CLASSROOM IMPLEMENTATION OF THE PRACTICES LEARNED IN THE MASTER OF CHEMISTRY EDUCATION PROGRAM BY THE SCHOOL DISTRICT OF PHILADELPHIA'S HIGH SCHOOL CHEMISTRY TEACHERS

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by

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ABSTRACT

CLASSROOM IMPLEMENTATION OF THE PRACTICES LEARNED IN THE MASTER OF CHEMISTRY EDUCATION PROGRAM BY THE SCHOOL DISTRICT OF PHILADELPHIA'S HIGH SCHOOL CHEMISTRY TEACHERS

Uma Devi Jayaraman

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This dissertation reports the results of an exploratory case study utilizing quantitative and qualitative methodologies intended to ascertain the extent and differences of implementation of research-based instructional practices, learned in an intensive 26-month professional development, in their urban classrooms. Both the extent and differences in the implementation of practices were investigated in relation to the lesson design and implementation, content, and classroom culture aspects of research-based practices. Additionally, this research includes the concerns of the teachers regarding the factors that helped or hindered the implementation of research-based practices in their classrooms.

Six graduates of the Master of Chemistry Education Program who were teaching a chemistry course in a high school in the School District of Philadelphia at the time of the study (2006-8), were the case.

The teachers completed a concerns questionnaire with closed and open-ended items, and rated their perceptions of the extent of implementation of the practices in their

urban classrooms. Additionally, the teachers were observed and rated by the researcher using a reform-teaching observation protocol and were interviewed individually. Also, the teachers submitted their lesson plans for the days they were observed. Data from these sources were analyzed to arrive at the findings for this study.

The research findings suggest that the group of teachers in the study implemented the research-based practices in their classrooms to a low extent when compared to the recommended practices inherent to the MCE Program. The extents of implementation of the practices differed widely among the teachers, from being absent to being implemented at a high level, with inconsistent levels of implementation from various data sources. Further, the teachers expressed the depth of knowledge (gained in the MCE Program), formal laboratory exercises and reports, administrative support, self-motivated students, and group/collaborative work as several factors that enabled or would have enabled the implementation of practices. Among the many factors that hindered the implementation of the practices in their urban classrooms were, the core curriculum and pacing schedule, followed by test preparation, administrative paper-work, large class-size, students not prepared for student-centered work, poor math and reading skills of students, students' lack of motivation, unsupportive department head, unresponsive administration, and lack of resources.

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Finally, throughout this journey, I derived a great deal of inspiration from the memory of encouragement and support that my parents always provided towards educational endeavors. In grateful appreciation, this work is dedicated to their memory.

This work is dedicated to the memory of parents

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CHAPTER 1

INTRODUCTION

Statement of the Problem

A challenge has been posed to the science education community to alter the manner in which science is taught in an effort to improve student learning outcomes (NRC, 1996). Science education reform efforts have suggested ways for teachers to move away from the traditional teaching practices to using more student-centered, teacher-guided strategies geared towards inculcating the depth of understanding of content through the vehicle of inquiry-based instruction. Despite the fact that reform efforts have come and gone, the traditional method for the teaching of science and the related dismal learning outcomes for students continue.

The "traditional" (Von Secker, 2002, p.151) teaching practices prevalent in most high school chemistry classrooms are driven by lectures and textbooks with exposition as the primary mode of instruction (Kelly, Suzuki, & Gaillard, 1999; Von Secker, 2002). Further, science is transmitted as a body of facts, terms, and procedures, i.e., as a "recitational" (Kennedy, 1998, p. 253) subject matter knowledge, with little connection among the parts, tasks, and activities, and not as a discipline with conceptual structures and scientific reasoning (Von Secker, 2002). Students are passive recipients of knowledge, sometimes working independently on seat work (Porter, Kirst, Osthoff, & Schneider, 1993; Porter et al., 1994). Labs are either 'cookbook' (they don't allow students to make choices or judgments) or 'confirmatory' (they follow lectures or student reading), neither being relevant to sense-making (Hilosky, Sutman, & Schmuckler, 1998;

NRC, 2001; Webster & Hooper, 1998). The traditional view of learning consists of students accepting the facts and theories without much thought, memorizing and reciting these on demand, defining terms accurately, recognizing the correct answers on multiple choice tests etc., with little emphasis on developing understanding and relevance of knowledge and its applications in the real world contexts (Duschl & Gitomer, 1997; Kennedy, 1998; Lopez, 2000).

Several undesirable consequences of the continued use of these practices have been reported in the literature:

1) It does not empower students with the conceptual knowledge of chemistry (Dinan & Frydrychowski, 1995; Phelps, 1996; Stofflett & Stoddart, 1994; Zoller, Lubezky, Nakhleh, Tessier, Dori, & Yehudit, 1995);

2) It does not promote the critical scientific literacy skills such as knowledge and understanding of scientific concepts and processes, analysis, problem solving, critical thinking etc., so essential to maintain the United States' competitive edge in the world economy (Carter, 2005; Friedman, 2006);

3) Students' lack of ownership and inability to see connections between science and the real world has resulted in a decline in attitude towards science among high/middle school students of all ability levels, with the urban students and students of color exhibiting exceptionally negative attitudes towards school science and their futures in the field (Atwater, Wiggins, & Gardner, 1995; Ayers & Price, 1985; Basu & Barton, 2007; Bohardt, 1975; Cannon & Simpson, 1985; Disigner & Mayer, 1974; Haladyna & Shaughnessy, 1982; Hill, Atwater, & Wiggins, 1995; Hofstein, Maoz, & Rishpon, 1990;

Ormerod & Duckworth, 1975; Randall, 1975; Simpson & Oliver, 1990; Wright & Wright, 1998; Zacharia & Barton, 2004); and,

4) Declining average score in science on the NAEP, with only 18% of 12th grade students performing at or above the proficient level (NCES, 2005, 2007a) and, in 2003, students in seven countries scoring significantly better than our 8th grade students on the Trends In Mathematics & Science Study (Martin, Mullis, Gonzalez, & Chrostowski, 2004; NCES, 2007b).

In the past four decades there has been an explosion of research on human cognition and epistemology in educational philosophy, cognitive psychology, and a diverse array of sciences (Bransford, Brown, & Cocking, 2000; Laws & Hastings, 2002; Luehmann, 2007). The cumulative knowledge from these disciplines has fundamentally altered the conception of best practices in teaching & learning and the processes that promote learning and understanding (Donovan, Bransford, & Pallegrino, 1999; Yager, 2000). These research-based practices, with the potential to address the problems mentioned above, are advocated by the current reform movement in science (AAAS, 1993; NRC, 1996).

Research-based reform teaching and learning practices require that the teachers relinquish control of student learning and allow the students to take responsibility for their learning, with the guidance of the teacher (Barr & Tagg, 1995; Heller & Hollabaugh, 1992; Heller, Keith, & Anderson, 1992; MacGregor, 1990). This entails that the teachers utilize student-centered instructional practices, e.g., probing for students' preconceptions, actively engaging students in activities and conversations that will promote construction of deep understanding of content through inquiry-based methods, providing opportunities for social construction of understanding via seeking answers to student generated questions, experiencing phenomena, conducting authentic investigations, reasoning, thinking critically, sharing ideas within small groups and the whole class, developing explanations, communicating their ideas, using computer technologies, and connecting science to other disciplines and the real world. (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997; Brown, Collin, & Duguid, 1989; Champagne & Bunce, 1991; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Duschl, 1990; ENC, 1996; Gardner, 1991; Hodson, 1992a, b; Lunetta, 1998; McGilly, 1996; Minstrell & Van Zee, 2000; NRC, 1996; NSTA, 2003; Pintrich, Marx, & Boyle, 1993; Roth, 1995a; Schneider, Krajcik, & Blumenfeld, 2005; Tobin, 1993; White & Gunstone, 1992).

There is evidence to support that "inquiry environments support student thinking in ways qualitatively different from traditional science classrooms" (Schneider, Krajcik, & Blumenfeld, 2005, p. 284) and the understanding of science content and process is enhanced through engagement in inquiry methods (Brown & Campione, 1994; Cognition & Technology Group at Vanderbilt, 1992; Metz, 1995; Zhou, 1995). Additionally, studies have established a link between the use of research-based practices and higher achievement scores in math and science (Adamson, Banks, Burtch, Cox III, Judson, Turley, Benford, & Lawson, 2003; Klein, Hamilton, McCaffrey, Stecher, Robin, & Burroughs, 2000; Roth, Druker, Garnier, Lemmens, Chen, Kawanaka, Rasmussen, Trubacova, Warvi, Okamoto, Gonzales, Stigler, & Gallimore, 2006; Wenglinsky, 2000, 2002).

It is reported that in spite of the substantial empirical and theoretical evidence that points to the fact that research-based instruction is a starting point for personal construction of meaning and can lead to higher achievement of all students (Anderson, 1997; Burkam, Lee, & Smerdom, 1997; Carey, 1985; Ertepinar & Geban, 1996; Freedman, 1997; Lee, Chen, & Smerdon, 1996; Schroeder, Scott, Tolson, Huang, & Lee, 2007; Stohr-Hunt, 1996; Von Secker & Lissitz, 1999), vast majority of chemistry teachers continue to practice traditional methods and perpetuate its detrimental consequences for the students (National Science Board, 2004, National Commission on Mathematics and Science Teaching for the 21st Century, 2000; NRC, 2000, 2001, 2005; Weiss, Pasley, Smith, Banilower, & Heck, 2003).

The following reasons have been advanced in the science education literature for the inability of teachers to practice research-based methods:

1) "Teachers teach as they were taught" (Goodlad, 1990, p. 35; Adamson, Banks, Burtch, Cox III, Judson, Turley, Benford, & Lawson, 2003; Lortie, 1975; NRC, 1996). Teachers are products of traditional content courses that promote delivery of content as bodies of disconnected and disorganized superficial facts with no mechanism to address their novice conceptions/misconceptions of the subject, little importance given to acquiring the depth of conceptual understanding, and the absence of any reference to pedagogical content knowledge required to make the content comprehensible to the students (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick & Lederman, 2000; Allen, 2003; Arons, 1990; Banerjee, 1991; Birk & Kurtz, 1999; Carlsen, 1988; Carnegie Forum on Education & the Economy, 1986; Gess-Newsome & Lederman, 1995; Gorin, 1994; Hashweh, 1987; Hawkes, 1998; Holmes Group, 1986; Koballa, Graber, Coleman, & Kemp, 2000; Kokkotas, Vlachos, & Koulaidis, 1998; Lin, Cheng, & Lawrenz, 2000;

McEwan & Bull, 1991; Millar, Osborne, & Nott, 1998; Roehrig & Luft, 2004; Selley, 2001; Wheeler, 2007);

2) Similarly, in their methods courses, the teachers are introduced to general pedagogical strategies (e.g., classroom management, lesson planning, scientific method, etc.) in a transmission mode of being passive recipients of information. This passive mode does not afford the teachers sufficient, if any, opportunities for full exploration and the necessary inculcation of necessary skills required to employ these strategies. As Kagan (1992) points out, "University courses fail to provide novices with adequate procedural knowledge of classroom, adequate knowledge of pupils or extended practica needed to acquire that knowledge, or a realistic view of teaching in its full classroom/school context (p.162)." Other researchers have voiced similar opinions of the inadequacy of traditional teacher preparation programs (Anderson, 1994; Bowman, 1997; Brown & Melear, 2006; Bullough, 1990; Eisenhart, Behm, & Romagnano, 1991; Feimen-Nemser, 1990; Fuller & Brown, 1975; Melear, Goodlaxen, Warne, & Hickok, 2000; Roth, McGinn & Bowen, 1998; Tom, 1985; Zeichner & Liston, 1990). Exposure to, much less experience with, engaging in inquiry-based methods such as exploration, analysis, critical thinking, data interpretation, providing explanation, and communication etc., is rarely the repertoire of the science methods course syllabus (Anderson, 2002; Davis, 2003; Good, Wandersee, & St. Julian, 1993; Tobin, Tippins, & Gallard, 1994; Van Driel, Beijaard, & Verloop, 2001; Von Secker, 2002; Weinburgh, 2003; Wells, 1995; Windschitl, 2002). As Beisenherz & Dantonio (1991) state very succinctly, "teachers cannot be lectured at, demonstrated to, and asked to regurgitate facts, in course after

course, and semester after semester, and then be expected to teach the processes of science without having experienced them" (p. 44; Borko & Putnam, 1996);

3) The school's cultural norms, constraining bureaucratic environment, and public expectations, generally, favor traditional teaching practices (Anderson, 2002; Cuban, 1993; Becker & Riel, 1999; Sarason, 1991);

4) Lack of access to laboratory facilities, safety equipment, laboratory instruments and supplies, and the lack of administrators' understanding and support of inquiry-based approaches in urban areas are a serious hindrance to the implementation of research-based methods (Lombardo, 2000);

5) Teachers in urban settings, such as Philadelphia, are additionally challenged by poverty, low student achievement and preparedness, disconnect between students' communities and science classrooms, and students' uncooperative and resistant behaviors towards classroom participation in activities and discussions (Barton, 2001; Bouillion & Gomez, 2001; Fusco, 2001; Seiler, Tobin, & Sokolic, 2001). These issues are just beginning to be addressed through research and are rarely discussed in any teacher preparation programs; and,

6) Urban areas have a serious problem attracting and retaining teachers, especially teachers of math and science. In the school district of Philadelphia, 70% of newly recruited teachers left the system between 1999-2005 (NCTAF, 2007), resulting in a large number of chemistry teachers teaching out-of field, i.e., without a major or minor in chemistry (NRC, 2007), and the resulting lowered academic achievement of students (Fetler, 1999; Ingersoll, 1999).

7) As waves of science education reform have surfaced from time to time, reform of education itself in America has been on the national scene, especially since the beginning of the 20th century (Callahan, 1964). Reform efforts in education have been strongly influenced by the political and social conditions of the time and have represented the dominant cultural and moral values (Harvey, 2005). The dominant values, those worthy of emulation, continue to be the core values of business and industry. Examples of the core values are efficiency and scientific management (Morgan, 2006), as well as 'accountability' which recently has been epitomized by the No Child Left Behind (NCLB) act of 2001.

Hallmarks of the current reform movement driven by NCLB include: state standards; district mandated curriculum; high emphasis on rote learning; (especially for poor children who predominantly reside in urban areas); performance on predominantly multiple-choice tests as a measure of academic proficiency etc. (Kohn, 2008). With the focus on technical skills rather than ideas, Gibboney (2008) articulates that the essential purpose of education is lost. Specifically, Gibboney (2008) maintains that what is lost is the "cultivation of democratic values and the cultivation of the mind" (p. 29). This is the case when the curriculum taught in schools reflects what the society values. In support of this, Kliebard (1995) states " Whatever else the curriculum may be in terms of what actually gets taught to children, it is also the arena where ideological armies clash over the status of deeply held convictions" (p. 250). In other words, the values inherent in the mandated curriculum may not have much in common with the research-based methods of science teaching, and may even be diametrically opposed to it, making it very difficult to implement the research-based methods in classroom instruction.

8) To implement the research-based practices guided by the mandated curriculum requires that the instructional leaders in the school (the principals) "understand the dynamic relationship among curriculum, instruction, and assessment' (Gross, 1998, p. 14). Also, they need to view the guidelines provided by the mandated curriculum as liberating, rather than restricting and locate the areas where there is freedom to operate. Gross (1998) states "once you accepted the contours of the bottle, you could concentrate on the freedom you had in organizing the sand in beautiful layers (p. 51)." When viewed in this way, the design of an instructional program that operated within the confines of the mandated curriculum yet implemented the research-based practices is possible (Gross, 1998). However, it requires creativity, flexibility, and willingness to experiment, if certain preconditions such as: success according to traditional definitions, safety, attendance, good communication, and team spirit are met (Gross, 1998). Urban schools are typically characterized by a high turnover of instructional leaders and other staff and the attendant instability (Flanary & Laine, 2006; Gates, Ringel, Santibanez, Guarino, Ghosh-Dastidar, & Brown, 2006; Hill & Banta, 2008; Partlow & Ridenour, 2008; Scott, 2003; Starr, 2007; Useem, Christman, Gold, & Simon, 1997). Therefore, in these schools the opportunity to build the solid foundation (the preconditions) that is the substratum of a functional curriculum leadership is scant, resulting in the sand not being poured into the bottles and acceptance of the rigidity of the surface of the bottles rather than exploration of the fluidity and possibilities of pouring the sand.

