis form with associated codes written as abbreviations. For example, ‘Mstd’ means male student, wfstd or whfstd may
mean white female student, ‘T’ means teacher. Categories of interactions were also coded T-Std interactions (teacher-student interactions) were noted and kinds of interactions (questions) were noted. For example, types of questions coded and noted were ‘rhetorical’ or ‘algorithmic’ or ‘conceptual’. These designations were based on prior theory and categorization as described in Appendix E.

If several faculty used the same class room, the physical characteristics of the room were noted in the first class observed in the room. The notes that follow show the greatest detail on the physical features of the room in Evan’s class because his was the first observed in a room that Marcus and Russ used. Marcus’s classes are presented next and Rita’s last. Rita’s class took place in a different school and room, however the notes provided here were chosen to demonstrate her classroom practice that focus on the style and frequency of her interactions with her students, which were among the most frequent of all faculty in the case study.

These synopses of data are provided to show the progression of data analysis and coding leading to the condensed synopses and the descriptive categories comprising the continuum of practice from lecture to learning groups displayed in Table 20. Three case study faculty have been chosen to demonstrate the process because they represent three significant points in the continuum from lecture to collaborative learning approaches. Evan’s class represents the one end of the continuum comprising lecture and Greg’s class represents the other end of the continuum. Marcus’ class is intermediate toward group
learning and Rita’s class is intermediate toward lectures. (Since an example of Greg’s synopsis has been shown above it is not repeated here.)

**********************************Data Synopsis Coding Examples Begin**********************************

**Evan: Class Synopsis I—Oct. 2004 (first class 8:30am)**

I first encountered Evan by calling him by phone after asking Marcus to intervene on my behalf to encourage his participation. Evan acknowledged that he had received my email and that Marcus spoke with him and was amenable for me to come to his class. The class took place in a small, tiered auditorium room, with a podium, a bench area and a separate sink on a low, small stage. Two ramped (low gradient) isles cut into the seating area which was divided into three sections: a large central section and smaller “wings” side sections. There were no outer isles between the wing seats and the walls of the room. The auditorium seats were small wooden fixed desks with non-moving writing surfaces. There was a lowered ceiling over the stage and a high ceiling in the audience area. From the standpoint of the audience there was a large 12x8ft screen to the left side of the stage with an overhead projector positioned in front of it. On the right hand wall nearest the stage there was a large (~8x10ft) hanging of the periodic table. A “white board” was positioned against the back wall of the stage and lighting above the stage illuminated the stage and the whiteboard. All three instructors described the acoustics in the room as “bad”. Creaking sounds of the wooden seats could be heard around the room if students squirmed in them and the voice of the instructor carried in an echo. When I came into the room, (about five minutes before class) Evan was already there and taking items out of a cardboard box such as student notebooks, a binder which appear to hold his classnotes, and whiteboard markers. When he saw me (by the time I reached the stage) he said “Oh, hello, you must be Beverly”. I introduced myself and he quickly came to the edge of the stage to shake my hand (I was standing at a slightly lower level which required for him to extend his reach to grasp my hand). Evan was dressed in an open-necked light blue short-sleeved ‘business’ shirt and long suit pants. His demeanor appeared to be a composite of friendliness and shyness. He asked somewhat awkwardly and somewhat rhetorically so, you’re studying education? I mentioned at this point that I was trained in chemistry and was obtaining a degree in chemical education and wanted to learn about chemistry faculty teaching philosophy (he already heard this from me on the phone). I asked him whether it was ok that I interviewed him after Marcus’ class which took place directly after his. He said this was fine because he was teaching another class immediately afterward and he wouldn’t be able to see me then, regardless. Several students had approached the stage to ask questions and Evan turned his attention to answer their questions about homework and a pending exam (this was the Friday class
and the coming Monday was their examination class). With about a minute left before class he writes on the board details about the homework and the quiz. He started class punctually with the loudly spoken, “OK!” He made announcements about the coming exam on Monday and reminded the students about a review period which will be offered to them on Sunday in the same room. The instructor providing the review was a female (Ph.D.) who taught general chemistry and physical chemistry and appears to have been teaching at this college for a couple of years and who did not hold a permanent position in the department. The other instructors were all males (two tenured in chemistry—Evan and Marcus, and Russ, not yet tenured?)

IN CLASS—20-25 students in attendance

Evan starts his class with a quiz on doing calculations on dilutions of solutions (M1V1=M2V2) and using the definition of the van’t Hoff factor in combination with recognizing soluble ions among ionic compounds that are dissolved in water. After the quiz he gives the answers on the board. He comes to the front chairs while he speaks to the class…he later tells me that there is a “dead spot” on the stage that makes it difficult for him to hear any responses from the students.

Verification sequence: Given molarity and volume of first solution and add 75 mL of water (dilution) give new volume and molarity

Verification sequence: Barium Hydroxide gives 3 ions

Finishing up chapter 5 then doing a review:

Content, New concept: Π = MRT → “like gas law”
We have 3 particles Π = iMRT get the ionic strength of sea water
Since most of you are Marine Science Majors
(Students laughing and shuffling feet)

Example/verification: Using 0.7M NaCl in sea water, gas constant and temperature (K) and plugging in the numbers without giving units in the equation get out of the equation 34 atm uses conversion factor (14.7Psi/atm) to convert atm to psi

Anecdote: Evan attempts to make a connection of this information above (example) with “real life application”…”most of you folks live in Tampa Bay well that plant (reverse osmosis plant to convert sea water to drinking water) is supposed to be working now but is million in debt and 2 years late…was supposed to make 25 million gallons a day…that’s a lot”…

Model: gives diagram of reverse osmosis in overhead… the figure comes from the text book…describes the elements in the figure

Rhetorical Q: How much pressure? (no wait time) (Evan answers:) “A lot of pressure”
Content, New concepts: Boiling point elevation, Freezing point depression, colligative properties—stated no immediate details begins with figure from textbook put on overhead.

Model: figure from textbook showing two blowups of particles inside two beakers one with pure water and one with water mixture showing contrast of contents in beakers and then labels with effects on temperature constants.

Example/verification: equation: \( \Delta T_b = iK_b m \quad \Delta T_f = iK_f m \)
These are constants every substance will have a constant
What do you think the units of \( K_f \) and \( K_b \) are

Male student answers correctly (allowed wait time)

Molal solution of NaCl

Example/Verification: \( \Delta T_b = iK_b m \quad (2)(0.52)(1.0) \rightarrow \) no units given
\( \Delta T_b = 1.04 \quad T = 100 + 1.04 = 101 \)
So will elevate the boiling point one degree

Example/Verification: repeats same idea with \( T_f \)

Anecdote: “I’ve never seen an example (ie real life) of using Boiling point elevation…Freezing point can be used to determine molecular weights”
Describes how in words no figures or writing

Example of freezing point depression anecdote: Describes how salt is used on the roads in the north “I used to live in Detroit…Detroit sits on a large salt mine…cars get rusted out…easy to calculate but not use the boiling point elevation.

Transition: You guys have any questions on Chapter 5? (no response)…will go over previous years test.