There is sufficient evidence to show that well-prepared teachers with deep conceptual understanding of their subjects, and applying research-based methods in their classrooms have a significant impact on student achievement (Carlsen, 1988; Chaney, 1995; Darling-Hammond & McDonald, 2000; Druva & Anderson, 1983; Ferguson, 1991; Ferguson & Ladd, 1996; Hashewh, 1987; Hawk & Swanson, 1985; McDiarmid, Ball, & Anderson, 1989; Monk, 1994; Nye, Konstantopoulos, & Hedges, 2004; Rivkin, Hanushek, & Kain, 2005; Sanders & Horn, 1998; Sanders & Rivers, 1996; Steinberg, Haymore, & Marks, 1985; Wright, Horn, & Sanders, 1997).

To actualize the change to research-based practices, the solution emphasized in science education literature is that, the teachers themselves need to acquire the depth of content knowledge via construction of understanding of new experiences/topics based on their prior knowledge, experience inquiry-based practices, and internalize these before implementing them in their classrooms (Ball, 1998; Borko et al., 1993; Brown & Borko, 1992; Coble & Koballa, 1996; Cooney, 1994; Manouchehri, 1997; Wright & Wright, 1998).

The vehicle to bring about the change in classroom practices from the traditional to research-based is effective and sustained professional development of in-service teachers informed by social constructivism and the assumptions of Andragogy (Desimone, 2002; Education Trust, 1998; Fullan, 1993; Guskey, 2000; King & Newman, 2000; Knowles, Holton, & Swanson, 2005; Levitt, 2002; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Lumpe, Haney, & Czneriak, 2000; NCTAF, 1996; Vygotsky, 1978; Wright & Wright, 1998). During the effective and sustained professional development, teachers are modeled those practices by their instructors that they are expected to implement in their classrooms in a supportive environment of exploration, collaboration, reflection, and communication of ideas with the realization that change occurs in stages, often idiosyncratically, over time, and requires constant adjustments (Coble & Koballa, 1996; Kennedy, 1998; Loucks-Horsley, Stiles, & Hewson, 1996; Loucks-Horsley, Hewson, Love, & Stiles, 1998; National Staff Development Council, 1994; Palincsar & Brown, 1984; Prawat, 1991, 1993; Shulman, 1986,1987; Siegel, 1978, 1993).

Some studies have found that the teachers are able to implement the research-based practices in their science classrooms after having participated in effective and sustained professional development programs, typically, for 80 or more hours (Cohen & Hill, 2000; Garet, Biman, Porter, Desimone, Herman, & Yoon, 1999; Irving, Dickson, & Keyser, 1999; Porter, Garet, Desimone, Yoon, & Birman, 2000; Radford, 1998; Supovitz, Mayer, & Kahle, 2000; Supovitz & Turner, 2000). However, these studies have occurred in, typically, suburban settings and/or in K-8 classrooms, utilizing teacher self-reported and/or observation data (Corcoran, McVay, & Riordan, 2003; Harcombe, 2001).

Complementary theories that support research-based practices are social constructivism and Andragogy (Zappala, 2007). Social constructivism is a theory of how people learn that takes the position that all cognitive functions originate in, and can be explained as a product of social/cultural interactions. Vygotsky was the main proponent of this theory that has the potential to integrate various schools of psychology. The main ideas of this theory are the concepts of higher mental functions and the zone of proximal development. Higher mental functions are uniquely human, as opposed to lower mental functions possessed by all animals. The transformation from lower to higher mental functions is cognitive development and it is always mediated by more mature members of the society using culturally sanctioned signs, symbols, and language etc. As the children actively engage in problem solving in the company of adults or more mature members of society, they appropriate the methods, processes, representations, and tools (i.e., “cultural artifacts’) used by the more mature members (Kozulin, 1990). As this continues, the cultural artifacts undergo a series of qualitative, dialectical transformations (Moll, 1990) within the child, ultimately resulting in their internalization and ‘owning’ by the child. Thus, the characteristics of culture that were initially situated outside in the signs and symbols and processes (of others) are now encapsulated within the child as a uniquely transformed entity, brought about by the intersocial interactions and the efforts of the child (Davydov & Kerr, 1995). Development of scientific concepts in children, guided by a competent teacher is an important example of the development of higher order mental functions.

The second concept, Zone of Proximal Development (ZPD), is the “distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). ZPD is the “construction zone” (Newman, Griffin, & Cole, 1989, p. 1) where individuals participate in teaching-learning process, “an apprenticeship in thinking” (Rogoff, 1990, p. 8) to co-construct new knowledge, inculcate new skills and to appropriate (i.e., personalize) these. Scaffolding is a technique teachers use in guiding the children in the ZPD through activity, and other means that promote students’ construction of knowledge.

The theory of Andragogy is actually a set of assumptions about the adult learning process. It is a perspective that makes “an honest attempt to focus on the learner” (Feur & Gerber, 1988, p. 130). It is a set of six core adult learning principles that can be considered a set of rubrics to understand adults as learners. These principles are flexible enough to be adapted to any adult learning context and conform to the goals of the particular program (Knowles, Holton, & Swanson, 2005). There are six principles of Andragogy:

1) The learner's need to know: This is the primary need that drives the adults to enroll in programs (such as the MCE) where they can further their learning, and broaden their horizons. Educators can tap into this preexisting need, and enhance the outcome by collaborating with the adult learners (Clark, Dobbins, & Ladd, 1993);

2) Self-directed learning: Adults take ownership of their learning. However, due to differences among them, the adult learners are self-directed in various degrees, so will need different amounts of help to become independent and self-regulating learners and problem solvers (Candy, 1991);

3) Prior experience of learners: Adults come to a learning situation with a wealth of prior experiences that influence their new learning by acting as the foundation or the scaffold on which new learning is built (Savery & Duffy, 1996);

4) Readiness to learn: "Adults become ready to learn those things they need to know and be able to do in order to cope effectively with their real-life situations" (Knowles et al., 2005, p. 67);

5) Orientation to learning: Adults prefer a problem-solving orientation to learning as opposed to a subject-centered orientation to learning. They prefer to test their learning against new experiences and learn further as a result of the interaction; and,

6) Motivation to learn: Adults are more likely to be driven by internal rewards than external. Although external rewards are important, the internal rewards such as learning something of value and enjoyment of learning are, generally, better motivators of learning (Wlodowski, 1985).

Purpose of the Study

Many studies report that, as a result of participation in effective and sustained professional development programs, teachers are able to implement research-based practices in their classrooms. The purpose of the study was to ascertain the extent to which a group of six chemistry teachers in the study were able to implement the research-based practices, learned in an intensive 26-month professional development, in their urban classrooms. The extent of implementation was investigated in relation to 3 aspects of the research-based practices: 1) lesson design and implementation, 2) content, and 3) classroom culture. Further, this study also ascertained how the implementation of research-based practices differed among the six teachers. Also, this research determined the concerns of the teachers regarding the factors that helped or hindered the implementation of research-based practices in their classrooms.

Research Questions

This study attempts to answer the following research questions:

Question 1

How does graduation from a twenty-six month content intensive professional development program for high school teachers, whose goal is to improve the teachers' knowledge of research-based instructional practices (in the domains of lesson design and implementation, content, and classroom culture), affect the classroom practices of the group of teachers in an urban environment?

Three contributory questions assisted in answering this research question.

Contributory Question 1a

To what extent does the group's lesson design and implementation reflect the research-based instructional practices?

Contributory Question 1b

To what extent are the group's content knowledge and application of supportive procedures exhibited during their classroom instruction?

Contributory Question 1c

To what extent do the group's lessons promote a student-centered classroom culture, consistent with the research-based practices?

Question 2

How are the teachers' classroom practices (in the domains of lesson design and implementation, content, and classroom culture) different from each other when implementing the research-based MCE program practices?

Three contributory questions assisted in answering this research question.

Contributory Question 2a

To what extent are the teachers' designed and implemented lesson plans different from each other when implementing the practices?

Contributory Question 2b

To what extent are the teachers' content knowledge and application of supportive procedures exhibited during their classroom instruction different from each other?

Contributory Question 2c

To what extent is the teachers' promotion of a student-centered classroom culture different from each other, consistent with the research-based practices?

Question 3

What concerns do teachers express as factors that enable the implementation of the MCE program practices in their classrooms?

Question 4

What concerns do teachers express as the factors that hinder the implementation of the MCE program practices in their classrooms?

Definitions

Andragogy

The academic discipline that reflects and researches the education and learning of adults. “It is any intentional and professionally guided activity that aims at a change in adult persons” (Knowles, et al., 2005, p. 60).

Classroom Culture (Student-centered)

It is a social and intellectual classroom environment that enables the students the opportunity to develop the skills and dispositions to be lifelong learners (Hurd, 2002; NRC, 1996). When teachers promote this in their classrooms, they allow students’ thinking to be made transparent and enable them to be responsible for and involved in their learning. Some of the methods the teachers use are ; allowing the students to engage in discussions, expressing their ideas/explanations, generating conjectures and alternative strategies, critiquing each others’ work, providing guidance for students to construct their ideas, questioning, engaging in activities, and reflecting (AAAS, 1990; Bransford, Brown, & Cocking, 2000; NRC, 1996).

Conceptual and Depth of Understanding of Subject Matter

Conceptual and depth of understanding of subject matter refer to an integrated and functional grasp of scientific ideas generally built around central concepts. Students with conceptual understanding know more than isolated facts and methods. They understand why a scientific idea is important and the kinds of contexts in which it is useful. They have organized their knowledge into a coherent whole, which enables them to learn new ideas by connecting those ideas to what they already know. Conceptual understanding also supports retention. Because facts and methods learned with understanding are connected, they are easier to remember and use, and they can be reconstructed when forgotten. If students understand a method, they are unlikely to remember it incorrectly. They monitor what they remember and try to figure out whether it makes sense. They may attempt to explain the method to themselves and correct it if necessary. Although teachers often look for evidence of conceptual understanding in students' ability to verbalize connections among concepts and representations, conceptual understanding need not be explicit. Students often understand before they can verbalize that understanding (Glaser & Bassok, 1989).

General Pedagogical Knowledge (GPK)

This encompasses every category of knowledge that is relevant to teaching in general, independent of teachers' subject matter knowledge (Morine-Dershimer & Reeve, 1994).

(Classroom) Instructional Practices

Traditional Practices

These are didactic, logical-positivist, accept a body of empirically tested knowledge as truth, and believe that science is taught by transferring knowledge from the teacher to student.

Research-based Practices

These are based on the recommendations of National Science Education Standards, Benchmarks for Science Literacy, and Science for All Americans. The practices include constructivism, cooperative learning groups, students taking an active role in their learning, and inquiry etc. (Anderson, 2002; Tobin & McRobbie, 1996).

Lesson Design and Implementation

This reflects the structure and nature of a reformed lesson. It includes design, sequence, and pedagogical setting within which the lesson is presented, e.g., a reformed lesson acknowledges student preconceptions, envisions them as a community of inquirers who engage in exploration before attempting explication or definition (Sawada, Piburn, Judson, Turley et al., 2002).

Master of Chemistry Education (MCE) Program

A 26-month professional development program for inservice high school teachers of science, where the participants acquire a deep understanding of the content of chemistry and are modeled the best practices for teaching these concepts. This is achieved through ten graduate courses. Eight of these courses are content intensive and two are focused on chemistry education (Blasie & Palladino, 2005). At the successful completion of the requirements of the program, the teachers are awarded the Master of Science in Chemistry Education (M.S. Chem. Ed.) degree.

National Assessment of Education Progress (NAEP)

It is also known as the "Nation's Report Card", the only nationally representative and continuing assessment of what America's students know and can do in various subject areas. Since 1969, the assessments have been conducted periodically in mathematics, reading, science, writing and other subjects (NCES, 2007a).

Pedagogical Content Knowledge (PCK)

This "refers to the transformation of Subject Matter Knowledge, SMK (see definition below), used by teachers in the communication process with learners" (Gilbert, Jong, Justi, Treagust, & Van Driel, 2002, p. 371; Kennedy, 1998; Shulman, 1986). PCK focuses on a particular domain, such as chemistry. PCK becomes even more distinct when it is topic or concept specific (e.g. stoichiometry or equilibrium etc.) within the domain. Van Driel, Verloop, & DeVos (1998), as reported in Gilbert, Jong, Justi, Treagust, & Van Driel, (2002, p. 371), attribute the following elements to PCK;

1) knowledge of student conceptions with respect to a domain or topic, understanding specific student difficulties in the area,

2) knowledge of representations of subject matter for teaching, and

3) knowledge of instructional strategies incorporating such representations.

Professional Development (Inservice)

"Professional development is the ongoing growth of knowledge, skill, and values through deliberate learning efforts to enable individuals to more competently perform their professional roles, support their organization's objectives, and contribute to the evolution of the profession" (McLagan, 1987, p.28).

Reformed Teaching Observation Protocol (RTOP)

It is a classroom observation instrument designed to measure 'reformed' science and math teaching. The two referents for reformed science teaching are Science For All Americans (AAAS, 1990) and National Science Education Standards (NRC, 1996). RTOP consists of 25 statements, each with a Likert-type response on a scale of 0-4 (Never occurred to-Very descriptive). The 25 statements are clustered around 3 domains of: 1) Lesson design and implementation, 2) Content, and 3) Classroom culture. A high score on the RTOP represents a lesson that is closely aligned to the tenets of 'reformed' science teaching (Sawada, Piburn, Judson, Turley et al., 2002).

Reformed Teaching Observation Protocol Teacher Survey (RTOPTS)

This is a survey based on the RTOP. Each of the 25 statements in the survey closely resembles the 25 statements of the RTOP. However, the RTOPTS statements are in the first person singular, completed by the teachers, and designed to measure the teachers' self-reported assessment of how well their classroom practices are aligned with 'reform' practices.

Science Education Reform

It is the vision of science education leading to scientific literacy for all the students. This vision emphasizes a way of teaching and learning about science that is in alignment with the methods of scientists, engaging in inquiry to know and understand the world, changing the content and assessment of science, education of teachers, and the relationship between schools and the community (AAAS, 1993; Benfey, 1964; Crilly, 1974, NRC, 1996; Osborne, 1969; Pimentel, 1963; Pode, 1966; & Sherwood, 1978).

Social Constructivism

It is an epistemology that situates all learning in the sociocultural context. The basic tenet of the theory is that as children actively engage in problem solving under the guidance of adults, they appropriate the methods, processes, representations, ultimately transforming and internalizing these, resulting in ‘learning’ (Kozulin, 1990; Moll, 1990).

Stages of Concern Questionnaire (SoCQ)

The purpose of this questionnaire is to determine what teachers, who are using the MCE program practices in their classrooms, are concerned about at the time they complete the questionnaire (Hall, George, & Rutherford, 1977, 1979). It consists of 35 statements, each requiring a Likert-type response on a 0-7 scale (No concern-Prominent concern). The 35 items are evenly clustered around 7 developmental stages of concern. The researcher has attached 3 open-ended items at the end of the SoCQ to probe the teachers’ self-ratings and specific concerns.

Subject Matter Knowledge (SMK)

It is the content knowledge of chemistry and its organization in a coherent structure that promotes depth of understanding and interconnectedness of topics. This knowledge changes over time (Gess-Newsome, 1999; Hashweh, 1996).