Begins review:

Verification/example problems: showing problems on a previous exam a set of ~10 each equal 1 point… “you should be able to do this very quickly”…How many OH’s are there? (no response) “30% of the students got this wrong because it has a positive charge of 2”—given the name students will need to know the charges and stoichiometry

Which will have the largest number of moles?”
(male student answers correctly—same student is answering) which ever has the smallest molecular weight

Chemical Nomenclature—“expect these on the exam”…points to the molecular formula and students are calling out names…sometimes starts with a hint providing the prefix of
the name… “how about this one… (goes in reverse and gives the name then writes the formula on the board) students are watching but very few are writing down notes

**Rhetorical Q:** Do you think something will look like this on this year’s test?... One thing you have to do is write out the equation:

**Std/T interaction:**
Evan writes on board $2\text{Hg} \rightarrow \text{Hg}_2 + \text{O}_2$
Male student (same) corrects Evan “you forgot an “o”
Evan corrects the equation $2\text{HgO} \rightarrow \text{Hg}_2 + \text{O}_2$

**Std/T interaction**
When Evan writes on board students write but when he points to the overhead students stop writing

**Anecdote:**
“By the way I have a recollection… (missed some of this because of voice was either too low or student’s cellphone overwhelmed Evan’s voice)

**Std/T interaction**
→ cell phone going off… “Does anyone want to accompany the music?”

**Anecdote contd:**
“…teaspoon of mercury oxide… candle(?)… bubbles of oxygen forming… told the woman not to do the demo because mercury oxide is very toxic...” (laughs) “...this is a classic way of making oxygen”

**Std/T interaction**
Evan goes back to writing on the board and students go back to taking notes and when he stops to point to the overhead students stop writing

**Verification/example:** grams of HgO converted to grams O2

**Verification/example:** empirical formula of Ibuprofen … “A type of aspirin”

**Algorithm-model** “lets try my tried and true technique of constants”
Provides a table on the board of 3 elements: C, O, H and uses mass and amu to derive empirical formula

**Std/T interaction—Verification/example**
“So what are we going to do next?
(girl answers) divide by 0.969 (to get whole numbers in the empirical formula) Evan repeats her answer and writes the result of the operation on the board

**Std/T interaction**
(Girl STD) “so it’s ok to round?”
Evan laughs I did do that didn’t I but I would do that

**Rhetorical Q:** pointing to the next problem on the overhead of the previous year’s exam … “Do you recognize this as a limiting reagent problem?”

**Verification/example:**
Limiting reagent problem…points out the conversions necessary (grams to moles or to molarity) to do the problem…then does the problem

**Std/T interaction**
E: “what do I do to get the two answers? (std) have to get the limiting reagent..(T) which one is the limiting reagent? (std) the smallest one (T) ok you stated the limiting reagent is the smallest one

**Verification/example**
Balance the equation…

**Std/T interaction**
“so what do you expect to see? (Mstd answers) Fe reacts with OH…(T) “yes”…and writes the answer on the board

**Verification/example**
Solubility rules

**Verification/example**
Oxidation/reduction…oxidizing reagent…reducing reagent

**After class:**
Evan mentions that another faculty (Russ—other than Marcus) also teaches Gen Chem but is teaching the labs at this time…suggests that I solicit him for the study and that he will be teaching the Gen chem. lecture next semester…I find this curious because it came up in the context when he asked about whether I was staying in the classroom to observe Marcus. Evan encourages me to come to his analytical class at 9:30am to observe a different format in which his class works in “groups”. Because this class conflicts with Marcus’ class I decline but told him that I would be interested to hear more about it during the interview. We make arrangements for me to see him after Marcus’ class. He allows me a generous window of time 1.5hrs that I could come to see him.
Evan’s 1st interview addition: what was not recorded…spoken after I turned off the recorder:

Evan taught for one year as a visiting professor at the University of Wisconsin there were 100 students in each section and there were 7-8 TA’s

Worked at General Motors….then decided to teach…taught at his “alma mater” and taught there for one year…looked at the jobs advertised looked for smaller schools because he chose to have the “interactions” between students and teachers that exist in smaller schools He walked into the labs (at Wisconsin?) saw the TA’s how they did the labs…they also did the grading

Marcus Class Synopsis I—Oct. 2004 (first class—9:30am)

{there are 36 students 3-4 visible minorities}

Marcus teaches in the same classroom as Evan. Marcus is dressed in blue jeans and in a Central American woven shirt. His hair is a little longer about 2-3 inches down the neck and has a short beard. He is also wearing a “vote” pin and just as he starts class he encourages his students to vote in the coming election. He is active in a local democrat ‘unit’. He tells his students to “vote ahead” (prior to the election day) and mentions that the age group of his class had the lowest representation in the previous national election. He mentions that it is a privilege to vote and that there is a car pool available for their use and their participation.

Marcus mentions that the class did poorly on their last quiz…the median grade was “1”…(T)”you made it easy for me to grade”…students laugh

Begins Review...covering same material as Evan, Marcus also walks to the front of the stage near the front row of students to talk to the class. He begins by writing equations on the board and then puts on an overhead of the solubility rules (same as Evan)...a list of soluble compounds and a list of insoluble compounds. Marcus writes on the white board in two pen colors and his writing is somewhat small and more difficult to read relative to Evan.

Verification/example problem: Net Ionic equations (T) asks students to complete the equations:

(NH4)2 + S(aq) + ZnCl2(aq) →?
H2SO4(aq) + KOH(aq) →?
Fe(NO3)3 + BaCl2 →?
APPENDIX D (continued)

Std/T interaction:
After Marcus puts these equations on the board he directs his students to start working out the problem and begins timing and tells them when they should have the first problem done. Then he asks how many students have worked out the first problem. About ½ of the students raise their hands showing that about half of the class are able to solve the problem in the time frame that he expects.

Concept explanation/methodology: Marcus goes over the solubility rules uses a laser pointer to point to the periodic table… “Ca Carbonate is insoluble because its in the 2nd column”

Methodology: tells students to “talk to the person next to you to get help with solving the problems and move around to find someone you want to talk to in order to figure out how to solve the problems

Std/std interactions
Students are talking quietly and some get up to move closer to other students two female students in front of me turn around and ask me if I am a chemist and would I help them… I answered feebly that I didn’t know the answers so they go on to someone else to get help

Std/T interaction:
T chooses students to come to the board and write their answers… “so we have number two….Who wants to do number 3?…Ok lets do it!!...come down here…what are you doing?...you have to wash your hands? (students laughing…T appears to be talking to a male student who is slowly coming forward to the board)

There are 3 students at the board 2 fem and one male

Concept explanation: Std/T interaction
(T)“First of all recognize that the Ammonium Sulfide are insoluble…so I put them to the side…I know that NH is soluble so its not going to precipitate…so what’s right about this answer?...Is there something missing here?...(Fstd) “the net ionic equation?”…(T) “what else is missing here? Put the designation of aq (aqueous) and s (solid) here [writes these on the board and points to them with the laser pointer]…”so we will have a net ionic equation that looks like this:

\[
\text{Zn(aq)}^{2+} + \text{S}^{2-}(aq) \rightarrow \text{ZnS(s)} \quad \text{net ionic}
\]
\[
\text{NH(aq)} + \text{S(aq)} + \text{Zn(aq)} + 2\text{Cl(aq)}
\]
APPENDIX D (continued)

(Fstd) “do we have to write it just like that? (T) “yes because you’re showing how they dissolved…what’s the name of that compound?…raise your hand if you have it…is it an acid or a base? [two students answer simultaneously one is correct the other not]..(Fstds) “sulfide” … “sulfate”

(T) what is the name of this compound [H2SO4] what part will react? What part will react on the other side [KOH]?…(Fstd) OH…(T) break it up into ions that dissociate
(T)[writes on the board] 2H+(aq) + SO4^{2-} + K^+(aq) + OH^-(aq)→
(T) you see what is going on there? Water is formed…what do I do with this part…I need to balance the equation…now I can make this into a net ionic equation
(Mstd) that’s not a reaction
(T) no this is a reaction when water is formed [writes on the board]
   \[2H^+  + 2OH^- \rightarrow 2H_2O\]
(Fstd) do I need to leave in all the 2’s?
(T) that’s not the important part…you need to write something down [points to the overhead on the list of soluble ions and writes formula on the board]
(T) C2H2O2^-  CH3CO2^- there is another way to write this
(Mstd) why do you want us to show the ions?

Concept explanation T/Std interaction and use of multiple methods/teaching aids
(T) ok the reason why I want you to dissociate this into ions is so that you know what to do with the ions…what ions will precipitate? [draws a beaker with a line indicating the surface of water]…give a list of the ions [T is at the board and uses the laser pointer to point to the overhead screen then writes on the board the ions that will dissociate in the water
(Fstd) why doesn’t Fe+ and Ba+ precipitate together?
(T) good question, because they both have positive charges [jumps on a desk near the periodic table and uses the laser to point to specific elements in the table and indicating which will take positive charges which will take negative charges]
(Fstd) wants a photocopy of the solubility and ions lists
(T) ok I’ll make a photocopy
(T) please memorize this list…I don’t usually condone just memorizing but this is something that you have to know

New concept/explanation-T/Std interactions
(T) writes on the board—all students are listening and writing down what is on the board

   \[\text{Mn}^2+(aq)  + \text{ClO}_3^-(aq) \rightarrow \text{ClO}_2(aq)\]…Identify the oxidation state…the oxidation number…which is oxidized and which is reduced then write a balance equation for the reaction in an acidic solution…I’m not going to give you as much time as I did last time so go ahead and talk with you neighbor [wait time 2-3 minutes] raise your hand if you
APPENDIX D (continued)

need some guidance [both F and M students raise their hand periodically and T comes over to talk about and to praise what they have for solutions] Std ask T to go over the problem
(T) first of all determine the oxidation number…

[gives three more problems with similar interchange between students and between teacher and students] gives a table as a mnemonic devise to help understanding of half reactions and reminds students oxidation is loosing electrons and reduction is gaining electrons]

Interview took place directly after the in-class observation.

---

Evan’s second class Oct.2004

{came in 20minutes late} {23 students; 17 female; 4-5 visible minority}

Harmonic Oscilator
IR spectrum
Overheads and handouts

Shows MO diagram

Equation: Frequency is proportional to the square root of k/m (k = force constant; m = mass)

\[ f \propto \sqrt{\frac{k}{m}} \]

T/rhetorical Q
(T) the larger the wave numbers the higher the frequency Why? Because H has lower mass

Concept development/explanation
double bonds are stronger bonds and absorb { non specific} and higher frequencies
Triple bonds are stronger bonds means higher frequency
Overhead (picture from the textbook) carbon dioxide 3 different types of molecular motion

[Picture shows atoms attached by springs]

(T) two of these motions absorb {non-specific}

Concrete example: Greenhouse effect
[Draws picture on the board of sun and earth and word indicating atmosphere]
“a little green house effect is a good thing…it keeps the earth warm…water absorbs IR radiation and it doesn’t cool off very much at night does it? [students shake their heads]

T/demonstration/model
[ A weight suspended by a single spring from a metal bar supported by a base. T lets the weight bounce at the end of the spring] (T) notice that the spring action is much slower than the triple spring it takes a longer time to make the oscillations this is like the single and triple bond

Anecdote:
(T) Alaska used to have permafrost in certain places and now they have mud and people are not happy

New concept/explanation
(T Announces) Vesper theory
Valence shell electron repulsion theory

T/rhetorical question
(T) A B atoms …how are B’s oriented around A’s?

T/std interactions
Q Where do the electrons orient to keep the electrons as far as possible from each other?
(Mstd) they take opposite sides

(T) uses example of a linear molecule draws on board A and B atoms attached by a line used the overhead to show CO2 and electron clouds of the center carbon atom…”the electron clouds are as far away as possible”

(T) expands concept to “next case” AB₃…now we have 3 groups of electrons around A…How do we make them as far away as possible?
(Mstd—same student) the electrons take 120 degrees apart
(T) trigonal planar arrangement [shows overhead of the orbital arrangement and atomic arrangement…talks about O₃ resonance structure]

{Draws distinctions between electron and molecular geometry…the molecular geometry considers only the atoms}

Concept/expansion/ T/std interaction
AB₄…now how can the electrons separate as far as possible?

(Mstd—same person as before) “a pyramid”
(T) exactly right…its called tetrahedral…[demonstrates how to draw a tetrahedral on the board using wedges and dashes and straight lines]… “Can you see this in your mind’s eye?...[draws the structure of ammonia]… “the electron geometry is tetrahedral but the molecular shape is pyramidal.…the electron geometry for water is tetrahedral but the molecular shape is bent

(T)rhetoridalQ what is the angle of a tetrahedral? 109.5 degrees…so you guys have to know this….

Time is out and students are getting ready to leave and some are already leaving. Only student who is responding verbally to the teacher is a white male. Others nod their heads.

Marcus’ Class 2: Oct. 2004

{33 students; 5 visible minorities}

First 5 minutes handed back exams and gave directives for beginning the class

Concept explanation
Spectroscopy is a technique that helps us to find out how molecules and atoms fit together

We are going to focus on the IR part of the spectrum…when we say IR we think about heat what do we use IR for?
(Fstd 1) Infrared lamp…(F std 2) tanning salons…(T) no that’s UV

Begins with Lewis dot structure of CO₂ and explains that it has two double bonds…want to understand the nature of these bonds…they also absorb light…the bonds are not like
sticks the way they are drawn in the text book…don’t think about them as sticks anymore…think about them as springs because they have dynamic movement

**T/demonstration** [uses same demo model that Evan used] “there is a particular frequency with a single bond it is a longer frequency and with three bonds the frequency is shorter and the frequency varies with the different weights” [shows the effect of the heavier weight comparing it with the less heavy weight]… “so the take home message is that stronger bonds absorb at higher frequencies {disconnect between the frequency of the bond motion and the frequency of absorption}

**Concrete example/explanation:**
Greenhouse effect can be a lot better understood if we understand spectroscopy (has the same overheads as Evan showing the IR spectrum and draws similar picture on the board with sun and earth but instead of writing atmosphere Marcus has drawn clouds…

**T/std interaction**
(T)“what kind of light do we have coming from the sun? (F& M stds) IR, visible, UV
(T) a lot of the energy is coming in the IR and UV range…the important thing here is that there is water in the atmosphere and a lot of N2 and O2…it turns out that the gases lets most of the energy through, the CO2 does not absorb in the visible frequency…in fact they have a specific frequency that they absorb….What happens to the light? (F&M stds) the light bounces back?

**Concept explanation/model demo**
(T) some light is absorbed at a particular frequency [shows overhead with CO2 springs – the same figure that Evan used…students are looking at the overhead] T goes over to the spring demo and moves the weights to start the oscillations and describes the relationship of the light absorption to the motion of the bond… “the frequency of the light absorbed depends on the motion of the bond…CO2 absorbs at ___microns…water absorbs at ___...[shows overhead that Evan used depicting the IR spectrum of energy vs wavelength

**Concept/explanation with overhead**
solar radiation is on the side of the graph terrestrial radiation is at the bottom of the graph and the CO2 absorption has a peak at a particular wavelength

“CO2 absorbs in the IR, H2O is an important greenhouse gas, O3 is an important greenhouse gas, CH4 is an important greenhouse gas…we need some greenhouse effect to live here…the problem isn’t that the greenhouse effect exists but that the amount of CO2 and O3 is changing
APPENDIX D (continued)

**Transition**
That was a little foray into the IR spectroscopy this is more about the structure and how molecules are put together now we are going into chapter 7 about molecular structure

**New Concept/explanation**
Vesper Theory
(T) “the electrons are going to orient themselves so that there is the least amount of repulsion…there is a bus and there are two seats…they want to sit apart…this isn’t the best example…[writes on board a list]
(1) electrons in bonds and lone pairs stay as far apart as possible—first step is draw a Lewis structure and count the number of charge clouds
(2)2nd step arrange so that they are as far apart as possible

**Examples [on board]—T/std interactions**
“lets pick CO2”…[draws a circle around each bond between C and O and calls it the charge cloud]…”I see a charge cloud here and here…now have I drawn them as far apart as possible?
(F&Mstd) yes

(T) HCN…I see two charge clouds again…also a linear molecule…lets look at something that you are really familiar with…lets look at water…H2O can you do the lewis structure pretty quickly? [draws linear lewis structure of water on board] …how is this drawing is this right

(Fstd) I know it isn’t but I don’t know why because it looks right to me.