Trends in Mathematics and Science Study (TIMSS)

TIMSS is an international assessment that provides reliable and timely data on the mathematics and science achievement of U.S. students compared to that of students in other countries. TIMSS data has been collected in 1995, 1999, and 2003. The United States has also collected TIMSS data in Spring 2007 (NCES, 2007b).

Delimitations

The study was limited to the classroom practices of six chemistry teachers, who have graduated from the MCE program for 1-6 years, and were teaching chemistry in various high schools of the School District of Philadelphia in the year 2007-2008.

Limitations

The following points defined the limitations of this study.

(1) All the teachers, although graduates of MCE program, had diverse educational and teaching experiences.

(2) The teaching contexts of the teachers in the study admitted of a wide variation, from a comprehensive neighborhood school in one of the poorest sections of the city to a highly acclaimed magnet school.

(3) Corresponding to the diversity in schools, the diversity in students also varied a great deal. This ranged from students with substantial gaps in prior knowledge to very well prepared students working at the IB and AP levels.

(4) Although all the students were taught chemistry using the same curriculum, the core curriculum, or the IB/AP curriculum set by the IB Directorate/College Board, there was a large variability in the resources that schools could draw upon to aid in teaching.

(5) The researcher’s field notes and the instrument (Reform-based Teaching Observation Protocol) were the only two sources of information on class observation.

(6) Only one type of teacher generated document, the written or typed lesson plan, was examined.

(7) Student work of any sort was neither collected nor analyzed in any way.

(8) The responses of teachers on the SoCQ questionnaire and the semi-structured interview were assumed to be an honest and accurate representation of their perceptions and feelings.

(9) The artifacts pertaining to the courses in the MCE program were not analyzed.

(10) The exploratory case study design of the study bounded the generalizability of the research findings to the conditions defined in the study.

Need for the Study

This researcher offers several needs associated with the execution of the study. The needs fall into the categories of: 1) To Add to Current Research, 2) To Find New Avenues for Research, and 2) To Promote the Public Agenda. These needs are further discussed below.

Add to Current Research

a) Most science teachers are not fully implementing research-based teaching strategies in their classrooms (Haney & Lumpe, 1995; National Commission on Mathematics & Science Teaching for the 21st Century, 2000; Radford, 1998; Rhoton, Madrazo, Motz, & Walton, 1999). A great deal of research in ascertaining if the teachers are implementing the research-based practices in their classrooms employs attitude surveys or other teacher reported measures, and interviews that do a pre-post comparison of teachers' attitudes and beliefs to derive their conclusions (Abd-El Khalick & Akerson, 2004; Posnaski, 2002; Supovitz & Turner, 2000). All of these instruments report only the teacher perspective, rather than a combination of different perspectives. In light of the fact that teachers interpret and remold reform initiatives into prior constructs and views, making existing practice resistant to change (Yerrick, Parke, & Nugent, 1997), it is important to incorporate observational data in determining the extent of implementation. This study has triangulated multiple sources of data, e.g., teacher concerns questionnaire, teacher interview, examination of teacher lesson plans, and direct observation by the researcher using a valid and reliable instrument, to draw its conclusions.

b) Most of the extant research utilizes large databases, generally encompassing school-wide, system-wide, or multiple-systems approach (Dass, 2001; Johnson, 2006; Radford, 1998; Supovitz & Turner, 2000). The advantage of this broad base is greater confidence in the generalizability of the outcome. However, the breadth is gained at the expense of depth, the unique advantage of the case study approach, such as this study. Research suggests that only as few as 10% of teachers transfer their learning from professional development experiences to the classroom (Hirsh & Ponder, 1991). Therefore, an in-depth small-scale case study is better suited to probing the cause (s) of the lack of transfer. Additionally, case study's "naturalistic design contributes to the ecological validity of the data" thus strengthening the study (De Jong, Veal, & van Driel, 2002, p. 372).

c) In the literature, generally, the teachers participate in professional development that is geared towards changing their classroom practice, as a result of the school or district's decision, not by individual choice (Corcoran, McVay, & Riordan, 2003; Dass, 2001; Priestley, Priestley, Sutman, Schmuckler, Hilosky, & White, 1998; Supovitz, Mayer, & Kahle, 2000). There are two studies where teachers participate in professional development based on voluntary individual choice based on *their* desire to improve their practice, as is the case in this study (Bretz, 2002; Irving, Dickson, & Keyser, 1999). In Irving, Dickson, and Keyser's study secondary science teachers took three courses to improve their content and pedagogical skills. Pre-post survey, journals, lesson plans, and other teacher generated documents (no direct observation instruments) were utilized to arrive at the conclusion that transfer of skills to classroom practice had occurred. Bretz's study is the only one *currently* geared towards the improvement of content knowledge and inquiry skills of in-service chemistry teachers leading to a Master of Science in Chemistry Education (M.S. Chem. Ed.) degree, similar to MCE program (however, it is structured very differently). The evaluation of classroom implementation was conducted using surveys, focus group, and the analysis of classroom discourse using the RTOP. The conclusion was that the teachers are more likely to try new methods and assess student understanding in more substantive ways. The study was silent on many other aspects of implementation, such as the RTOP domains of lesson design and implementation, content, and classroom discourse. This study attempts to shed light on these missing areas of implementation.

Find New Avenues for Research

a) As Barton & Tobin (2001) point out,

> Urban centers provide unique settings and challenges for teachers and researchers alike. Yet, a cursory analysis of the science education literature shows that there has been a dearth of studies in major refereed science education journals over the past 10 years that have a primary focus on the needs of urban students and their teachers. (p. 843)

This study examined how a group of six in-service chemistry teachers in an urban setting (both in-field and out-of-field at the time they joined the program), working with a high percentage of poor and minority students, implemented research-based practices (acquired in an intensive 26-month program) in their classrooms, how did their practices differ from each other, and the challenges and supports they faced in this endeavor. This study fills a void in the current research on urban science education. In addition, this study serves as a point of departure for the continuation of related studies to achieve a better understanding of the issues involved in implementing research-based methods in the urban context.

b) In this study, the implementation of classroom practices of inservice chemistry teachers (who had participated in an intensive training in using research-based methods) was examined through the dual lenses of social constructivism (Vygotsky, 1978), and Andragogy (Knowles et al., 2005). The analysis and conclusions can serve to open yet unexplored dimensions in the extant literature in both of these areas, as well as those of professional development, implementation of current reform agenda in science, and teaching chemistry in an urban setting.

Promote the Public Agenda

a) Promoting scientific literacy for all with excellence and equity is the goal of the current reform movement in science education (NRC, 1996). Insights from the study can help to identify the aspects of reform-based practices that are easy to implement and those that pose challenges with the students. This information can be useful to the stakeholders and can incite further research.

b) The discussions and conclusions from this study can better inform teacher preparation programs and inservice programs, whose goals are to produce competent, qualified science and chemistry teachers.

CHAPTER 2

REVIEW OF THE LITERATURE AND RELEVANT RESEARCH

Introduction

The literature review for this study commences with an examination and description of the construct ‘research-based classroom practices’, particularly in relation to the ‘traditional practices’, and the rationale for espousing said practices. Since implementation of research-based practices is the overarching theme of the study, these will provide the focal points of the chapter, permeating each of the subsequent sections. Further, each of the subsequent sections in this chapter deals with a particular aspect of the practices that influence its implementation.

The second section describes constructivism, the theoretical substratum that informs and anchors the classroom practices. Since these practices are learned by adults and practiced by them in their respective classrooms, the next section discusses the process of adult learning informed by constructivist methods.

Professional development, the vehicle that exposes the teachers to these practices, is the topic of the following section. This section concludes with a description of the MCE program (i.e., the professional development program the teachers in this research participated in and the implementation of whose practices in their classrooms is the subject of this research). Since a very important factor in the implementation of the practices is the role played by teachers’ knowledge base and beliefs, these are also discussed.

Very often, the context of practice determines the extent (scope) of its implementation. Therefore, the impact of an urban setting on the classroom practices, as expounded in the literature, is described in the next section. Since implementation of change in practices is tied to the concerns the practitioners have, these concerns are explored via a questionnaire that is described in the next section. An account of the available classroom observation instruments to ascertain the extent of implementation of research-based practices follows. This chapter concludes with a brief summary of each of the aforementioned topics.

Classroom Practices

For the purpose of this research, classroom practices refer to the methods of conducting and carrying on instruction in the classroom employed by the Chemistry teacher participants described within. The concept of 'research-based' classroom practices is best understood in contrast to its antithesis, the prevalent 'traditional' practices. Therefore, the traditional practices are described first. Both the practices, traditional as well as research-based, are described with respect to the following 3 domains: (1) lesson design and implementation; 2) content (propositional and procedural knowledge); and (3) classroom culture (communicative interactions and student-teacher relationships) (Sawada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002)

Traditional Classroom Practices

Some salient characteristics of traditional lesson design and implementation, content, and classroom culture are described below. Although the list offered is not exhaustive, it serves to provide the reader with a substantial flavor for the strategies used by the practitioners of this type of craft.

Lesson Design and Implementation

As described in the literature, a teacher who utilizes traditional teaching strategies typically makes no attempt to explore and challenge students' prior knowledge, and the engagement of students is often absent while planning or implementing the lesson (Carey & Gelman, 1991; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Vosniadou & Brewer, 1992). Furthermore, when traditional strategies are employed there is no exploration of students' ideas, and laboratory work typically provides verification exercises rather than exploration (Harcombe, 2001; Tobias, 1990). In this type of learning environment, students are not encouraged to look for alternative explanations when seeking the solution to a problem and/or interpreting observations of science phenomena. Rather than pursuing student-generated ideas (Fosnot, 1996), the goals of traditional instruction defer to a set of behaviors and skills that are scheduled to be taught.

Content

The teacher is an expert in the field who primarily delivers/transmits knowledge to the students via lecturing/telling about, very often, the basics (Ball & Cohen, 1995; Kennedy, 1995; Lampert & Ball, 1995). Using this didactic approach, he/she relies heavily on the text books that explain the material. In addition, the goals of the lectures and the textbooks are to expose the students to the "factual findings" (Hurd, 1970, p. 7) or "rhetoric of conclusions" (Schwab, 1962, p. 24) in science, rather than to develop a depth of understanding of the true nature of science and the particular content (Moss, 2001). Typically, students memorize a multitude of facts, formulas, and procedures and reproduce these with fidelity on tests of achievement (Tobin & McRobbie, 1996; Weiss, 1997). Heavy reliance on textbooks provide only one view of complex issues, one set of truths (Ben-Peretz, 1990) with no emphasis on critical assessment, active engagement, or reflection (Russell, 1995). Also, the focus is on coverage of isolated topics and skill building, and concepts within a topic are presented in isolation and are not interrelated (Welch, Klopfer, Aikenhead, & Robinson, 1981). Students are not encouraged to apply the concepts, or to draw connections among concepts/topics (Lord, 2004).

Classroom Culture

The classroom culture is teacher-centered and teacher talk dominates the classroom, with the students as passive receivers, rather than generators of knowledge (Flanders, 1973; Goodlad, 1984). Students are required to replicate certain behaviors determined by the teacher (Ravitz, Becker, & Wong, 2000; Yager, 1991). Most of the interactions take place between the students and the teacher and very little check for understanding occurs between and among students (Fraser, 1994). Students work in relative isolation and are given tasks from worksheets, the chalkboard, and the textbook that require low-level skills, rather than higher-order reasoning and divergent thinking (Tobin & Gallagher, 1987; Tobin, Kahle, & Fraser, 1990). Since the minds of students are considered *tabula rasa*, their opinions are not valued (Byrnes, 2001).

Efficiency of covering the material is valued (Tobin & McRobbie, 1996), rather than listening patiently to students' ideas. Further, the teachers are interested in knowing if students know the 'right' answers, rather than in their conjectures and alternative solutions (Brooks & Brooks, 1993).

Research-based Classroom Practices

Now, the hallmarks of research-based practices in the same three domains are presented for reader edification.

Lesson Design and Implementation

In a classroom where research-based methods are practiced, teachers gauge students' prior knowledge on the subject and find ways to build on it. If misconceptions in the knowledge are detected, these are addressed in a variety of ways, including by directly challenging them (AAAS, 1990; Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997; Borko, Peressini, Romagnano, Knuth, Yorker, Wooley, Hovermill, & Masarik, 2000; Bransford, Brown, & Cocking, 2000; Caravita & Hallden, 1994; Jones, Rua, & Carter, 1998; Novak, 2002; Pearsall, Skipper, & Mintzes, 1997). Overall, the lessons emphasize student engagement, exploration, and explanations prior to formal presentation by the teacher (Brooks & Brooks, 1993; NRC, 1996; Trowbridge, Bybee, & Powell, 2000). Furthermore, the lesson plan is flexible to accommodate inquiry into student-generated questions (Brooks & Brooks, 1993; NRC, 1996, 2000, 2001).

Content

The teacher who has a deep knowledge of the subject, and the pedagogical skills and abilities can translate these into effective instruction (Evertson, Hawley, & Zlotnick, 1985; McDiarmid, Ball, & Anderson, 1989). These teachers strive to develop a deep understanding of the subject among the students, similar to those of experts in the discipline, by focusing on 'big ideas' around which explorations of content-specific topics are woven (Brooks & Brooks, 1993; Chi, Feltovich, & Glaser,1981; Kozma & Russell, 1997). In the process of acquiring a depth of understanding and building their own knowledge structures, the students learn related skills through active engagement. Some of these skills developed are: (a) gathering information; (b) making predictions; (c) devising experiments to test their ideas; (d) reflecting; (e) thinking critically; (f) challenging each other's ideas; and (g) using multiple representations to explain their findings (Alexander & Murphy, 1998; Borko & Putnam, 1995; NRC, 1996; Trowbridge, Bybee, & Powell, 2000). The instructional practices include emphasis on the tentative nature of scientific knowledge, and establishing connections to other disciplines and to the real world (AAAS, 1990; Anderson, Greeno, Reder, & Simon, 1997; Brown, Ash, Rutherford, Nakagawa, Gordon, & Campion, 1993; Brown, Colloins, and Duguid, 1989; Gollub, Bertenthal, Labov, & Curtis, 2002; NRC, 1996).

Classroom Culture

The classroom culture is said to be student-centered, when the teachers place less emphasis on lecture and more emphasis on acting as the "guides on the side" who provide students opportunities to test the adequacy of their current understandings (Hoover, 1996, p.1). This is facilitated by allowing the students to interact, collaborate, and communicate ideas with each other, in small groups and as a whole class, and with the teacher (Ravitz, Becker, & Wong, 2000). Students are encouraged to actively engage in 'substantive conversations' about the subject matter to build improved or shared understanding of topics/concepts (Alexopoulou & Driver, 1996; Carpenter and Lehrer, 1999; Frantz, Lawrenz, Kushner, & Millar, 1998; Newmann & Wehlage, 1995; Towns & Grant, 1997). Teachers encourage student inquiry by asking thoughtful, open-ended, and divergent questions, wait for answers, and patiently listen to student responses before responding (Brooks & Brooks, 1993; Trowbridge, Bybee, & Powell, 2000).

The reader is directed to Appendix A for a comprehensive list of research-based practices.