[T takes out large balls and sticks from a box and shows three dimensional model of the molecule]… “We need to imagine the 3 dimensionality of it there are 4 charge clouds that find a place as far part as shown in the picture [makes a tetrahedral out of the structure he’s holding]…adding two more balls…what shape is this?

(Fstd) a tetrahedral
(T) but we have to draw water in 2 dimensions and depict 3 dimensions…the overall structure is a tetrahedral shape [uses overhead of diagrams from the text…the same ones that Evan used] CO2 is linear…lets look at formaldehyde CH2O…draw the lewis dot structure and [drawing on the board] I want to make this bond and that bond as far apart as possible…so I’m going to start drawing like this…

(Mstd Q) why didn’t you draw the electrons on the oxygen?
(T) the reason that I didn’t draw the electrons is that we’re concerned about the geometry about the central atom {not explained yet in class}
T/std interaction
(T) refers to overhead CH2O structure and electron clouds are shown} … “lone pairs and bonding pairs count”…F student raises hand and T calls on her by name
(Fstd) Are we using the octet rule?
(T) we should proceed as I’m showing rather than trying to just satisfy the octet rule…lets look at PCl5…this involves the expanded octet rule [shows overhead of the structure]
(Mstd) what about the noble gases how do they form compounds?
(T) sometimes the compounds break the rules…fluorine is very electronegative can bond to that….

End of class students leaving

Rita Class 1 (Nov. 22, 2004)
{18 students; 4 males; 4 visible ethnic minorities; 3 “non-traditional” older students}

[T makes announcements and writes some of the details on the black board…Quiz 3 on Web assign on trends of ionization energy…Lab on molecular geometry]

[T starts lecture with Power-point (ppt) slides]

T/std interaction and teaching aid and concept explanation
ppt slide: figure showing Ei general trend increasing (T) “Explain it!!”

(Fstd) answers incorrectly (T) no (Mstd) this is a special case? {students appear to be off track and don’t have a clue how to begin} (T) Ok which has the higher Ei…Na or Al?
(Mstd) Al…(T) how about Al or __In (?)..(a few std answer)…(T) which element in the periodic table has the smallest Ei? (Mstd) answers (T) which element has the largest Ei? (several students answer)

(Fstd) are we skipping higher electron energy? [student apparently was referring to electron affinity] (T) no lets see a movie on electron affinity

Teaching aids
{movie was shown taken from McMurray text series however the text they are using in their class is Zumdahl}
Teaching aids and flexibility

PPT Ea definition [T also writes on board at the sides of the screen] change of energy that occurs when an electron is added... [on the power point slide there are sentences with blanks in them that students call out the answer as T reads the sentences and pauses a the blanks=the cue for the students to call out the missing word]...[apparently students have access to the PPT slides online through “Blackboard”, however I don’t see any student with a print out of the slides as reference]

Use of PPT with blanks

“If the atom has a tendency to accept electrons Ea will have a ____ sign. The more___ the value, the _____ the tendency of the atom to accept electrons. If the atom doesn’t have a tendency to accept electrons, Ea is stated as_____”

T/std interaction

O + e → O- ? (Mstd answers) -ΔE
O- + e → O2- ? (Mstd answers) +ΔE= unfavorable energy change

The above was asked as questions regarding the change of energy with male students (mix of ethnic) responding

(T) note the atomic relationships...electrons are not stagnant...how about the trend...which way does it go? (several students) right to left (T) does that make sense?

You who made those answers explain your rationale {not correct}(T) explains and writes on the board Na with valence electrons then Cl with valence electrons...(T) why is Cl smaller than Na? (both F& M answer simultaneously)

Std/Std interactions/problem solving

(T) lets do an exercise arrange in the requested way: [students working together]

Increasing: Rb Na Be Sr Se Ne Fe P O
Decreasing: S+ S- K Rb+ Br- {this is from their homework in the text pgs 339, 85, 89}

T/std interactions

[T calls on specific student by name] (Which are the trends for #1? FStd answers {but T treats the correct response as though it was wrong})[T calls on second student] Mstd [several students respond to T and say that she is asking about the wrong trend and T admits mistake] T reasks the question but does it on the board herself and then asks the students did she do it correctly and they answer yes

T/std interactions and use of PPT/demo of concept using her body
T points to the ppt slide and asks students to provide answers to more blanks various students answer

Subsequent passes over these synopses of the raw transcriptions were used to create broader categories of description and condensed synopses of types of classes observed. This process led to the creation of descriptive categories shown in Table 20 and produced here.

Practice categorizations are coded and ascribed numerical values of a Likert Scale from 1= Collaborative learning to 7= Lectures. Seven values were chosen because statistical research indicates that seven categorizations have greater propensity for reproducibility.[98]

<table>
<thead>
<tr>
<th>Practice Categorization [and practitioners]</th>
<th>Observations-Synopses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture= 7</strong> [Kim (General Chemistry Course), Cindy, Howard, Evan, Russ]</td>
<td>5. Teacher stands in front of the class, writing on the board or writing on an overhead or pointing to PowerPoint projected slides</td>
</tr>
<tr>
<td></td>
<td>6. Talk is often oral repetition of written words or vocalizations of equations with occasional elaboration or an oral description of a diagram drawn or depicted model of molecular phenomena</td>
</tr>
<tr>
<td></td>
<td>7. Subject content is either problem solving or a description of a chemical model</td>
</tr>
<tr>
<td></td>
<td>8. Occasional anecdotes may be described or ‘real world’ examples used from the text</td>
</tr>
<tr>
<td><strong>Lecture Intervals=6</strong> [Vern]</td>
<td>Same as lecture above but in approximately 15 minute intervals interspersed with 1-2 minutes wait-time for students to spontaneously/voluntarily interact to obtain a solution to a problem presented by the instructor.</td>
</tr>
<tr>
<td><strong>Lecture-Interactive=5</strong> [Rita (General Chemistry), Laura (chemistry preparatory)]</td>
<td>A lecture with frequent (every 5-7 minutes) short answer questions directed to specific students or to have students “fill in the blank” orally in a narrative about a chemistry concept. Or as the teacher solves a problem, she may stop to ask students help her complete the particular component of the solution.</td>
</tr>
</tbody>
</table>
Examples of a progression between ‘Lecture Intervals with Collaborative Learning’ to Collaborative Learning Groups’ were not observed in this data. However categories can be set up that might be observed in future studies. An intermediate class between Marcus’s class and Greg’s class would entail a collaborative learning format with fewer, shorter lecture intervals. A next category closer to Greg’s class would be a collaborative learning class where students participated in loosely structured groups (that would be less structured than Greg’s, for example, where students were not assigned designated roles). Features of these intermediate group learning approaches were observed in Kim’s and Marcus’s class but did not have significant duration in their classes.

To observe how Rita’s class was categorized and placed in this table shown above in the category designated as ‘Lecture-Interactive,’ a synopsis of all her observed classes
(four in all) was created from four synopses of transcriptions of raw data. Her class was placed in a continuum between Greg’s which entailed the most group oriented collaborative work, and Evan’s which entailed a more lecture-based format with fewer student-teacher interactions involving more verification/algorithmic-lower cognitive order questions. Based on the frequency of interactions and the occasional working in groups, her class was considered more lecture based than Marcus but more interactive with more frequent conceptual questions than observed in Evan’s class. Thus the deciding factors in this categorization entailed general organization, pace, content, number of interactions both student and teacher and student-student, percent time observed in these interactions, type of interactions, and types of student learning processes observed. These decisions were listed at the beginning of the synopsis and characteristics of the class were listed afterward.

*******************Begin Sample Condensed Data Synopsis*******************

**Rita’s classes:** General organization, pace, content, # interactions std-T & std-std, % time in interactions, type of interactions, types of student learning processes

Main technique: Power point presentations on large screen covering a black board Ppt slides of two types: introducing overview of concepts and linkages and giving details of concepts. The second type of slide often has blanks interspersed in the presentation for students to verbally speak out the appropriate word to complete the sentence as T reads the slide aloud. Sides of the blackboard are used for writing out explanatory and example problems pertinent to ppt slides.

Class 1 ~15 slides per class,
Class 2 ~10, ppt slides & 6 overheads, 1 handout;
APPENDIX D (continued)

Class 3~17 slides and students doing in-class problem set;  
Class 4~example class detail:  
11ppt slides, 1 overhead ➔ T-std interactions asked students 30 questions for which she
waited for and received voluntary answers or called on people by name or went down
row of desks to get answers. These questions tended to be listening checks and mainly
algorithmic. Class also included a 5 minute problem set from the back of the chapter in
which students were allowed to discuss and share their answers.

**************************************************************************End Sample Condensed Data Synopsis**************************************************************************

A condensed synopsis was formulated for each faculty member in the case study
and placed in relation to each other. Further condensation of the description of each style
of class was formulated to create a descriptive category for the table as shown above.
While these descriptive categories were useful for much of the data analysis and
triangulation, coding notes using abbreviations from the coding list were used before and
after construction of these categories. Reviews and re-checks over the initial synopses
and raw data were taken throughout data analysis and reflections.
APPENDIX E: CLASSROOM RUBRIC FOR LEARNING PROCESSES AND TEACHING PRACTICES (41, 56, 66, 67)
<table>
<thead>
<tr>
<th>Bloom's Taxonomy</th>
<th>Description</th>
<th>Cognitive Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall</td>
<td>Learning pieces of information such as facts and definitions enough so that you are able to repeat them.</td>
<td>Information processing</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Understanding enough about a topic so that you are able to explain it to someone else.</td>
<td>Critical thinking</td>
</tr>
<tr>
<td>Application</td>
<td>Putting what has been learned into practice; applying what you know.</td>
<td>Higher order critical thinking</td>
</tr>
<tr>
<td>Analysis</td>
<td>Breaking a topic into specific parts and studying the interaction of the parts.</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Synthesis</td>
<td>Integrating prior knowledge and creativity to gain insights into a topic.</td>
<td>Research</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Knowing a topic so well that you can judge its quality according to established criteria.</td>
<td>Assessment</td>
</tr>
</tbody>
</table>
Learning Cycle

Exploration → Concept Development → Application

Types of Questions: (71)

Low Order Cognitive Skills Questions or Surface Learning Approach:

Algorithmic question definition:
Questions that require the use of a memorized set of procedures for their solutions (e.g. computations)

Examples:
Q1 Calculate the maximum weight of SO$_3$ that could be obtained from 1.9 moles of oxygen and an excess of sulfur in the reaction $2S + 3O_2 \rightarrow 2SO_3$.

Q2 Potassium, vanadium, and iron crystallize in a body-centered cubic unit cell. Given the lengths of the unit cell edges and the atomic weights listed below, which of these elements has the highest density?

Low order cognitive skills questions:
Knowledge questions that require simple recall information or a simple application of known theory or knowledge to familiar situations and contexts. They can also be problems solvable by means of algorithmic processes—mechanistic application of taught/recalled/known, but not necessarily understood, procedures (algorithms)—that are already familiar to the learner through previous specific directives, practice or both.

Examples:
Q3 The atomic number of the element magnesium is 12 and its molar mass is 24.3 g/mole. The mass numbers of its three natural isotopes are 24, 25 and 26. Which of the following statements is true: (Circle the appropriate letters)
   a. The three isotopes have the same chemical properties.
   b. The three isotopes have the same nuclear charge
   c. The mass number of the most abundant isotope is 26.**
   d. A portion of the nuclei of Mg atoms contain 14 neutrons
APPENDIX E (continued)

e. All elements have two or more natural isotopes.**
 (** denotes correct answers)

Q4 Is PH₃ or BH₃ a base or acid?

High order cognitive skills questions or Deep Learning:
Knowledge questions that require students to engage in the learning cycle shown in Figure 1 and above. Questions for which students may not have prior knowledge or algorithms that pertains directly to the question—that prompt students to explore, generate and apply their own algorithms and models of phenomena, that require them to be able to break a topic, phenomena, data or concept into parts and relate the parts to each other. Questions that prompt students to explain their knowledge to others and to critique knowledge claims of others effectively by established criteria.

Examples:
Q5 Ionization potential refers to the energy required to remove an electron from an atom. The first ionization potential refers to the energy required to remove the first electron, the second potential refers to the removal of the second electron, etc. Which of the following two would you expect to have a higher ionization potential: a sulfur (S) or a phosphorus atom (P)? Explain.

Q6 Adding an electron to an oxygen atom is a reaction which is associated with emission of energy. Adding a second electron to the resulting O⁻ ion is associated with energy absorption. What is your explanation to the phenomena?

(Note more examples can be found in the activity located in Appendix A.)

What follows is an excerpt from field data of observed, in-class questioning behavior in Vern’s class. Examples of teacher-student and student-student interactions involving both lower order and higher order questioning are presented.

CONTEXT

In Vern’s general chemistry class, students were typically shown PowerPoint slides containing concepts from their textbook. Generally Vern asked students to solve
Algorithmic, lower order questions however as several mature students (apparent age of >26 years) proceeded to answer the posed questions they shared their ideas aloud with each other and then asked each other (and finally their instructor) more thoughtful questions.

**Student characterization summary:**

The class had 16-20 students attending the class when observed. Nearly half of the students were females. Five students appeared to be non-traditional age (3 males 2 females, one of which was a visible ethnic minority)

**Class organization and physical lay out:**

PowerPoint slides were used to present information. Vern read the slides aloud and the slides also contained the questions that students were to answer in class. (Pre-planned questions) Students had print-outs of the slides in their hands or notebooks, indicating that the PowerPoint lecture file was made available to students in advance of their class. The screen covered 2/3 of the whiteboard behind the screen. The classroom was rather small (approximately 15x15 feet). Students sat at tables forming three rows with three isles between the rows of tables and three tables form each row abutted end to end, leaving no break between tables in each row. Students appeared to be scattered randomly but appeared to sit in groups of two’s or threes in each row. Each group of two’s and three’s were formed by mixes of sexes with few groups (approximately two
APPENDIX E (continued)

overall class periods observed) forming single-sexed groupings. Three students can sit comfortably at each table (between the legs of each table).

Figure 8. Vern’s Classroom

Example 1: TEACHER—STUDENT INTERACTIONS

Vern: (standing front right of the screen (as viewed from the perspective of students) facing students, reading the text from the slide which shows a section of the periodic table with an arrow showing the direction of increasing atomic radius)

Question posed to students: “Arrange these atoms in increasing order of atomic radius: S, Se, Te” (students are shown the periodic table on the screen – Vern points to it—and the periodic table has spheres representing each element atom and its relative size to
surrounding atoms. The text on the screen and arrows drawn in the slide suggest that the students are to visually follow the arrows drawn in the PowerPoint figure, to note the changing sizes of the atoms in a column, indicating that the atomic radii increase within and going down a column in the periodic table.)

Observations of student behavior: Students did not immediately answer this question aloud, although to the researcher, the question and the expected answer seemed very apparent and easy to answer. However, the students appeared to be perplexed as they were looking at distinctions between the section of periodic table shown on the slide and what they had in their texts, which apparently had a table that was slightly different from the one depicted on the slide. Their text contained a periodic table that included ionization energies that appeared to follow a trend that coincided partially with atomic size. While they were looking at their textbooks and the slide they talked with each other. Vern waited for 2.5 minutes for an answer for the question posed above, and while he waited the students deliberated on questions that they posed to each other:

STUDENT—STUDENT INTERACTIONS:

Male (mature) student (nearest me) is talking to neighbor student (apparent traditional age female) sufficiently loudly for me to hear: “why does the energy decrease between Boron and Carbon?”
Female student: “maybe it has something to do with how many electrons there are in the outer shell.”
Male student: “But the electrons are coming out of the same p orbital, won’t they have the same energy?”
Female student: “maybe it has something to do with the size of the atom?”