Rationale for Espousing the Research-based Practices

The major goal of science education has been to develop, in students, ways of thinking that mirror how the scientists think about the natural world (NRC, 1996). Some of the skills that can be taught in science classrooms towards achieving this goal are the skills of problem solving, critical thinking, reflection, science process, scientific method, and inquiry (Anderson, 1998). Research on learning focused on these areas has been a part of the history of science education for over a hundred years (DeBoer, 1991). However, in the past 4 decades, two bodies of research, one psychologically based, mainly on the works of Piaget, Ausubel, Vygotsky, and Bruner, and the other, research on brain function, have substantially increased our understanding of human cognition, organization of knowledge, metacognition, role of experience in understanding, and acquisition of expertise etc. (Alexander & Murphy, 1998; DeBoer, 1991; Donovan & Bransford, 2005; Gollub, Bertenthal, Labov, & Curtis, 2002; Jansen, 1998; Kotulak, 1996; Lasley, 1997). A synthesis of the two strands of research reveals that there is considerable agreement on some of the key findings (Bransford, Brown, & Cocking, 2000; Lambert & McCombs, 1998; Michael, 2006). These findings include:

(1) Learning involves active construction of meaning of the experiences the learners have, i.e. knowledge cannot be transmitted but must be constructed by the mental activity of the learner (Bruer, 1994; Driver, Asoko, Leach; Mortimer, & Scott, 1994; Driver, & Oldham, 1986; McGilly, 1994; Sachse, 1989; Watson, & Konicek, 1990)

(2) Learning facts and learning problem solving involve two different processes (Anderson, 1983; Romiszowski, 1999; Ryle, 1949; Segal, Chipman, & Glaser, 1985)

(3) Some things that are learned are context specific, while others are more amenable to transfer to other domains (Haskell, 2001; Mestre, 2005; Perkins, & Solomon, 1987, 1989).

(4) People learn more in collaboration with others than individually (Blumenfeld, Marx, Krajcik, & Soloway, 1996; Bossert, 1998; Gardner, Greeno, Reif, Schoenfield, DiSessa, & Stage, 1990; Johnson, Johnson, & Stanne, 2006).

(5) Meaningful learning is facilitated by communicating explanations to oneself or others (Chi, deLeeuw, Chiu, & LaVancher, 1994; Evens, & Michael, 2006; Lemke, 1990; Rivard & Straw, 2000).

For science education to be effective, this body of research should guide classroom instructional practices (Tobin, Tippins, & Gallard, 1994). The theory that undergirds these research findings is constructivism. This ‘constructivist’ approach requires very different classroom practices in science instruction in the secondary school (Trowbridge, Bybee, & Powell, 2000), necessitating a change from the traditional practices. Some characteristics of these practices were described in the previous section.

The next sections elaborate on a brief historical overview of constructivism, including proponents of the theory of constructivism, epistemology, as well as the roles of both the teachers and the students.

Constructivism

A Brief Historical Overview

As alluded to earlier, “the idea that knowledge is constructed by the knower is as old as Western philosophy” (von Glasersfeld, 1995a, p. 24). In the recent past, writings of many thinkers, particularly, Vico in the 17th century (Bettencourt, 1995), and Dewey

(Fosnot, 1996) in early 20th century reveal a definite constructivist stance. Rousseau's ideas on the education of Emile and, Pestalozzi's "object-teaching" (Null, 2004, p. 184) methods relate very closely to the advocacy of contemporary constructivist practices in classroom instruction in the process of teaching and learning.

However, for the greater part of the last century, the dominant epistemology that eclipsed constructivist ideas, and was the driving force behind the classroom practices in K-20 education, has been (and still is, to a great extent) behaviorism (Dana, & Davis, 1995; Fosnot, 1996; Herron, 1975; Herron & Nurrenbern, 1999; Mintzes, Wandersee, & Novak, 2005; Roth, 1995b). Beginning in the 1960s, the works of psychologists such as Piaget, Ausubel, Bruner, and Vygotsky turned the tide in favor of constructivism as the most discussed and written about paradigm in science education research (DeBoer, 1991; Duit, 1995). Very aptly, Fensham (1992) posits that "the most conspicuous psychological influence on curriculum thinking in science since 1980s has been the constructivist view of learning" (p. 801). Strong support from research in education, psychology, and brain function, as well as, the National Standards in mathematics and science ("student understanding is actively constructed through individual and social processes" (NRC, 1996, p. 28)) have contributed greatly to the sustenance of constructivist epistemology as the basis for the desirable practices to aim for in K-20 classrooms (Jenkins, 2001; Jonassen, 2006; Matthews, 1998).

Constructivist Epistemology and Varieties of Constructivism

As von Glasersfeld (1995b) commented, "constructivism does not claim to have made earth-shaking inventions in the area of education; it merely claims to provide a solid conceptual basis for some of the things that, until now, inspired teachers had to do without theoretical foundation" (p.15).

Constructivism is simultaneously a theory of knowledge and how one comes to know the world. It is not a theory of teaching. However, the principles of constructivism can be the basis for classroom teaching practices (Fosnot, 1996; Tobin, 1993).

The essence of constructivist epistemology is expressed in the following sentences. Knowledge is constructed in the mind of the learner rather than transmitted by an outside agent (Bodner, 1986; Eisner, 1993). "Meaning is not given to us in our encounters, but it is given by us, constructed by us, each in our own way, according to how our understanding is currently organized" (Duckworth, 1987, p. 112).

Constructivism has been described as 'post-epistemology' (Noddings, 1990) since it is not concerned with the traditional view of knowledge as a representation of an ontological reality, rather it "focuses on the manner in which knowers construct viable knowledge" (Tobin & Tippins, 1995, p. 4). Coherence of knowledge with extant understandings and fit with experience makes it viable and leads to its acceptance by the scientific community, whose goals, in turn, are tied to the societal context (Kuhn, 1970). As described in the literature, two views of constructivism are embraced by its practitioners in classrooms. These are, constructivism as a referent (Wheatley, 1991), and as a teaching methodology (Fosnot, 1992). Since this study is concerned with the classroom practices of Chemistry teachers, both of these approaches find their places in it.

There are many varieties of constructivism (Bodner, Klobuchar, & Geelan, 2001; Geelan, 1997; Good, 1993; Good, Wandersee, & St. Julian, 1993; Phillips, 1995).

However, there are some common themes that run through this multiplicity of interpretations. The prominent themes discussed in the literature are: (1) active agency- human beings are active constructors of knowledge and meaning makers, not passive receivers of information; (2) order- much of meaning making by humans involves ordering, organizing, or restructuring of conceptual structures; (3) self- the mental activities mentioned above are self-referent and recursive, rendering a sense of self-identity; (4) social-symbolic relatedness – human beings can be understood only in the context of their social and cultural systems; and (5) lifespan development- all of the above constitute a developmental flow marked by essential dialectical tensions (Mahoney, 2004).

With the setting of this present research being the classroom, the variety of constructivism considered here is educational constructivism. Both the subdivisions of educational constructivism, personal and social are expounded in this section.

Personal constructivism emphasizes the creation of knowledge, primarily, as an individual activity, whereas social constructivism lays stress on the importance of the sociocultural milieu in the development and validation of knowledge (Matthews, 1998). Piaget and von Glasersfeld are the best known proponents of two closely related types of personal constructivism (cognitive and radical, respectively), and Vygotsky's work informs social (or sociocultural) constructivism.

As with any theory, constructivism's presence in science education has been challenged, especially the notion of connecting its epistemology and pedagogy. The reader is referred to the works of Gross, Levitt, & Lewis (1996), Matthews (2000), and

Scerri (2003) for accounts of arguments and supporting explanations regarding the challenge.

In the next three sections the theories of Piaget, von Glasersfeld, and Vygotsky are considered and elaborated upon with respect to epistemology, role of the teacher, and the role of the learner.

Piaget and Cognitive Constructivism

Piaget was primarily interested in the development of knowledge in humans. He wrote and conducted research on the development of understanding (cognition) in children for over six decades (Kamii & DeVries, 1980). His general theoretical framework called 'genetic epistemology' was influenced by concepts in Biology and Philosophy (London, 1988). It has been a powerful influence in the recent paradigm shift towards constructivism in education in the U.S.

Epistemology

Piaget's theory of cognitive development has two parts, one is stage dependent and the other stage independent. When Piaget's theory was introduced in the U.S. in the 60s, the focus was on the stage dependent part, represented by the four stages of development (sensorimotor, preoperational, concrete operations, and formal operations) that humans presumably progress through in sequence in advancement of thinking across a broad set of problems (Mayer, 1983; Rogoff, 1990). Since the 80s and beyond, the stage independent part has received greater attention. It consists of two complementary and dynamically interacting processes: *adaptation* (the response of an individual to make sense of a constantly changing environment); and *organization* (the need to achieve stability and coherence in the knowledge and understanding of the world (the organized structure of knowledge and understanding possessed by an individual is called a schemata). The contrasting goals of the two processes create an intrinsic conflict that provides a platform for lifelong learning (Rieber, 1995). This conflict is resolved through the process of equilibration using the mechanisms of assimilation and accommodation. Upon exposure to new information, an individual attempts to assimilate (incorporate) it by subsuming it under existing schemata, thus expanding the schemata (Singer & Revensen, 1978; Tsou, 2006). When the new information does not fit into the existing schemata, accommodation, or a reorganization of existing structure/s takes place. This is the source of learning (Santrock, 1998).

As posited by Forman & Pufall (1988), "central to constructivism is that to know is to continually reconstruct, to move from a more to a less intuitive state" (p. 240). As Piaget (1971) expresses it "the essential functions of the mind consist in understanding and in inventing, in other words, in building up structures by structuring reality" (p.27). Children at all ages possess schemata. However, only older children, adolescents, and adults possess 'concepts' that are formed as a result of abstraction across different objects and situations (Byrnes, 2001). To summarize, according to Piaget, there are three essential properties of constructivism: (1) *epistemic conflict; (2) self-reflection*; and (3) *self-regulation* (Forman & Pufall, 1988). Epistemic conflict is a problem encountered by an individual that is not a part of his/her repertoire that the individual seeks to resolve. Resolution is achieved by individual construction through the process of self-reflection, an attempt to represent reality objectively and explicitly. Self-regulation is the outcome, the spontaneous restructuring of knowledge and thought. In addition, Piaget related the importance of social interaction (DeVries, 1997) and the role of language (Becker &

Varelas, 2001) for intellectual development of children. However, Piaget's primary efforts were devoted to examining how the *individual* makes sense of an unexamined generic world. The sociocultural context was an add-on and did not receive as much attention as the individual in the bulk of his work. It was viewed as another source providing the cognitive conflict, leading to efforts at establishing equilibrium.

Role of the Teacher

For Piaget (1973), "knowledge is mental activity which actively organizes and acts on reality and thereby also fits itself to it" (p. 52). Therefore, in keeping with this tenet, the teacher's role is to

> organize situations that create useful problems for students and discussion which creates the need for reflection and reconsideration….What is desired is that the teacher cease being a lecturer, satisfied with transmitting readymade solutions; his/her role should be that of a mentor stimulating initiative and research.. This obviously leads to placing all educational stress on the spontaneous aspects of students' activity. (Piaget & Inhelder, 1973, p. 11, 16)

The most important role of the teacher in a constructivist class room is that of a facilitator of student learning with understanding, a provider of the "fertile soil" (Brainerd, 1978, p.286) for students' cognitive growth. A constructivist classroom is a student centered environment, not teacher centered (Jakubowski, 1995). To fulfill this role, the teacher organizes the classroom learning environment such that it promotes the following *cognitive practices*: (1) Perturbing the environment of the students in such a way that their extant knowledge is constrained; (2) focusing on how students organize methods/ideas not on answers; (3) asking students to generate and organize models and observations; (4) probing for student's preconceptions and adopting instructional strategies that make children aware of conflicts and inconsistencies in their thinking (Kyle, Lee, & Shymansky, 1989); (5) letting students produce and 'own' the results of their activities (feedback via presentation to peers provides opportunities for correction); (6) posing problems and following student explanations leading to activity and investigation; (7) appealing to children's interests and engaging their purposes (DeVries, 1997; DeVries & Zan, 1994); (8) allowing students time for reflection and construction of their model and procedures; (9) letting understanding precede vocabulary building; (10) emphasizing understanding over recall and active organizing of information and experiences over storage (Saettler, 1990); (11) developing imagery by having students transform objects in thought and drawings; (12) inference making; (13) negotiation of meaning (Dana & Davis, 1995; Oregon Department of Education, 1989; Wheatley, 1995); and (14) modeling the class activities after the practices of scientists, e.g., devising investigative methods, consulting colleagues on details etc. (Linn & Burbules, 1995), and using the learning cycle (Abraham, 1997; Lawson, 1995; Renner & Marek, 1990).

In the role of a constructivist, the teacher exercises great flexibility in the pedagogical methods employed to achieve meaningful learning. The repertoire of methods include: lecture; whole class interactions; use of cooperative learning group; working in pairs; and individually (Driscoll, 1994; Linn & Burbules, 1995).

Role of the Student

In keeping with the student centered nature of constructivist practices, the most important role of the student is to accept responsibility for his/her learning. A student does so by the following: actively participating in the activities arranged by the teacher, reflecting on and testing his/her ideas individually, with the teacher and peers, asking questions and providing explanations, discussing the differences in understanding and disagreements and resolving these through shared understanding, articulating and monitoring their learning, and being metacognitive (Donovan & Bransford, 2005; Jakubowski, 1995).

von Glasersfeld and Radical Constructivism

von Glasersfeld's philosophy was influenced by the works of Berkeley, Vico, Vaihinger, Kant and, above all, Piaget. Like Piaget, he was interested in how we come to know what is called 'knowledge'. His "theory of knowing" (von Glasersfeld, 1995a, p. 24) is called radical constructivism because it breaks from convention by conceptualizing knowledge as an organization of the world comprised of our experiences, rather than a representation of the objective 'truth' (von Glasersfeld, 1984).

Epistemology

In the radical constructivist epistemology also, as in Piaget's, knowledge is always built up by human beings to make sense of their experiences. Even the transmitted knowledge is transformed by the receiver using the elements of his/her experience (Bettencourt, 1995; Fleck, 1986; Inhelder, 1977; von Glasersfeld, 1983). In fact, the fundamental ideas of how we come to know something, according to Radical constructivism, are drawn from Piaget's concepts of accommodation, organization, and equilibration. The added contribution of radical constructivism is its forceful explication of the unrelatedness of the constructed knowledge with the 'truth' or 'reality', which does exist, but is not knowable through the senses and space-time bound experiences at our disposal (von Glasersfeld, 1992). When one encounters a new experience, existing knowledge structures have to pass through four selecting devices: characteristics of our previous experiences; reference to other human beings; the range of our experiences; and the network of our cognitive structures (Bettencourt, 1995). The result of this filtration is either the rejection of the solution (knowledge/knowledge structure) that does not fit the experience, or its intact/modified acceptance. There may be several solutions that fit the experience (or, are viable), with neither matching the underlying reality, just as several keys can *fit* and open a lock, with none *matching* the lock (Bodner, 1986; Pring, 2000; von Glasersfeld, 1984). Therefore, to know something in the radical constructivist epistemology is to look for keys that fit (*viable* knowledge constructions), the totality of our experiences in the context, rather than to look for one perfect match.

Role of the Teacher

In radical constructivist conception of learning teachers play, with patience and imagination, the role of a "midwife in the birth of understanding" (von Glasersfeld, 1995c, p. 383) as opposed to being "mechanics of knowledge transfer" (von Glasersfeld, 1995c, p. 383). Their role is not to dispense knowledge but to provide students with opportunities and incentives to build it up (von Glasersfeld, 1996). The teachers are variously described as guides, co-ordinators, facilitators, resource advisors, tutors or coaches (Gergen, 1995; Mayer, 1996).

Understanding the role of the teacher in the constructivist classroom provides a useful vantage point from which to grasp how the theory impacts on practice. Some examples of actions associated with the role of the teacher are: creating opportunities to trigger students' thinking, connecting situations of interest to the students with the concepts to be learned, acknowledging student efforts (even if 'wrong'), then arranging learning situations to steer their thinking in the 'right' direction, probing students' extant ideas and theories on topics, provoking and providing time for reflection, encouraging articulation of student ideas through conversation or explanation to the class, peers, and teacher (Bettencourt, 1995; von Glasersfeld, 1995a).

Role of the Student

Just as the role of the teacher in radical constructivist stance is similar to that in Piaget's theory of cognitive constructivism, so is the students' role. Here also, the students are regarded as responsible 'sense makers' (Gergen, 1995; Mayer, 1996).