At the opposite side of the room a male student then asks Vern a question aloud for the whole class to hear: “What if you hit an atom with an electron, how does this change their
size and their energy?—Can atoms lose all their electrons? I’m trying to understand what plasma is, like in the sun.”

Another male student sitting next to this student asks a similar question: “Would that be the same plasma that’s in a plasma torch?” Vern goes “off-task” from the content presented in the PowerPoint slide to answer these questions. While he does this, students continue to deliberate their questions regarding the numerical value of ionization energy and its relationship to electron valence and atomic radii.

**Commentary:**

These students appear to be looking at a periodic table in their texts that resembles the one in the PowerPoint slide but the table in their text presents additional information on ionization energy that they spontaneously try to incorporate into the information that they had just received on the PowerPoint slide. The question that Vern asks is a lower order cognitive skills question. His question in categorized as lower order because Vern presented a pattern or algorithm in the slide (sequential variation in atomic size going down a column in the periodic table) and asked students to use the presented pattern (not generate their own) to order a set of elements presented on the slide. In contrast to the level of questioning that Vern used, the students proceeded to ask each other higher order questions without Vern verbally prompting them. However, behaviorally, he appeared to ‘give permission’ for the spontaneous discussions by allowing time for these deliberations. A few students (who were discussing and trying to understand the phenomena of plasma) explored ideas that they obtained elsewhere, either in their texts or outside the course, and attempted to integrate that information with the content on the slide and in their texts. The spontaneous behavior of students deliberating and
questioning their understanding of ionization energy and plasma are examples of processes occurring in the learning cycle, where students explore and build concepts—accommodating or assimilating new information into their prior knowledge. However this behavior is not the usual response to a lower order cognitive skills question. Typically students comply in kind with the skill level of the question posed, responding without additional critical analysis or additional exploration to algorithmic questions. An example of a more common response to an algorithmic question was also observed in Vern’s class:

Example 2 TEACHER—STUDENT INTERACTIONS:

CONTEXT: Vern presented content from the text on electron shell filling order. He showed a PowerPoint slide of an algorithm depicting the order of filling electron valence shells shown below:

```
1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d
7s
```

Vern read from the PowerPoint slide text which didactically described that the 3s orbital is filled after the 2p orbital. Vern then asks the following question:

**Question posed to students:** “What orbital is filled before the 5d orbital and what two orbitals are filled after the 5d orbital?”
Several students answered aloud, almost simultaneously: “The 4f is before and the 6p and 7s are after.”

**Commentary**

This is a lower order question because students are shown an algorithm and are asked to follow the given pattern to answer the question instead of giving students the opportunity to create their own algorithm to explain to each other the electron filling patterns. Additionally, students answered in a way indicating that they understood the algorithm but not necessarily understanding the atomic phenomenon. (Note they responded by naming the order of the symbols rather than including in their description the action of electrons filling orbitals). One female student attempted to explore further and asked two related questions, why the electrons ‘behaved this way’ (the way shown in the algorithm) and why the convention of labeling didn’t involve a sequential order (where 5f would be filled after 5d). Her questions were not answered, and no other student engaged in these questions. She may have been out of both Vern’s and students’ hearing range. However, other students seemed satisfied with the level of understanding they had because I heard no spontaneous deliberations among the students. Alternatively, it’s also possible the time that the topic was covered (near the end of the class period) may have curtailed students’ and Vern’s desire to draw out the topic and finish the lecture content for the day.
APPENDIX F: INTERVIEW TRANSCRIPTS AND QUOTES

The following quotes have been included to reveal distinctions about the general chemistry course that may influence in-class pedagogy. Below are sample responses to interview questions probing the case study faculty esposed conceptions regarding their different approaches in general versus higher level courses.

Russ: [referring to using reform pedagogy in the upper level course] Um, it worked well for, I had my juniors and seniors…the problem is that the students [referring to the general chemistry class] wouldn’t always communicate and they would get poor turnouts.

Laura: [referring to implementing reform pedagogy in an honors class] And, it became a little bit more apparent that it might need to be like an honors level course and then we went back to the objectives situation and just nobody felt that we would be able to cover everything that we need to cover so that they could go on to General Chemistry II…

Howard: In other words, I believe you should come in…if you’re going to take a course like chemistry or physics, you’d better come in prepared…that means you have to know the language…so…so I’m a very strong believer in, um, starting at the foundation and building up. You can’t do the fun things until you’ve some of the preparation.

Evan [using group learning in his advanced analytical class] what I’ll do is just have them do problems. So everyday, what I do is…[I give out] a handout of that, divide the students into four groups, each student…each group is assigned to do a
problem...they solve it...put the answer on the board so the other people can see what they do.

Faculty in the case study, as shown in previously with the exception of Kim’s, Howard’s and Cindy’s general chemistry classes, teach classes of a size that could easily accommodate the reform pedagogy using group learning, based on prior reports and research. Kim, Greg and Marcus taught classes having enrollment sizes that were either larger or of similar enrollment to those that were ascribed as “too large” by other faculty in the study. Beyond the claims that included problems with class size, faculty also mentioned lack of administration acceptance, or lack of convenience, however these claims often conflicted with other perceptions that either they or other faculty held in this study. One claim that was reported consistently and had no counter claims among faculty was that the general chemistry course content was normative and required specific topics “to be covered”. Several faculty also explained why having normative content in the general chemistry course required the use of the traditional lecture format, as observed in the following quotes.
Faculty Perspective

(Note: The bold font used in these quotes was intended to emphasize specific words suggesting the existence of normative subject matter in general chemistry)

Greg: “I don’t think you can do this [group collaboration] in General Chemistry because you have a serious amount of content...you just can’t do big ideas...you really have to be more detailed oriented...so you can deliver more material at a higher level.”

Laura: “…I approached our dean about actually implementing it [ChemConnections pedagogy] and she was very supportive, but what I came across was the fact that we have to teach a certain number of objectives within our curriculum, and the things [pedagogy] they stressed at the [MIDP] workshop is that you’re not really able to cover every single objective that you normally would.”

Rita: “…But it seems like a consensus that this is the material that needs to be covered. There’s so many examinations that students need to take if they go to premed, if they go to pharmacy, if they go to this or that...so we have to cover so much material to make sure that they’re prepared for those tests.”

Howard: “…it’s like learning Tai Chi...the learning of 108 [set number of] moves sequentially from week to week...and also its imitation...when you’re doing a rehearsal...what you’re really like is the conductor doing a complete performance of the work”

Marcus: But, along the way, we don’t try to get them to discover how to do it, we tell them how to do it. Um, you can’t cover as much when you ask them to discover how to do it...you can’t cover nearly as much, um, and you know, I’m given...working with my other colleagues here...certain expectations on what we cover, so...
APPENDIX F (continued)

Faculty | Perspective

(Note: The bold font used in these quotes was intended to emphasize specific words suggesting the existence of normative subject matter in general chemistry)

Kim: Yes, it’s just too overwhelming for me to think about doing it in a class that big. Also in the general chemistry…institutional thing…is the general chemistry is that we **have a common syllabus**, we have five sections or whatever, they’re all going on a common syllabus so you’re really **forced to keep on a common track** and be **covering exactly what everyone else is covering**, whereas in the nurses chemistry, I’m the person that makes the schedule, and I’m the person that makes the syllabus, so that I have more flexibility if things go a little bit more slowly, it’s not a disaster, whereas in general, we have to cover certain things. So, I do feel more constrained in General [chem.] by being one of the teachers in one of several sections where we’re all covering the same material over the same period of time.

Vern Yeah, it’s kind of a bottom up approach, and **it’s a matter of hitting the standard fundamentals of general chemistry**. I mean, **general chemistry is a pretty standard course**. So there are certain things that you are expected to learn in general chemistry, but within that it’s kind of personal preference of how you approach it. [regarding his approach] Yeah. It varies from chapter to chapter. Depends on what the chapter lends itself to. :That’s pretty much it. **The content intensive approach**.