Vygotsky and Social Constructivism

Vygotsky was a teacher turned psychologist who lived during the infancy of the Russian revolution. Therefore, many of his ideas were shaped by Marxism (Moll, 1990). Commenting on Vygotsky's work, Bruner (1987) said that his "educational theory is a theory of cultural transmission as well as a theory of development" (p. 1-2). His approach to the study of dialectic phenomenon was holistic, rather than reductionist. The analogy he advanced in support of this approach was that the properties of water cannot be known by studying the properties of its constituents, hydrogen and oxygen (Vygotsky, 1987). In keeping with this view, Vygotsky regarded education as a quintessentially sociocultural activity as well as central to cognitive development.

Epistemology

The cornerstones of Vygotsky's epistemology are the development of higher (uniquely human) mental processes and the zone of proximal development. Both of these ideas are expounded upon in this section.

First and foremost, the definitions of terms like individual, context, environment etc., take on a very broad, inclusive, and interconnected meaning in his theory. His unit of analysis is not the individual, but the "(processes of) sociocultural activity, involving the active participation of people in socially constituted practices" (Rogoff, 1990, p.14). Therefore, an understanding of the social context of the child is essential to understanding his/her cognitive development. For Vygotsky, the social context is "not so much a set of stimuli that impinge upon a person as it is a web of relations interwoven to form the fabric of meaning" (Rogoff, 1990, p. 27). In other words, the cognitive development of the child is inseparable from the sociocultural context he/she is a part of. It is the social context that plays a vital role in the construction of meanings and the development of understandings.

Appropriation and Internalization of Higher Mental Functions

Culture, the unique medium of human existence that sets us apart from other organisms, plays a central role in cognitive development in Vygotsky's theory (Vygotsky, 1978). As Cole (1990) posits, "(higher) human psychological functions differ from the psychological processes of other animals because they are *culturally mediated"* (Cole, 1990, p. 91). The psychological processes of other animals, also called the lower order mental processes include basic biologically determined processes such as "perceptual, attentional, and memory capacities (e.g. capacity to perceive contrast and movement, the capacity for eidetic memory, and arousal/habituation responses to environmental stimuli" (Diaz, Neal, & Amaya-Williams, 1990, p. 127)). Through enculturation and stage wise development, these lower mental processes (or functions) are transformed into higher psychological functions (e.g. voluntary attention, logical memory, and thinking), the unique possessions of humans. This transformation constitutes human cognition and is mediated by more mature members of society via culturally sanctioned signs, symbols, and tools. In this theory, cognition and thinking are not passive, rather these are active, functional, and goal directed manifestations of problem solving. As the children actively engage in problem solving in the company of adults and other members of society, they appropriate the methods, processes, representations, and tools (i.e., 'cultural artifacts') used by the more mature members (Kozulin, 1990). As this continues, the cultural artifacts undergo a series of qualitative, dialectical transformations (Moll, 1990) within the child, ultimately resulting in their internalization and 'owning' by the child. Thus, the characteristics of culture that were initially situated outside in the signs and symbols and processes (of others) are now encapsulated within the child as a uniquely transformed entity, brought about by the intersocial interactions and the efforts of the child (Davydov & Kerr, 1995). The most important point here is that the origin of all higher psychological processes (or functions) "cannot be found in the mind or brain of an individual person but rather should be sought in the social 'extracerebral' sign systems a culture provides" (Vygotsky & Luria, 1994, p. 103). Unlike lower functions, higher psychological functions are; self-regulated rather than stimulus controlled, originate in social or cultural activity rather than biological, the object of conscious awareness rather than automatic, and mediated through culturally accepted signs and tools (Vygotsky, 1994; Wertsch, 1985). Since the origin of higher mental processes is social and cultural, they necessarily appear in an external form first, i.e., the child practices the activities in social settings, attains mastery and then internalizes them (Bakhurst & Sypnowich, 1995; Wertsch, 1985, 1990). The transformations of interpersonal processes and the emergence of intracultural thought processes is called the “general genetic law of cultural development” (Vygotsky, 1981a, p. 163). Vygotsky (1981a) states that

> Any function in the child's cultural development appears twice, or on two planes. First, it appears on the social plane, and then later, on the psychological plane. First, it appears between people as an interpsychological category, and then within the child as an intrapsychological category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition…. It goes without saying that internalization transforms the process itself and changes its structure and function. (p 163)

In other words, the students’ construction of meanings begins with classroom interactions with the teacher and peers. The ongoing construction of meaning constitutes the transformation of the cultural processes and artifacts through mediation guided by more mature members (e.g., teachers) through active engagement in problem-solving activities with peers and reflection of related experiences.

Concept Development

Development of scientific concepts in children is an important example of the development of higher order mental functions. Children, often, possess lower-level pseudo concepts (or spontaneous concepts) arising from their everyday experiences. These concepts are personalized, perceptual, functional, contextual, idiosyncratic, and show familiarity with the labels without an understanding of the defining criteria. On the other hand, scientific (or true) concepts are characterized by their systematicity, generality, abstract nature, and context independency. According to the sociocultural theory, the transformation of everyday concepts into scientific concepts takes place in social interactions with competent teachers (and more competent peers) in a school setting, mediated by signs, symbols, and tools such as language, symbolic representations, instruments, and equipments etc. Everyday concepts are the foundations upon which teachers help the students build scientific concepts, i.e. the spontaneous concepts ‘grow up’ to meet the scientific concepts. Similarly, with consistent instruction, the scientific concepts ‘grow down’ to meet the spontaneous concepts, allowing these to be more accurate, general, and abstract (Vygotsky, 1987). This aspect of Vygotsky’s theory is especially important in a secondary science classroom, such as in this study, since many students come to science classes with misconceptions about natural phenomena based on their everyday experiences (Bransford, Brown, & Cocking, 2000). They often hold on to these misconceptions tenaciously. Therefore, one of the important goals of a science teacher is to address these misconceptions and to promote the understandings held by the scientists (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Driver & Bell, 1986).

Zone of Proximal Development (ZPD)

Children acquire the higher mental processes (or intellectual skills), mentioned above, in a progressive manner. In between the two extremes of novice and expert levels, children can perform well with assistance from adults or more capable peers. The range of skills that can be developed with adult guidance or peer collaboration exceeds what the child can attain on his/her own (Cole, 1985; Kearsley 1994; Moll, 1990; Rogoff, 1998; Rogoff & Wertsch, 1984). The guided/collaborative participation with adults or peers is ultimately responsible for transitioning from naïve concepts to scientific concepts, the internalization of culturally mediated signs of language and thought, as well as emergence of meaning (Rogoff, 1990).

This potential for advancing children’s cognitive development, given appropriate assistance, is expressed by the concept of the ‘zone of proximal development’ (ZPD). It is the “distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). ZPD is the “construction zone” (Newman, Griffin, and Cole, 1989, p. 1) where individuals participate in teaching-learning process, “an apprenticeship in thinking” (Rogoff, 1990, p. 8) to co-construct new knowledge, inculcate new skills and to appropriate (i.e., personalize) these. ZPD consists of four learning stages (Kearsley, 1994), ranging between the "lower limit of what the student knows and the upper limit of what the student has the potential of accomplishing" (Gillani & Relan 1997, p. 231). These stages are: assistance provided by more capable others (teachers, coaches, peers, and experts); assistance provided by self; internalization; and going through the above stages recursively (Tharp & Gallimore 1988).

Therefore, the ZPD is an important analytic tool for instruction and when deployed takes place in the context of formal schooling (Hedegaard, 1990).

Role of the Teacher

In this sociocultural theory, the teaching and learning situations in classrooms are described as working in the ZPD. Working in ZPD is operationalized through a teaching technique called scaffolding. Scaffolding is a conceptual metaphor for the quality of teacher intervention in student learning (Hammond, 2002; Mercer, 1995). It describes the way that “teachers or peers supply students with the tools they need in order to learn” (Jacobs, 2001, p. 125). Since the idea is to use any means to mediate student learning, it admits of a range of roles played by the teacher in order to facilitate student learning (i.e., appropriation of higher mental functions). At one end is the behavioristic approach as teacher driven imposition of structure on the passive learner (Stone, 1998). On the other end it is characterized by the co-construction of knowledge in a dialogic discourse, mediated through activity and cultural artifacts (defined earlier) that promote learning (Wells, 1999). This is the constructivist stance consonant with research-based practices, and it will be pursued in this study. The distinguishing feature of this interpretation of scaffolding is the role of dialogue between teacher and student. As Moll (1990) states

> Within the ZPD the child is not a passive recipient of the adult's teachings, nor is the adult simply a model of expert successful behavior. Instead, the adult –child dyad engages in joint problem solving activity, where both share knowledge and responsibility for the task. Rather than simply modeling, the adult teacher must create first a level of "intersubjectivity", where the child redefines the problem situation in terms of the adult perspective. Once the child shares the adult's goals and definition of the problem situation, the adult must gradually and increasingly transfer task responsibility to the child. (p. 219)

Therefore, the role of the teacher is to facilitate the intent of the above statements in their classroom instruction, so that the student progressively moves toward being an independent and self-regulating learner and problem solver. In his/her role as the planner/organizer of the lesson, the teacher should arrange the tasks to progressively spiral up with regard to the level of challenge and spiral down with regard to the level of teacher support (Hartman, 2002; Henry, 2002). Also, the extent of teacher intervention slowly decreases, fading away ultimately. This implies dynamic and multiple roles of the teacher. The teacher must find the optimal balance between supporting the students and pushing them to act independently towards the desired goal, always challenging them to reach beyond their current ability level without frustrating them (Roth, 1995b). Some strategies that help accomplish this are: using demonstrations; dividing the task into simpler steps; providing clear guidelines; keeping students' attention focused; questioning; breaking content into smaller chunks; giving hints; providing comprehension tasks that start at the accessible level and progress to difficult; motivating or enlisting the child's interest related to the task; and cooperative learning (Berk, 2002; Eggen & Kauchak, 1999; Krause et al., 2003; Lewin, 2001; McDevitt & Ormorod, 2002).

Appearing in the literature are three metaphors applied in this context that describe the relationship between the teacher and the students: "participatory appropriation"; "guided participation"; and "cognitive apprenticeship" (Rogoff, 1995, p. 141). To actualize these, the teacher practices the following techniques and assumes the concomitant roles; modeling of desired behaviors, offering explanations, inviting student participation, verifying and clarifying student understandings, and inviting students to contribute clues, thus progressing from teacher-centeredness to student centeredness. These techniques can be used individually or in combination, depending on the material taught (Lange, 2002). An important role of the teacher that undergirds all the above strategies is that of a perpetual learner, with the understanding that teaching & learning is a bidirectional exchange, not a unidirectional flow from the teacher to the student (Crawford, 1996; Driscoll, 1994; Vygotsky, 1978; Wertsch & Sohmer, 1995).

Role of the Student

Vygotsky's most important contribution was to acknowledge children as active agents in the educational process (Blanck, 1990). They are elaborators of the content presented to them (Vygotsky, 1978). In keeping with the statement, "in the ZPD adult-child dyad engages in joint problem solving activity, where both share knowledge and responsibility for the task" (Diaz, Neal, Amaya-Williams, 1990, p. 140), students participate collaboratively with the teacher and peers (Finkel & Monk, 1983; Whipple, 1987). Students need to be reflective, engage in dialog and discourse with the teacher

(Mercer, 2000), and make their thinking explicit through "active redefinition of the problem situation in terms of the adult's goals and perspective" (Diaz et al., 1990, p.140). As the teachers provide them with increasing responsibility for problem-solving tasks, students should be willing to take these responsibilities (Rogoff & Gardner, 1984; Wertsch, McNamee, McLane, & Budwig, 1980), till they become independent problem-solvers and acquire the ability to control and regulate their own behavior (Vygotsky, 1981b).

Some Salient Points of Sociocultural Theory

Vygotsky considered "school the best lab for human psychology and formal education an essential tool of enculturation" (Blanck, 1990, p. 49). During the active engagement of teachers and students, students are provided the psychological tools that will enable them to reorganize their mental functions (Blanck, 1990).

The learning processes resulting from teaching lead to cognitive development. This results in the creation of the zone of proximal development. The typical way it works is; student is presented with a difficult problem solving activity and solves it with the assistance of the teacher. He/she is offered another challenging activity that he/she solves with some assistance from the teacher, or by him/herself and the process continues till the student can engage in problem-solving activity independently (Gallimore & Tharpe, 1990; Hedegaard, 1990; Rogoff & Wertsch, 1984; Tudge, 1990).

Sociocultural theory's framework has the potential to integrate various schools of psychology, varying from many postulates of classical and operant conditioning to Piagetian ideas of ontogenesis (Blanck, 1990). In Piaget's (also von Glasersfeld's) theory, instruction and teachers provide the fertile soil for cognitive development. The implication being that, although the presence of teachers and instruction is highly desirable, development will follow its natural course even in their absence. For Vygotsky, instruction and teachers (and more capable members of society) *are* the soil, quintessential for cognitive development, the development of higher order processes, of which scientific concept development (the essence of science education) is an example. As Rogoff, Matusov, & White (1996) posit

> Learning is a process of transformation of participation in which both adults and children contribute support and direction in shared endeavors…. The sociocultural context in which learning occurs, and the way in which something is learned, are necessarily a part of the learning. (p. 389)

Rationale for the Choice of Sociocultural Theory

As reported in the literature, there are central ideas of research-based reform in science education that are identified: the primacy of learning and learners; the active nature of science learning with teachers and students as members of a learning community; use of inquiry in which students interact with teachers and peers; teachers guiding and facilitating learning through orchestrating discourse among students about scientific ideas; challenging students to accept and share responsibility for their own learning; and the need for school science to reflect the "intellectual and cultural traditions that characterize the practice of contemporary science" (NRC, 1996, p. 21; AAAS, 1990). As is evident from the above summary, as well as the rest of the section, of the three constructivist theories presented above (Piaget's, von Glasersfeld's, and Vygotsky's), the one that encompasses *all* of these principles is Vygotsky's sociocultural theory. Therefore, it provides the theoretical support for this present research.

Adult Learning

A Brief Historical Overview

Great teachers in many cultures, such as Lao Tse, the Hebrew prophets, Socrates, Plato, and Cicero etc., were teachers of adults who realized the need to engage their students in inquiry through methods such as the case method and Socratic dialog. It is curious that although historically adult learning has been an area of concern, little research has occurred in the field till the end of World War I, the time when the unique characteristics of adult learning began to receive attention (Knowles, Holton, & Swanson, 2005). With the founding of American Association for Adult Education in 1926 and the pioneering work of Thorndike, Sorenson, and Lindeman, most of the components needed to constitute a theory of adult learning were in place by 1940. These components were discussed and elaborated upon in the subsequent decades (Gessner, 1956; Knowles et al., 2005). Lindeman (1926), strongly influenced by Dewey's educational philosophy, distinguished adult education from the 'conventional' education by emphasizing the centrality of the learner and his/her experiences. Also, he identified certain assumptions behind adult learning. These assumptions were later supported by research and became the cornerstone of a framework of adult learning called Andragogy. Many theories of adult learning were advanced in the latter half of the 20th century. In this section, some of the important theories of adult learning will be explained (Merriam, Caffarella, & Baumgarten, 2007) and the theory most in consonance with the research-based classroom practices based in constructivism will be elaborated upon.

McClusky's Theory of Margin

According to this theory, some of the experiences faced by adults such as growth, change and integration require them to seek a balance between 'load' and 'power' (McCluskey, 1970, 1971). Load consists of internal and external factors that dissipate energy, while power consists of factors that add to the energy of the adult learner. Examples of 'load' are; family responsibilities, work, desires, and aspirations etc. Examples of 'power' are; family support, good income, resilience, and personality attributes etc. Adults need some 'margin in life' (ratio of power to load) in order to engage in learning activities. Most adult learners relate to this theory as "an epiphany in terms of their own life circumstances" (Hiemstra, 1993, p. 43). This theory is helpful in explaining developmental changes that characterize adult life and is a better counseling tool than an explanation of how adults learn. Therefore, in a classroom learning situation such as the present research, this theory has limited application and will not inform this study.

Illeris's Three Dimensional Learning Model

In this model, adult learning consists of three dimensions: (1) cognition; (2) emotion; and (3) environment that occur within the society (Illeris, 2002). The three dimensions are pictured to be at the apices of an inverted triangle, with cognition and emotion at the apices of the base and the environment at the vertex. In any learning situation, all the three interacting dimensions are always present in a variable mix. The cognitive, emotional, and environmental dimensions involve knowledge and skills, feelings and motivation, and participation/communication respectively. The cognition/emotion/environment triangle is embedded in society that provides the context of learning. “The strength of Illeris’s model lies in its comprehensiveness but also its simplicity” (Merriam et al., 2007, p. 99). However, since this theory has not been tested sufficiently for its power to explain or predict adults’ learning behavior, it will not be used in this research.

Jarvis’s Learning Process

In this model the learning process begins when an adult encounters an experience in his/her social context that provides a “disjuncture” (Jarvis, 2006, p.9). “A disjuncture occurs when our biographical repertoire is no longer sufficient to cope automatically with our situation so that our unthinking harmony with our world is disturbed to some degree or other” (Jarvis, 2006, p.9), At this point, a person can choose to dismiss the unease caused by the disjuncture, or choose to learn. Learning can occur through thinking, doing, and feeling, or any combination of these. The learning may change a person’s self-concept, meaning of concepts, or coping mechanisms. Now, this changed/learned person is ready to repeat the cycle, awaiting the next disjuncture. Jarvis’ model is the most comprehensive of the above models. It emphasizes learning as an interactive process in a social context. However, it suffers from the same shortcoming as the Illeris’s model, i.e., lack of adequate research to verify the veracity of its application. Additionally, this model has been evolving for the past 20 years. The new version, proposed in 2006 looks quite different from its predecessor proposed in 1987 (Jarvis, 1987). For these reasons, this model will not inform the present study.

Knowles' Andragogy

Introduction

Andragogy is derived from the Greek words *andɍ* (man) and *agogos* (leading). Principles of andragogy are eclectic, drawn from the philosophies of pragmatism, behaviorism, humanism, and constructivism, and "free from any single idealogical dogma" (Knowles, 1989, p. 112). It is a learner centered process model of adult learning that emphasizes the "procedures and resources for helping learners acquire information and skills" (Knowles et al., 2005, p. 115), as opposed to the content-driven pedagogical model that is teacher centered and is concerned with transmittal of information (Grace, 1996; Hartree, 1984; Knowles, 1990; Merriam & Brockett, 1997). Also, andragogy places a great deal of importance on the learner's prior knowledge/experience and desire/motivation to learn. Due to the similarity of these characteristics with the research-based classroom practices and constructivism, andragogy is the approach to adult learning that will inform the present research.

Andragogy - A Process Model

This model was first proposed by Knowles in 1968 and it also has evolved. The final version, proposed in 1980, consists of six assumptions or principles of adult learning embedded in the context of individual and situational differences (acknowledging the differences among learners) which, in turn, are situated within the goals and purposes of learning (admitting of diversity, also) (Henschke, 1998; Hiemstra, 1993; Knowles, Holton, & Swanson, 2005; Merriam & Caffarella, 1999; Reischman, 2000; Savicevic, 1999; Schugurensky, 2005; Zmeyov, 1998). The model can be visualized as a set of three concentric rings, with the six core principles of andragogy as the innermost ring, surrounded by the middle ring of individual and situational differences, and the outermost ring of the goals and purposes of learning (Knowles et al., 2005). See Appendix B for a diagram of the model. This model results in a unique characteristic of andragogy that is absent in other models, i.e., its flexibility of application, responsiveness to the context in which it is applied, and capability of alteration depending on the situation. As Knowles (1984a) articulates

> The andragogical model is a system of elements that can be adopted or adapted in whole or in part. It is not an idealogy that must be used totally without modification. In fact, an essential feature of andragogy is flexibility. The appropriate starting point and strategies for applying the andragogical model depend on the situation. (p. 418)

Some of the areas of adult learning where this model has been applied are; adult education, critical theory, transformative learning, and self-directed learning (Brookfield, 1986). The application useful to this present study is that of adult education. In this research this application occurred twice. First as the chemistry teachers engaged in acquiring the reform-based practices (including depth of content knowledge) in the MCE program classes, and then as they implemented these practices in their classrooms-a forum for learning for *both* the teachers and their students.

The Six Assumptions of Andragogy

Providers of adult education find the six assumptions to be a helpful rubric to understand adults as learners. There is a significant research base that buttresses each of the six core principles or assumptions articulated by Knowles' Theory of Andragogy

(Knowles et. al, 2005). Each of the six assumptions, their supporting research, and applications will be discussed now.

Assumption 1: The Learner's Need to Know

This is the primary need that drives the adults to enroll in programs (such as the MCE) where they can further their learning, and broaden their horizons. Educators can tap into this preexisting need, and enhance the outcome by collaborating with the adult learners. Collaboration will satisfy their "need to know" (Knowles et.al, 2005, p.183) as well as appeal to their self-concept as independent learners. Various aspects of collaboration, such as informing the adult learners of the goals and objectives of the program, finding out about their expectations, involving them in planning and connecting to their jobs will improve their commitment, motivation, and satisfaction with the program of learning (Clark, Dobbins, & Ladd, 1993; Tannenbaum, Mathieu, Salas, & Cannon-Bowers, 1991).

Assumption 2: Self-directed Learning

Self-directed learning is conceptualized in two ways; as self-teaching and as personal autonomy or autodidaxy (Candy, 1991). In this study the autodidaxy (taking ownership of learning) definition will be most appropriate, since the teachers have chosen to enroll in the MCE program and are not teaching themselves. Due to differences among them, the adult learners are self-directed in various degrees. Therefore, one of the goals of the program will be to work in the teachers' zones of proximal development, resulting in all the teachers 'becoming independent and self-regulating learners and problem solvers' (see 'Role of the Teacher" in the section under Vygotsky). Since self-directed learning is context dependent, factors such as learning style, prior exposure to subject matter, social orientation, efficiency, previous learning, socialization, and locus of control play a part in how the learners will behave and their progress towards the goal of being self-directed (Garrison, 1997; Grow, 1991).

Assumption 3: Prior Experience of Learners

Adults come to a learning situation with a wealth of prior experiences. These experiences influence their new learning by providing a rich resource for learning, and creating biases that facilitate or hinder new learning. In any event, prior learning acts as the foundation or the scaffold on which new learning is built (Savery & Duffy, 1996). Therefore, programs for adult learners need to ascertain their prior knowledge and use it as a springboard to build new knowledge and skills.

Assumption 4: Readiness to Learn

"Adults become ready to learn those things they need to know and be able to do in order to cope effectively with their real-life situations" (Knowles et al., 2005, p. 67). Generally, readiness to learn is context specific and is triggered by life situations. By enrolling in the MCE program, the teachers have declared their readiness to learn the research-based reform practices. However, their preparedness and levels of commitment may differ and may need different kinds and amounts of support (Pratt, 1988).

Assumption 5: Orientation to Learning

Adults prefer a problem-solving orientation to learning as opposed to a subject-centered orientation to learning. They prefer to test their learning against new experiences and learn further as a result of the interaction (Cross, 1981; Knox, 1986). An application of this approach is Kolb's (1984) experiential learning cycle (similar to Karplus' learning cycle). The four steps in this cycle are; the exposure to/involvement in concrete experiences, observation and reflection from multiple perspectives, formation of abstract concepts and generalizations, and applying the concepts learned to solve problems. Two similar methods, POGIL and PIM (Appendix C), are practiced in the MCE program courses.

Assumption 6: Motivation to Learn

Adults are more likely to be driven by internal rewards than external. The degree of importance that external versus internal rewards have depends on many factors, particularly the stage of life. Although external rewards are important, the internal rewards such as learning something of value and enjoyment of learning are, generally, better motivators of learning (Wlodowski, 1985). For the teachers in the MCE program, some of the internal rewards consist of being more knowledgeable in chemistry content and teaching through research-based practices that they can take back to their classes and apply. The external rewards are the free tuition and a Master's degree from a reputed university.

Andragogy in Relation to Pedagogy

In later years, Knowles (1980a) amended his view of andragogy as the opposite of pedagogy and proposed that the two be viewed as two ends of the learning continuum, "the seamless robe of learning" (Kidd, 1978, p. 49). Therefore, age is not the distinguishing feature that separates andragogy from pedagogy. Rather, andragogy is a set of learner-centered assumptions (supported by progressive education) and pedagogy is teacher directed learning (supported by the traditional education) (Knowles, 1970; Rachal, 1983). See Appendix D for a juxtaposition of the assumptions of the two methods. Knowles (1980b) adds that the goal of all the learning situations should be to do everything possible to help learners take increasing responsibility for their own learning. In practice this requires the instructor to determine where the adult learner falls in the continuum and use the corresponding pedagogical (teacher-directed) or andragogical (learner-centered) strategies in the beginning, with the goal of facilitating/guiding the learner to the androgogical end of the learning spectrum (Friedman, 2001; Hiemstra, 2006).

Application of Andragogical Principles in the Classroom

In keeping with andragogical principles, the role of a teacher needs to change to being a facilitator of learning, a co-learner, and a resource person. Some of the teaching methods in harmony with this role include: actively engaging the learners; initially scaffolding the learning and gradually withdrawing as the learner becomes self-directed; building on the learner's prior experiences; making learning experiences relevant to learner's lives; establishing a collaborative and supportive learning environment; and providing opportunities for reflection etc. (Brookfield, 1986; Knowles, 1975, 1984a, 1984b; Lawler,1991; Pratt, 1993; Smith, 1996, 1999; Zemke & Zemke, 1984).

Professional Development

Definition and Introduction

American Society for Training and Development (ASTD), the society representing "professional developers" (McLagan, 1987, p.27), defines professional development as "an ongoing process enabling professionals to improve their performance. It is a benefit to the professional, the professional's organization, and the profession in which he or she works" (McLagan, 1987, p. 28). In the teaching context, professional development constitutes those experiences that enable educators to acquire and apply knowledge, understanding, skills, and abilities to facilitate the learning and achievement of students (Fenstermacher & Berliner, 1985). It is a bridge between where the educators are now and where they need to be to guide the students in meeting the challenges of being scientifically literate in a society whose progress depends on advancements in science and technology (NCMST, 2000). National Science Education Standards (NRC, 1996) recommends that the professional development for teachers should be a continuous process that stretches from preservice experiences to the end of their professional career.

The first subsection of this section begins with establishing a need for professional development. It includes the reasons for the perpetuation of traditional classroom practices and the need to institute research-based practices through the vehicle of professional development. A description of the traditional professional development practices and the guiding principles and characteristics of effective practices follows. The last subsection cites some findings from the implementation of effective professional development practices, culminating in a description of the MCE program (the professional development program examined in this research).

Need for Professional Development

There is an overwhelming evidence of the lack of preparedness of our population in science and math and its detrimental effects (Cavanaugh, 2006; 2007).

Scientific Literacy and its Consequences for the Economy

According to Holton (1998), "Less than 7 percent of U.S. adults can be called scientifically literate by the most generous definition, and only 13 percent have at least a minimum level of understanding of the power of science" (p.11). While over 67% of new jobs created in this century will be in the fields of science and technology (Brown, 2004; Bureau of Labor Statistics, 2003; CEO Forum on Education and Technology, 2001; Chao, 2001), less than 20% of the current workforce possesses the skills required to fill them (Gardner, 1993; National Science Board, 2002; Uchida, Cetron, & McKenzie, 1996). The major consequence of this will be the erosion of U.S.'s economic and scientific/technological advantage in a world where advanced knowledge is easily acquired and widespread, low-cost labor is readily available (Carter, 2005; Friedman, 2006; NRC, 2007).

Therefore, to participate productively in a world increasingly shaped by science and technology, citizens require, at least, basic scientific literacy (NRC, 2007).

Schools cannot conduct business as usual, yet successfully train its students to take up these demanding jobs (Day & McCabe, 1997; McCabe & Day, 1998). Schools need to provide students with deep knowledge of science and technology and the ability for performing at high levels (Darling-Hammond, Berry, Haselkhorn, & Fideler, 1999). Towards achieving this goal, several national organizations and commissions have underscored the importance of improving math and science teaching in our schools by professionally developing the teachers to acquire a deep understanding of these subjects and the ability to teach in ways that will enable all the students to learn at high-levels (NCMST, 2000; NCTAF, 1996; NSB, 2006).

Students' Low Test Scores

The inadequate preparedness of our students is reflected in low scores on national and international assessments.

National Assessment of Educational Progress (NAEP- 1996, 2000, and 2005) the nation's report card, assesses students' knowledge of facts and the ability to integrate and apply these in physical, earth, and biological sciences. The most recent result showed that only about 18% of 12th graders have attained mastery in these areas, with 54% performing at the basic level (Cavanagh, 2006; NCES, 2005, 2007a).

Results of the international assessment, Trends in Math and Science Study (TIMSS, 1995; 1999; 2003) show that U.S. students start out in the 4th grade science ahead of their counterparts in many developed and underdeveloped nations. However, this advantage is systematically eroded by the time they graduate from high school, placing them towards the very bottom. Analysis of the data shows that their learning is too superficial, factual, and fragile, with little ability to reason and apply the knowledge (Kearns & Harvey, 2000; NCES, 2007b).

At least a part of the reason for the poor performance of students is the low quality of teaching caused by weakness in the knowledge and skills of the teachers in the subject (Schmidt, McKnight, Houang, Wang, Wiley, & Cogan, 2001).

Recently released results of the math and science performance of our 9th graders on the Program of International Student Assessment (PISA) reinforce the above trends (Cavanagh, 2007).

Inadequate Teacher Qualification/Preparation and High Teacher Turnover

It is expected that about two-thirds of the nation's K-12 teachers will retire or leave the profession in this decade, leaving over 200,000 positions to fill in secondary math and science classrooms (NCES, 1999). Thousands of these positions will be filled by teachers without proper credentials to teach the subjects, since more than 40 states allow districts to hire teachers who have not met basic requirements (NCTAF, 1996). Studies show that nearly a quarter of newly hired American teachers lack the qualifications for their job and, in 1999-2000, 61% of students in public schools were taught chemistry by teachers without a major or certification in the subject (NCES, 2003). A recent survey of 40 large urban schools, for example, showed that more than 90% had an immediate need for a certified math or science teacher (Ingersoll, 2001; Lewis, Baker, & Jepson, 2000), and the nation made no progress in reducing out-of-field teaching. In fact, the problem got worse between 1994-2000 (Ingersoll, 1999, 2002; Jerald, 2002). Nationwide, about 40% of beginning math and science teachers leave teaching within 5 years, creating a perpetual demand for qualified teachers and a constant need for professional development, lending support to the assertion that teaching is increasingly an "occupation with relatively high flows, in, through, and out of schools" (NCTAF, 2003, p. 25; Glenn, 2000). The turnover is a third higher in low income urban districts (NCTAF, 2003, p. 28). In Philadelphia, 70% of new teachers left the school district between 1999 and 2005 (NCTAF, 2007). These grim statistics underscore the lack of adequately qualified teachers and the inability to retain them as two quintessential factors responsible for the poor quality of science education in our nation's schools. Effective professional development has the potential to impact both the factors.

There is a robust research base that illustrates a very strong correlation between the preparedness of teachers and those of their students, as well as the effectiveness of qualified teachers in improving students' academic achievement (Darling-Hammond & Berry, 2006; Ferguson, 1991; Ferguson & Ladd, 1996; Fetler, 1999; Goldhaber & Brewer, 2000; Hanushek, Kain, & Rivkin, 2001; Hill, Rowan, & Ball, 2005; Monk, 1994; Murnane & Phillips, 1981; Sanders & Horn, 1998; Sanders & Rivers, 1996; Sparks & Hirsh, 2000; Wright, Horn, & Sanders, 1997).