In these quotes faculty reveal that the material presented in a general chemistry course is normative and vast and that there is an insufficient amount of in-class time to engage in the process of learning typical of reform pedagogy. Furthermore, Greg points out that not only the amount of material but also the level of material, is better served by pedagogy that does not use reform practices such as collaborative learning processes. Laura indicates that there exists a set of objectives in the general chemistry class
(suggesting normative material) in which “every single objective” requires “coverage” in the classroom. Both she and Rita (at the same community college) indicated that the administration, comprised of a dean and a core group of senior faculty, were responsible for determining “the objectives” of the course. Rita also explained that maintaining the normative content was necessary as a responsibility to students to help them pass entrance exams to other programs.

Howard’s explanation echo’s a similar theme about the normative content in general chemistry by his analogy of a set number of “moves” in Tai Chi. He also provides a colorful description of the meaning of ‘topic coverage’. He describes a run-through of a complete “performance” of chemistry topics where the instructor acts as conductor and musician, while students act as the audience, being attentive listeners rather than participants in the creation of the music. With these analogies in conjunction with a quote presented previously, Howard conveys that there is a fixed set of topics presented in a sequential fashion, delivered by the teacher which students are expected to hear but are not expected to understand during class.

Given that faculty have conceptions about the general chemistry course content as normative, it is possible that they either do not agree with the reform perspectives about changing course content away from ‘science as product’ conceptions or perhaps do not understand it. Alternatively there may be additional external influences that might affect their teaching approaches. The following quotes indicate how the faculty perceived the
MIDP workshop intervention. In addition to their conceptions about the workshop, these quotes reveal their possible contextual influences both for and against reform uptake.

Greg  Q: Um, you mentioned that when you went to the MID project workshops that you didn’t see that much new. You already had built up a fairly…

G: Well that was a long time…that was three years ago…so that was already…I mean I’d been to a lot of national meetings on this subject and spent a lot of time reading about it …

Q: …were there any specific things that you found out from the MID project workshops that prompted you to think ever…or rethink about anything or did you find it more like a reiteration….?

G: I….O.K., the answer is, yes, the peer led learning is directly useable in chemistry and in perhaps other courses. Most of the other stuff focused on chemistry courses and most of them were chemistry courses that I don’t teach and therefore it was of less value… I think if I were doing those particular courses, that that would have had more relevance and interest. But I think the difficult thing ultimately with any of these is that you cannot get agreement amongst the faculty that you want to do things in this way, instituting one of these courses is probably going to fail miserably in that you may have some small successes and you’ll have some students that absolutely love it, but you will not get it institutionalized because once that faculty member wears out on putting all that time and energy in, and the next faculty member takes it over, they’ll revert back to something much simpler. In all likelihood. And the other element is it’s difficult to get the materials completely….the materials in such a way that you can hand them to somebody to do without…it’s almost impossible to do without some sort of professional development. The problem with the professional development is you really need direct mentoring not a workshop to institute something because its like, okay, wait, I don’t know…it sounds great at a workshop, but the day to day implementation turns out to be messier and different.

Evan  Q: Was there anything that you remember there that you found provocative or interesting or new or was it pretty much reinforcing some things that you had known from the past? How did that experience….?

E: I was paying attention to what they were doing and, the overall
impression I had was that these movements or trends or whatever the hell you want to call them, seem to be trying to simulate in a big school what people have always been doing forever in a small school. For instance, like, uh, like New Traditions, this is sort of a way…when you have a lecture of three hundred students, how do you get interaction with your students. I mean, that’s the idea. How do you do that? And, of course, we get interaction with our students because our classes are a heck of a lot smaller than that…This appeared to me to be a university…sort of like Florida Atlantic, that needs lots and lots of TA’s because the TA’s are the ones who do most of the teaching in the labs. But they don’t have enough graduate students. So how you get around that problem is using your undergraduates to fill that role….what they’re doing is they pick up like four or five modules…they do it in a given semester…and the second semester they do another four or five modules picking them so that they’ll cover the material they need to cover, but at the same time they still have to use the text book. Those modules omit some of the nitty-gritty details like the greenhouse one…they have them do Louis dot structures of molecules, but they never actually explain how to do a Louis dot structure. So …either the professor has got to come up with handouts or what they do at Berkley is that they simply used…everybody bought a general chem. book and they used it as a reference book. And I’m thinking to myself those modules cost like fifteen bucks apiece so the students are now paying sixty dollars a semester for four modules plus another sixty for the second semester so we’re paying an extra hundred and twenty dollars in addition to the textbook they’ve already bought.

Rita Q: What were the key things that you think really impressed you? Like what was most provocative about…?

R: The MID [New Traditions] was the approach that had guided inquiry. How to change the class from traditional to guided inquiry. I’d done very little of that in the classroom although they say it doesn’t take up more time than usual teaching, I find that it does.

Q: It takes away from the actual time in the classroom?

R: Yes, but in the lab…I’ve changed my lab…all of my labs to that format.

Q: Can you explain a bit more about how it takes time away from the class situation.
APPENDIX F (continued)

R: If I’m allowing them to discover the concepts and work on it, they all move at different times. And it takes longer for them to go to the book and analyze and come up with their answers on their own versus if I’m prompting them. I can move them at a quicker pace. I think there’s too much material that needs to be covered in general chemistry. What’s required to be covered.

Q: So this sounds like, is guided inquiry the main thing that you feel like you got from these other workshops or are there other things you got too that you thought were interesting?

R: So the…let’s see, what’s the correct term for it…I forgot…but it’s having like a test question where they have to vote on the answer and come up with the answer. I’m keeping those in between. I think those are very helpful.

Q: It kind of looked like you were doing something like that in class. Is that what you would say you were doing?

R: Yes. And sometimes I’ll have them vote on it if I see that the class is very divided on opinions…and then depending if it’s divided after the vote I’ll have them discuss it between them and then make a new vote.

Laura Q: I’ll probably ask a few questions as you go on.

L: Please do. One of the things that I really liked at the MID Project conference that I went to was the Chemistry Connect…uh, was it called Chemistry….ChemConnections. But I actually attended a follow up workshop in New York for, I think it was three days on that, which was very intensive, and I was very, very excited. I really wanted to come back and implement that in our lab program, because I thought it was just wonderful that it was very student focused, not so much teacher focused…that they were facilitating…I was a facilitator not just a person up there feeding them information, that they had to come up with their own ideas and really, I was mainly there to help them, not necessarily to just lecture and give them all the information. And I approached our dean about actually implementing it at our campus and she was very supportive but, what I came across was the fact that we have to teach a certain number of objectives within our curriculum, and the things they stressed at the workshop is that you’re just not really able to cover every single objective that you normally would… And I know you’ve talked to [Rita], so one of the things that kind of came out of that when [Rita] came on board, was that she was
interested in the guided inquiry, cooperative learning teams and that was kind of along the lines of what I wanted to try at least do in the laboratory, and so we both moved in that direction, for general chemistry I and General Chemistry II, and I’m really, really excited by what we’re doing in the laboratory because the students really have to do a lot more work on their own, come up with ideas, they’re using the scientific method versus, you know, us just giving them a set procedure, where they just follow it and verify what they already know.

Kim K: You’re asking me to think about two influences?
Q: Yes, two possible influences, and there might be others...
K: One influence was definitely [New Traditions, POGIL]. With…guided inquiry. One influence was definitely [a POGIL facilitator], when he came to talk about it. I was very influenced by him and his working groups. And that’s….I’ve tried to introduce that into the nurses chemistry more…not really in the general chemistry because the nurses chemistry group is smaller. The idea of having students talk to each other and actually be solving problems in the class…not just sitting there and me lecturing, but actually having to work and think about problems in the class…so that’s been one influence. And it does mean the class goes more slowly but it does mean that they really have to think a lot more…and they have to work, actually, while they’re in class. It’s very different from the old idea that you would lecture and then they would go away and do their homework.