Cochhran-Smith & Zeichner (2002) posit, "Students learn best from teachers who have strong content knowledge and pedagogical skills" (p. 35). Research shows that teachers assigned to teach subjects for which they are not adequately prepared, tend to overly rely on the textbooks, resort to low level of questions, emphasize rote learning, and assessment of factual recall, i.e., use low level traditional teaching methods (Ingersoll, 1999).

Kruse & Roehrig (2005) examined the performance of chemistry teachers participating in a professional development using a Chemistry Concepts Inventory. They found that teachers holding a degree in chemistry or a teaching credential in chemistry, held significantly fewer misconceptions than did those who were teaching chemistry but whose subject matter background was in a different field. Additionally, the students' misconceptions paralleled those of their teachers (Lantz & Kass, 1997).

Exacerbating these conditions is the fact that a vast majority of science teachers, even those with proper credentials, do not themselves have a deep understanding of the subject, the research-based practices espoused by the science standards, and the science standards' intent of inculcating a deep understanding of the subject in all the students, consistent with the twin goals of equity and excellence (Banilower, 2000; NRC, 1996; Weiss & Paslay, 2006). Evaluators of Local Systemic Change, one of the biggest NSF funded initiatives to promote research-based practices in K-12 math and science classrooms, cited "glaring differences in teacher self-reported changes in their instruction and their actual classroom practice" (Banilower, Boyd, Paslay, & Weiss, 2005, p. 51). These conclusions are also supported by the videotape study of eighth grade math teachers who said that they were using research-based methods, but actually were teaching traditionally (Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999)

Traditional versus Research-based Classroom Practices

To review, as described earlier in this chapter, the traditional practices place teachers at the center of the process of teaching and learning as the "chief conduit of most of the content knowledge to be transmitted to students" (Simmons, Emory, Carter, Coker, Finnegan, & Crockett et al. 1999, p.936). Additionally, knowledge is viewed as facts, learning as memorizing, knowing as reproducing the facts, teaching as telling, and lab work as following a recipe to get predetermined results (Singer, Hilton, & Schweingruber, 2005). There is little evidence to show that the traditional methods of teaching promote conceptual understanding of (chemistry) content (Dinan & Frydrychowski, 1995; Phelps, 1996; Zoller, Lubezsky, Nakhleh, Tessier, Dori, & Yehudit, 1995). However, teachers have witnessed this method in their sixteen or more years' "apprentice of observation" (Lortie, 1975, p.25) as students, resulting in a deeply ingrained view of teaching as a tradition of transmission of knowledge from the teacher to the passive learners (Tsai, 2002).Therefore, these teaching practices stubbornly endure and get perpetuated when the teachers teach their own students, confirming the adage, teachers teach the way they themselves were taught (Adamson, Banks, Burtch, Cox III, Judson, Turley, Benford, & Lawson, 2003; Haberman, 1985; Lortie, 1975; Nemser, 1983).

The research-based practices, on the other hand, emphasize the centrality of the learner, "Learning science is something students do, not something that is done to them" (NRC, 1996, p. 20). In this paradigm, according to Thompson & Zeuli (1999), the learners need to develop a deep understanding of the subject that is always a result of thinking in order to

> solve problems, resolve dissonances between the way they initially understand a new phenomenon and new evidence that challenges that understanding, put collections of facts or observations together into patterns, make and test conjectures, and build lines of reasoning about why claims are or are not true. Such thinking is generative. It literally creates understanding in the mind of the thinker. Thinking is to a student's knowledge as photosynthesis is to a plant's food. Plants do not get food from soil. They make it through photosynthesis, using nutrients and water from the soil and energy from the sunlight. Students do not get knowledge from teachers, or books, or experience with hands-on materials. They make it by thinking, using information and experience. (p. 346)

In this mode, the classrooms are regarded as learning communities in which members communicate with each other, struggle together to solve challenging problems and develop a body of shared knowledge that slowly evolves towards the knowledge held by experts in the field, i.e. "classrooms are scientific communities writ small" (Thompson & Zeuli, 1999, p. 347). Research-based practices consider knowing as a form of cognitive constructivism nested within social constructivism (Phillips, 1995). The scientific understandings are first externalized through social processes and later internalized by the students as they learn how to carry out the thinking processes played out in the classroom with the teacher's guidance. Therefore, the teachers need to be knowledgeable about the students' thinking/understanding/preconceptions, have sufficient depth of knowledge of the subject, and necessary skills to pose questions, engage in discussions, and use inquiry methods that will lead the students from their current level of understanding to that of the practitioners in the field (NRC, 1996). The role of the teacher in this paradigm is that of an expert facilitator and guide as the students construct their own understanding of the subject.

Thus, the reform vision of science teaching is a complete departure from the traditional methods that both qualified/well established, as well as "out of field" (Ingersoll, 1999, p. 26) teachers are familiar with, and practice. The change in practice requires that science teachers' instructional repertoire be retooled (Thompson, Spillane, & Cohen, 1994) to include, first and foremost- a deep knowledge of content, learner-sensitive pedagogy, multimodel assessments, focus on understanding and application of concepts, active inquiry, communication, collaboration, reflection, integration of technology in teaching, facilitating the learners to "make sense of their experiences in terms of their extant worldview and the way others, including peers and teachers, mediate the sense-making process" (Taylor, Gilmer, & Tobin, 2002, p.121).

According to the recommendation of American Chemical Society's Science Teacher Preparation team, this retooling of teachers' arsenal of strategies is highly likely to occur when they experience professional development in "chemistry in the context of well-designed, inquiry-based courses" (Moore, 2003, p.719).

The teachers *themselves* need to be taught via the new practices before expecting changes in their classroom practices. Professional development of teachers in and using the research-based practices is the most important vehicle to effect the change (AFT, 2002; Elmore, 2002; Hawley & Valli, 1999). To be effective, the professional development practices themselves need to be equally substantive and challenging to realize the change and to bridge the gap between the current state of affairs and the one envisioned by the reform movement in science (Porter, 1993; Wright & Wright, 1998).

Traditional Professional Development Practices

School districts spend, on an average, between $1,700 to $3,500 per teacher on staff (professional) development [Stout, 1996 (citing research of Little, Miller, Lord, & Dorney)]. Professional development encompasses a wide array of activities, from highly focused work with teachers around specific curricula and teaching practices through short-hit and run workshops designed to familiarize school personnel with new rules and regulations, to university-based credit-bearing courses designed to improve content/technology knowledge. Some are mandated by the school district, while the others are chosen by the teachers for various reasons (Hargreaves, 1991; Little, 1993).

In 1999-2000, 95% of public school teachers reported that they had attended a workshop, seminar, conference or training, 70% of teachers mentioned that they had participated in activities that focused on teaching methods, and 57% on in-depth study of content in their main field (Choy, Chen, & Bugarin, 2006). A vast majority of these traditional professional development endeavors can be characterized as shallow-“a mile wide and an inch deep” (Kahle, 1999, p. 1), fragmented, scattered, brief (often one-shot sessions), offering unrelated topics, having ‘expert’ presenters with passive teacher-listeners, emphasizing skill development, atheoretical, often based on current instructional fads, and expecting quick visible results (Cohen & Hill, 2000; Collinson, 2004; Corcoran, 1995; Desimone, 2002; Elmore, 2002; Fenstermacher & Berliner, 1985;

Loucks-Horsley, Love, Stiles, & Hewson, 1998; McDiarmid & Corcoran, 2000; Smylie & Conyers, 1991; Sparks, 1995; Supovitz, 2003; Sykes, 1996).

The success of above events is "typically judged by a 'happiness quotient' that measures participants' satisfaction with the experience" (Sparks, 1995, p. 2). There is little connection between these 'adult pull-out programs' and the enhancement of knowledge and skills of the teachers in classroom practice as envisioned in the reform agenda, let alone the academic improvement of students (Feiman-Nemser, 1983; O'Day & Smith, 1993; Smith & O'Day, 1991).

According to Thompson & Zeuli (1999), even coherent, aligned and sustained professional development programs delivered in the training or presentational mode perpetuate the traditional practices steeped in the culture of "knowledge as facts and skills, teaching as telling, and learning as remembering" (p. 353). These kinds of professional developments, often, do not present a strong enough reason for teachers to even reflect on their current practices, let alone transition to research-based practices. In the absence of this impetus to change, 'inquiry groups' of teachers easily become emotional support groups, techniques designed to bring about fundamental change in practice are molded to adapt to the existing structures resulting in superficial changes, discussion and dialog about true change in practice become forums to exchange craftsmanly techniques within the existing paradigm of teaching, and transformation to new methods is equated to tinkering with new materials/techniques and fitting them to one's familiar style. Thus, it is quite easy to defeat the true purpose of professional development due to the "bricoleur" or "instructional handyman" (Huberman, 1995, p.195) habits and dispositions of most teachers.

This is why, inspite of the amount of resources spent on professional development, virtually every effort to improve the quality of instruction has left the classroom practically untouched (Sparks & Hirsch, 2000). It is suggested that the traditional varieties of professional development lack focus, intensity, and continuity needed to change classroom practices and prepare the teachers to meet the challenges posed by research-based practices (Corcoran, Shields, & Zucker, 1998; Fullan, 1993; Joyce & Showers, 1988, 1995; Little, 1993).

This has led many researchers to examine the characteristics of effective professional development and come to a widespread agreement that the guiding principles of effective professional development should be the same as that of the research-based instruction, i.e., learner-centered strategies and emphasis on building the depth of understanding of the subject (Goals 2000, 1998; Grant, 2002; Hawley & Valli, 1999; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Sparks, 2002; USDoE, 1996).

Guiding Principles of Effective Professional Development

Alexander & Murphy (1998) expound these principles as the following 5 core points:

(1) One's existing knowledge serves as the foundation for subsequent learning.

(2) Reflection on one's thoughts and behaviors is essential for the growth of knowledge and understanding

(3) Motivational factors, both within the learner and task-related, play a significant role in learning, e.g., teachers' belief that participation will enhance student learning, or their need to resolve some dilemmas of teaching (Smylie, 1995). Not

acknowledging or addressing the personal identities and moral purposes of teachers, their contexts of work, will not lead to the desired changes (Hargreaves, 1995).

(4) Learning, although idiosyncratic, proceeds through developmental stages, influenced by factors within and without the learner.

(5) Learning is a result of both individual and social processes

These principles are in concert with the constructivist principles and the core assumptions of andragogy.

Characteristics of Effective Professional Development

Although, the ultimate goal of every professional development of teachers of science is to enhance students' academic achievement, there is no agreement among researchers as to the criteria to rate the effectiveness of professional development (Loucks-Horsley & Matsumoto, 1999). According to Joyce & Showers (1988), the degree of transfer of content knowledge and pedagogical skills from professional development programs to actual classroom practice is the most relevant measure of the effectiveness of the program. In line with this definition, in this study the effectiveness of professional development is gauged in terms of the extent of implementation, in high school classrooms, of the depth of understanding of chemistry and research-based practices that the participants were immersed in, in the MCE program.

There are many complex characteristics that influence the effectiveness of professional development. According to Hawley & Valli (1999), there is consensus on 8 points of effective professional development. However, Guskey (2003) adds that it is highly unlikely that a consensus will emerge out of the 13 major lists and 21 major criteria published in the last decade. Loucks-Horsley et al. (1998) have synthesized research on professional development in science (Coble & Koballa, 1996), based on the recommendations of national organizations interested in improving science education (AAAS, 1990, 1993; National Center for Improving Science education,1993; National Staff Development Council, 1994, 1995; NRC, 1996), to propose seven principles (and their elaborations and premises) that need to be addressed in an effective professional development in science. These seven principles are:

(1) Use of classroom teaching and learning 'best' practices such as an emphasis on inquiry-based learning, investigations, problem-solving, applications of knowledge, understanding of core-concepts, challenges likely to promote construction of new understandings, and the use of instruments to measure meaningful achievement. Change occurs over time through active engagement with new ideas, understandings, and real-life experiences.

(2) Exposure to experiences and opportunities for teachers to develop in-depth content knowledge and pedagogical content knowledge, listening to students' ideas, recognizing common and naïve misconceptions, and choosing strategies that will aid in constructing understanding similar to those of experts. Change occurs as beliefs are restructured through new understandings and experimentation with new behaviors.

(3) Model with teachers the strategies they will use with their students, start with their current understandings and build on it, provide sufficient time for explorations, collaboration, reflection, and connect with teachers' other professional development activities. Learning through constructivist principles themselves is the only way for the teachers to understand why their students learn this way and to break away from traditional practices (Little, 1993; Loucks-Horsley et al., 1996).

(4) Build a learning community, where teachers continuously learn, take risks, and share together. Recognize that change in attitudes and behaviors is iterative, mediated by practice (Guskey, 1989; Hollingworth, 1989).

(5) Support teachers to serve as leaders in supporting other teachers, recognize that change occurs in stages and at variable rate, be change agents, and reform promoters.

(6) Link to and integrate with other school/district initiatives, actively supported by the school community (Corcoran & Goertz, 1995).

(7) Continuously assess its impact on teaching practices, student learning, leadership, and community and make improvements. (p. 36-39)

Examples of Effective Professional Development Programs

Elucidated in the literature are several examples of programs or schools professionally developing their teachers using the effective practices delineated above, to inculcate a deep understanding of the subject and practice research-based methods. These teachers are, in turn, using the understandings and practices with their students, essentially changing their traditional practices to those aligned with research-based. Some insights from these studies are given below.

In a study of California's mathematics teachers, Cohen & Hill (2000) reported that sustained professional development of teachers, situated in curriculum aligned to standards, enhanced their knowledge of the curriculum and the use of research-based instructional practices in classroom practice. Also, greater opportunities for teachers to learn and practice were linked with higher performance of their students.

Using the data from Local Systemic Change initiative, a teacher enhancement program funded by the NSF, Supovitz & Turner (2000) showed that the teachers who participated in 80 or more hours of reform-based professional development were strongly inclined to use inquiry-based practices in their classrooms and promote an investigative classroom culture. Also, a big shift towards investigative classroom culture occurred after 160 hours of professional development. Teachers' content preparation had a powerful influence on both inquiry-based practices and investigative classroom culture.

Supovitz, Mayer, & Kahle (2000) conducted a longitudinal study of the impact of Project Discovery's (Ohio's Statewide Systemic Initiatives, SSI, funded by the NSF) professional development on teachers' attitudes towards inquiry-based instruction and its use in their classrooms. Their findings reveal that sustained professional development leads to changes in classroom practice in the desired direction (Kahle, Meece, & Scantlebury, 2000).

Project LIFE, a Louisiana SSI, reported similar results (Radford, 1998).

Secondary science teachers from a variety of public schools took 1-4 professional development graduate courses at a university. The courses integrated content with constructivist pedagogy. Analysis of data confirmed that teachers transferred the content knowledge and constructivist practices to their classrooms (Irving, Dickson, & Keyser, 1999; Fowles, 2005).

The Eisenhower Professional Development Program, Title II of the Elementary and Secondary Education Act (ESEA), was the federal government's largest investment solely focused on developing the knowledge and skills of classroom teachers. The national evaluation of this program (Garet, Biman, Porter, Desimone, Herman, & Yoon, 1999) found that

> professional development focused on specific, higher-order teaching strategies increases teachers' use of those strategies in the classroom. This effect is even

> stronger when the professional development activity is a reform type (e.g., teacher network or study group) rather than a traditional workshop or conference; provides opportunities for active learning; is coherent or consistent with teachers' goals and other activities; and involves the participation of teachers from the same subject, grade, or school. (p. 5)

With a commitment of $20 million over 10 years from Merck Pharmaceuticals, Merck Institute of Science Education (MISE) developed partnerships with 4 school districts in PA and NJ, aimed at reforming K-8 science education. The initiative sought to teach science with active engagement and use of inquiry through guided instruction using standards-based curricular units like FOSS/ STC. The main vehicle to achieve this goal was professional development of science teachers over several summers with support throughout the year. Results show that teachers who had 80 or more hours of professional development were much more likely to change their teaching practice to be aligned with the reform methods. Also, teachers more familiar with content were more likely to use reform-based practices. There was some positive relationship between the achievement of fifth graders and the extent of professional development of their teachers (Corcoran, McVay, & Riordan, 2003). Similar results were found in Washington State's LASER program (Weaver & Wiitala, 2006).