Howard H: Well, actually I….years ago…let’s see…about eight or nine years ago now….when J. E. was running things, I did the…his…active learning stuff. Although I found a lot of the techniques not really applicable to science and a lot of them don’t work in large lectures. But, um, certain things…ideas I got from that were a little bit useful. They did work…they worked well….because one of the things that we learned in there through the years was web teaching…and I like to use web teaching as a supplement to the lecture… But the main thing is that really, all the different parts of technology that can be used, not just computers, also audio-visual things, all the things that they have that are available impressed me the most. Then, the other thing was the…just some of the teaching techniques, and some introduction into the education literature. But, um…there are just so many things that went through there, I…like I said, I’ve been to about fifteen, twenty
workshops...I don’t remember which one each one did.

Q: What sort of things have you tried?

H: Okay, well I, um, in smaller courses, I have tried occasionally having discussion groups, and, in advanced courses, I know the science students don’t like that. They hate it. So I’ve actually also do a lot of questions...I’ll ask the class questions, and sometimes I’ll even go so far as to point at somebody and say, “alright, what does this mean?” And so, some kind of an active component. Also encourage questions of me while I’m lecturing, and a lot of students....even in a big lecture...they do ask them.

Marcus Q: Um, so was there anything at the MID project workshop that surprised you given that you had some background already...you said you went to different workshops. Was there something that stood out, that was provocative, or anything that you remember that...and if not, that’s fine...

M: You know, I don’t know if you’re into, kind of, science education...do you know CN?. [Q: No I don’t.] He’s fantastic. He does biology. He’s retired now, and he goes around the country giving talks about science education. He’s at Indiana University. And you should check his stuff out if you’re interested in science education. He’s certainly informed me a lot about what works and what doesn’t work...the Chem Modules, have I used the right words?...we actually ended up adopting that...adopting one of them the following year on global warming and we used it the last week and I think we made the mistake of not assessing for it, and, um, you know...clearly if you don’t grade it at the end, all parties take it less seriously. So I liked that. But again, we have a certain amount that we need to cover and I’d rather spend time on the material that we need to cover and do that in a creative way, than add more stuff on. And so, what the Chem Module did was just add more to the student’s plate instead of replace something. Does that make sense?

Vern Q: Was there anything in particular that impressed you about it [MIDP workshop], or that you disagreed with, or....?

V: Well, it was interesting seeing different approaches. It was nice that they kind of brought in a bunch of different methods in. I mostly go to the workshops just to see what people are doing.
APPENDIX F (continued)

Q: What did you think of [POGIL in New Traditions]?  
V: Once again, a little different than the way I do it but, you know, it was an interesting approach...purely problem solving approach...having the students work through the things themselves...and the guided inquiry approach. One thing I’ve come to a conclusion of, in looking at all the way people do things is that lots of different ways things will work and it really comes down to what you’re comfortable with because if the professor is not comfortable with a particular approach it’s just not going to work, no matter how good the approach is. So, the other thing is enthusiasm. Just about anything will work if there’s enough enthusiasm to make it work. So, yeah, I just go to see if there’s something there and pick up a few things here and there.

Q: Is there anything in particular that you disagree with, that you thought wasn’t well thought out or....?
V: No. No. Occasionally I’ll see something....I particularly detest the latest book from the American Chemical Society.

Q: They have a few different ones. Which one....?
V: The latest one. [looks for the book]. This one. Yup, this is the one. This is what threw me off. They put hydrogen right here on top of carbon and that just killed my interest right there. It was kind of like, you’ve got to be kidding.

Cindy C: Well, to be completely honest, when I first started, when I was getting ready...when I knew that I was teaching this large General Chemistry I class, obviously I was not concerned about getting the material...or knowing the material myself. But I emailed the coordinator at the time and said this is the first time I’ve ever done this. What do I need to know. And I got no response. None. Therefore, and I guess, one of my problems was when I did this, is I didn’t take general chemistry in college. I A.P.’d out of it, so I never took it. I don’t even know what went on in a freshman level general chemistry class. And so, um, I just assumed that I would get up and talk. And that’s what I did. I know that there are other things out there, but without any guidance, without any support, without any time, if I were gonna research it myself, to figure out what to do, I just was gonna get up and talk. And that’s still my default, you know. A couple times in class I would pass out a worksheet, and say let’s get together in groups, but since my students weren’t used to
working in groups, because we only did it once or maybe, I guess, three times that semester, you know, it didn’t always go over well because, you know, [mimics student] “I don’t want to work with these guys”…I didn’t make them do it, you know. I didn’t…it wasn’t something that was part of the thing…it was just something I would try.

….and so I guess, realizing the amount of work that goes into it, I think that my first semester, I was getting completely stressed out because I was spending so much time doing this class and I think that even if you had one class of ten students, and nothing else to do, you could still manage to spend 40 to 50 hours a week planning for that one course. I don’t think you could… and I think I was disappointed on some level that I couldn’t put all that time into it, I just couldn’t.

Russ   Q: You mentioned that there were like three different… I think you said three different institutions that you taught at. And you did different things in different institutions?

R: At bigger schools there are positions for professional educators…chemical educators. Like at NAU, one of my colleagues, they hired him as a professor of chemical education….But, it was an interesting teaching experience because I had about 150 students in a big lecture hall and it was somewhat impersonal. I went up there, I taught, it was very rare that people would come see me… At a big school, the only….the disadvantage at a big school you’re going to get a lecture hall of a hundred plus, and it becomes…it’s not personal anymore…you’re just teaching a crowd. And you might recognize a few people and that’s about it. You can do peer learning…you know, you can grab some people that are really good and have them work in groups…and that’s probably one of the best ways to do it because that kind of takes that middle section [C students] that I was talking about and gives them a chance to move up. But you have to be able to really trust those peer leaders. It’s not as easy as it sounds. It’s a lot of work.

Q: Tell me about some more about that, about your experience about how that worked for you?

R: Um, it worked well for, I had my juniors and seniors…the problem is that the students wouldn’t always communicate and they would get poor turnouts.

Q: So they…who wouldn’t communicate…the undergraduates who needed help wouldn’t communicate to the more experienced ones, or
APPENDIX F (continued)

the….?

R: It was kind of both ways actually…because we would set up a room and we would set up a time, and say okay, let’s work in assigned groups or whatever you want to do, and have them working with a certain individual. The problem is that the people in that middle region which are the people that really need the help so you can boost them up to a B level and get potential chem. majors are too busy doing other things and they feel they’re okay. And so it’s tough. You know, if you have a really dynamic person that’s leading the group, sometimes that works out. But, that’s another problem, finding people that are like that…that even want to do that because they’re busy as well. So, it’s tough. You can do it, and I think that’s the best way to try to do it, but…..

Q: How is it a lot of work for you? How does that……?

R: You have to set everything up. So you have to set up the room, you’ve got to set up the time, you’ve got to make the schedules, you got to recruit people to do it, and sometimes they have a good experience and sometimes they don’t. It’s one of those things that….

Q: Would you be involved in the monitoring? Does that also encroach on your time?

R: Yeah. Especially initially when you’re doing it. You want to make sure everything is set up. So it’s a big time sink.
ABOUT THE AUTHOR

Beverly Barker received her B.Sc. in Chemistry (1997) from the University of Victoria in the field of photo-organic chemistry under Dr. Peter Wan with whom, as first author, she published two papers in that field while an undergraduate, one of which won a Merck research award. For her graduate work, she pursued her interest in cytochrome-c oxidase by joining Dr. Randy Larsen’s group at the University of Hawaii, Manoa where she won her Masters of Chemistry (2000), in Physical Chemistry. She published two papers with Dr. Larsen in the field of bio-physical chemistry involving photo-acoustics and photo-thermal beam deflection. In 2002, she joined Dr. Jennifer Lewis at the University of South Florida to pursue a Ph.D. in the emerging field of Chemical Education. She was hired ‘ABD’ by the University of Alaska, Anchorage in August, 2005 where she is presently employed as a tenure track Assistant Professor.