Model Science Laboratory, a partnership between Rice University and Houston public schools affords 8 middle school science teachers each year with time, space, and support to enhance their professional skills. The teachers spend a year away from their schools in a Model Lab/Classroom complex located in an urban middle school, immersing themselves in learning and teaching science through reform-based methods. They enroll in special courses to improve their content knowledge and pedagogical skills where they are taught through constructivist methods, and team teach one class per day where they apply the newly learned strategies. They also engage in research with scientists, and attend conferences. It is a unique experiment that combines the best practices in professional development and adult learning with constructivist practices in an urban setting. At the end of the year, the teachers are required to return to their own schools. Even five years after attending their residency, teachers continue to use research-based reform practices and their students continue to outperform students taught by other teachers on standardized tests (Harcombe, 2001).

Professional Development in this Study: Master of Chemistry Education Program

Introduction and Goals

The Master of Chemistry Education (MCE) is a degree program offered by the Chemistry Department of the University of Pennsylvania in collaboration with the University's Graduate School of Education. The impetus for the program was the acute need for adequately prepared chemistry teachers in the region, especially in the School District of Philadelphia. MCE program has been cited by the National Academies Press's recent publication, 'Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future', as a rigorous program of professional development for high school chemistry teachers that emphasizes "content knowledge, keeping them updated and providing the skills to teach for the future" (NRC, 2007, p.130). MCE program strives to provide extensive professional development for teachers who are underprepared or inadequately prepared to teach chemistry according to the standards-based practices. To do so, it focuses on the development of deep knowledge of content, pedagogical content knowledge, and inquiry-based methods to teach high school chemistry.

Design of the Program

MCE is a 26 month program spanning 3 summers and the two intervening academic years. Between 20 and 22 teachers are admitted to the program each year and move through the courses as a cohort. Each cohort of students takes 8 chemistry content courses and 2 chemistry education courses. As teachers in a cohort progress through the sequence of courses, a community of learners develops that continues well beyond the completion of the program. Unlike typical graduate degree programs, where one takes either the teaching courses (thereby improving expertise in pedagogy), or the content courses (designed to enhance the subject matter knowledge), with no attempt to integrate the two, MCE courses are designed to "work in concert to provide the pedagogical content knowledge that is necessary if teachers are to develop the skills they need to implement inquiry-based, deepened content knowledge in their high school science classes" (Blasie & Palladino, 2005, p. 567). Integration of courses, their sequencing, and alignment with the professional development standards (learning science, learning to teach science, and learning to learn- NRC, 1996) are important consideration in the design of the program.

The first two courses, taken during the first summer, are very intense and serve the dual purposes of attaining graduate level content development and learning appropriate technological skills useful throughout the program. Each of the 3 summers, the teachers spend 8 weeks@ 4days a week on campus, taking 2 courses. Mornings are used for class meetings and afternoons are spent in small group tutoring sessions or problem solving related to group projects led by graduate TAs and/or MCE graduates. During the academic year, the teachers take two courses alternating between two

Saturdays per month from September to April. One of these courses is a chemistry content course and the other is a chemistry education course. The chemistry education course is purposefully placed during the academic year, rather than during the summer. This allows the teachers to conduct action research on a problem chosen by them, unique to their classroom context, with guidance from the instructor and their peers. Another reason for the placement of education courses during the academic year is for teachers to collectively dialog the results of implementation of the content and methods and learn from each other. The culminating project for the program is a master's thesis, where participants apply their understanding of chemistry to their chosen real life situation. They create a unit of study around this application for their classroom, complete with inquiry activities and assessment, and present their research to a group of peers and instructors. These presentations are disseminated as a resource to all the teachers, past and present, on CDs, in print, and website (Blasie & Palladino, 2005). The database of all the teachers is regularly updated and communications sent to them via periodic listserve e-mails. Other details of the program, a description of its10 courses, and their sequence can be found in Appendix E.

Teaching and Learning Methods

In all the courses, the content of chemistry is developed in depth and the interconnectedness of concepts and connections to real world is emphasized. This is achieved through the locally developed Penn Inquiry Model (PIM), used both in the classroom and in assignments (see Appendix C for a schematic diagram of the model). This model is a device to build on the teachers' existing knowledge through the processes of inquiry to attain deep understanding of scientific concepts. It provides instructors the necessary flexibility to teach the content in a rigorous manner while allowing teachers with diverse backgrounds to acquire the pedagogical content knowledge necessary to teach the subject in their classrooms (Blasie & Palladino, 2005). Two other learner centered approaches are modeled in teaching and learning chemistry in these courses. These methods are Process Oriented Guided Inquiry learning (POGIL) and Peer Lead Team Learning (PLTL).

POGIL is a classroom and laboratory technique that seeks to simultaneously teach content and key process skills such as the ability to think analytically and work effectively as part of a collaborative team (Farrell, Moog, & Spencer, 1999). POGIL is an inductive method in which information is provided, followed by asking leading questions to get the students to think in the right direction, and ultimately they come up with the general idea, close to the scientific thinking on the concept (Farrell, Moog, & Spencer, 1999; Hansen & Wolfskill, 2000; Hinde & Kovac, 2001).

PLTL model engages teams of students (in this case, teachers) in learning chemistry guided by a peer leader (Lewis & Lewis, 2005). It provides an active engagement in various problem solving techniques, opportunities for guidance, and creates leadership roles, helping to fulfill one of the goals of the program to empower the teachers to be the catalysts of change in their schools. It fosters a classroom culture where individual points of view are respected, criticism is constructive, and everyone has an equal opportunity to participate (Alger & Bahi, 2004), ideas consonant with the recommendations of National Science Education Standards (Cracolice, & Deming, 2001; Kampmeier, 2001; Roth, Goldstein, & Marcus, 2001).

Cogenerative dialog is the driving force in the two chemistry education courses (Roth, Tobin, & Zimmerman, 2002). It allows the participants to “reflect on and transform classroom structures while at the same time creating opportunities for all the stakeholders to develop collective responsibility for teaching and learning” (Lavan, 2004, p.1).

The teachers are provided the means and support to build on their prior knowledge, be life-long learners, reflective practitioners, and metacognitive thinkers, by instructors and peers modeling these practices.

Accepted Applicants and Graduates from the SDP

Between the years 2000, when the MCE program commenced, and 2006, the year this study got underway, 33 teachers from the School District of Philadelphia were accepted in the program. Ten of these teachers dropped out of the program, and 8 left the school district after successful completion. In Fall 2006, only 15 graduates of the program were working in various schools in the school district. Of these fifteen, eight teachers were not teaching any Chemistry course, and only seven teacher graduates had at least one chemistry course (at any level) in their rosters. Six of these seven teachers agreed to participate in this multi site case study. Therefore, this study is an account of how these six teachers are implementing the research-based practices that they were exposed to in the MCE program, how are their implementations similar or different, and the factors that help or hinder the implementation.

Teachers’ Knowledge Base and Beliefs

Reference is made in the earlier sections of this chapter to the importance of enhancing the depth of knowledge base of teachers, if they are to implement research-based practices in their classrooms. National Science Education Standards states, "Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching" (NRC, 1996, p. 62; De Jong, Korthagen, & Wubbles, 1998).

Furthermore, the personal components of all the above requirements, broadly termed beliefs, are powerful undercurrents that influence the decisions teachers make about implementing the practices learned in the professional development. Beliefs also help or hinder the advancement of teachers' knowledge base (Veal, 2004). There are studies that show that both, teachers' knowledge base and beliefs, deeply affects their classroom practice (Baxter, Richert, & Saylor, 1985; Carlsen, 1988, 1991; Clermont, Borko, & Krajcik, 1994; Dobey & Schafer, 1984; Hashweh, 1987, 1996; Nespor, 1987; Smith & Neale, 1991). The reciprocal effect, teaching practices influencing the knowledge base is even stronger (Gess-Newsome & Lederman, 1995; Gess-Newsome, 1999; Hauselien, Good, & Cummins, 1992). A teacher's knowledge base is intertwined with his/her beliefs in the guidance of classroom practice (Bullough & Baughman, 1997; Gess-Newsome, 1999; Grossman, 1990).

Therefore, this section first explores what constitutes teachers' knowledge base for teaching the subject supported by research, and then investigates the construct of teacher belief.

Teachers' Knowledge Base

Dewey (1902/1990) was, perhaps, the first educator to draw attention to the *teachers'* knowledge of the subject matter. He drew a distinction between the subject matter for *teaching* science and the subject matter of the *discipline* of science. According to him, the subject matter for a scientist entails the logical aspect of the experience and the subject matter for the teacher entails its psychological aspect (Deng, 2001). A scientist's knowledge base of the subject is research oriented with the focus on adding to the body of knowledge. Different from this, a science teacher's knowledge base is organized for teaching, in order to facilitate students' conceptual understanding of the subject.

Traditional Knowledge Base of Teachers

Teacher preparation/development programs, the bedrock of courses that build the knowledge base of teachers, come in many varieties distinguished by a dichotomy between those primarily emphasizing pedagogy and those focusing on content. In recent years, the focus between content and pedagogy has shifted frequently (Hurd, 1997). However, historically the teacher preparation/development programs have stressed the art of teaching at the expense of content knowledge (Shulman, 1987). The teaching methods courses teach generic teaching and classroom management strategies, and are "notorius for presenting philosophical theory without assisting teachers in translating those constructs into practice" (Mason, 1999, p. 277). On the other hand, the content courses emphasize vocabulary, detail and facts over articulation and depth of conceptual understanding. This results in teachers "who have learned science as discrete bits of information and lack an overall view or understanding of the relationship among the bits" (Mason, 1999, p. 278; Mason, 1992; Kennedy, 1998). Both the teaching methods and content courses provide teachers with "an array of noncontextualized, unconnected activities, concepts and demonstrations" (Mason, 1999, p. 277), never achieving a coherence of the two aspects required for effective teaching. As alluded to earlier in this chapter under the classroom practices section, in the absence of an alternative, the teachers model the familiar teacher-centered, text-driven, lecture style of teaching devoid of rich discourse and depth of content.

Research-based Knowledge Base of Teachers

Based on his research, 'knowledge growth of teachers', Shulman (1986, 1987) proposed that the knowledge base relevant to teaching should consist of seven categories: (1) subject matter knowledge; (2) pedagogical content knowledge; (3) curricular knowledge; (4) general pedagogical knowledge; (5) knowledge of learners and their characteristics; (6) knowledge of educational contexts; and (7) knowledge of educational purposes. Over the years several domains constituting the knowledge base teachers need, to practice research-based instructional strategies, were proposed (Shulman, Sykes, & Phillips, 1983; Grossman, 1990). The interrelated domains common to all of the above knowledge bases are: (1) general pedagogical knowledge; (2) subject matter knowledge; (3) pedagogical content knowledge; and (4) knowledge of general and specific educational context (Carlsen, 1999; Zeidler, 2002). As referred to earlier in this section, the undercurrent permeating all the domains are teachers' beliefs and personal practical experiences, to be dealt with later in this section. Now, these domains will be elaborated upon individually. However, consistent with the hallmark of research-based knowledge base (as opposed to traditional), the strong connections among these domains will be established through the cementing force of the pedagogical content knowledge exercised in the contextual milieu. The unique characteristics of the context of practice (the urban science classroom) of the teachers in the present research, warrants a separate section and follows.

General Pedagogical Knowledge (GPK)

General pedagogical knowledge refers to teachers' knowledge of *generic variables* that impact the classroom instruction irrespective of the subject matter. Some general factors that enhance student learning are; the amount of time students spend on appropriate academic tasks, structuring of new information, relating to students' prior knowledge, monitoring students' performance, and providing feedback (Brophy, 1997; Brophy & Good, 1986).

Additionally, scholarly research mentions three categories of GPK that impact teaching and learning: (1) classroom organization and management; (2) instructional models and strategies; (3) and classroom communication and discourse.

Classroom Organization and Management

Some effective classroom management techniques that need to be a part of the repertoire of 'best practices' include: setting clear behavioral expectations and standards for work; productive use of time; using group and instructional strategies with high levels of student involvement; and being consistent (Evertson, 1997; Evertson and Harris, 1992). However, these strategies must be adopted to conform to the specific context in which the teachers work, e.g., the age, ability level, cultural background, and circumstances of the institution etc.

Instructional Models and Strategies

Teachers' familiarity with a variety of instructional approaches to accomplish the goals of the lesson, is likely to provide greater flexibility in the execution of the lesson and enhance its impact.

Based on theory and research in psychology, and the learner capabilities emphasized, Joyce, Weil, & Showers (1992) have organized models of teaching into four categories that teachers need to be cognizant of: (1) Social, with a focus on cooperative and productive interaction in the classroom; (2) Information Processing, with a focus on acquiring and organizing information and problem solving; (3) Personal, with a focus on understanding oneself and taking responsibility for one's growth; and (4) Behavioral Systems, with a focus on behavior modification based on feedback. The reader is referred to the source for details.

To adapt to a variety of circumstances, the teachers' GPK needs to include a continuum of academic tasks (Rosenshine, 1993), with highly structured tasks such as direct instruction (including skill of presenting material in small steps, high levels of student practice, guided practice, and feedback) at one end (Rosenshine and Stevens, 1986), and less well-structured tasks like expert scaffolding (with skills of modeling, thinking aloud etc.) at the other end (Palincsar & Brown, 1984).

To implement research-based practices, teachers' GPK knowledge base needs to include constructivist approaches, such as emphasis on active and purposeful learning, recognizing individual differences, exchange of ideas and higher level thinking, and teaching in the zone of proximal development (Brown, 1997; Brown & Campione, 1990, 1994).

Classroom Discourse

Teachers need to have the knowledge and skills to create an effective climate of discourse in the classroom, to ensure full and culturally appropriate interactions among the participants (Green, 1983; Heath, 1982; Michaels, 1984). In constructivist classrooms, the teacher's role is shifted from an all knowing lecturer to that of a 'metacognitive coach" as the students make observations, analyze data, actively apply their knowledge to solve problems, and appropriate and internalize reasoning skills, (Gess-Newsome, 1999, p. 32; Joyce, Weil, &, 1992; Morine-Dershimer, 1983). Teachers need to "understand the questions to ask during problem definition, information location, analysis and synthesis, and to sort through potential interpretations and/or resolutions" (Gallagher, Stepien, Sher, & Workman, 1995, p. 138). Teachers' GPK needs to include scaffolding student experiences, in the zone of proximal development, to be able to effect a shift from their extant understanding of the topic to those of a community of scientists. Some discourse patterns that promote this shift are; students working in cooperative learning groups, engaging in discussions, and carrying out investigations to test their hypothesis. The teacher needs to be aware of these strategies and facilitate their usage (Lonning, 1993). An understanding of the patterns of discourse in reform-based diverse classrooms is a necessary component of a science teacher's GPK (Morine-Dershimer, & Kent, 1999).

Often, teachers' deeply entrenched traditional behaviors are resistant to change (Calderhead & Robson, 1991). Teachers' practical experiences, active examination of behaviors, and reflection may help in the shift towards constructivist practices (Kagan, 1992; Tobin, 1990).

Subject Matter Knowledge (SMK)

SMK of a science teacher refers to his/her quantity, quality, and organization of information, conceptualizations, and underlying constructs in the subject and its field of specialization (e.g. Chemistry, Physics, and Biology etc.). Inadequate and/or ill-organized

SMK has been a barrier to science teaching (Gess-Newsome, 1999; Gess-Newsome & Lederman, 1995; Koballa et al., 2000). Students' understanding of many chemistry topics appears to be related to the conceptual problems of their teachers (Birk & Kurtz, 1999; Kokkotas, Vlachos, & Koulaidis, 1998; Lin, Cheng, & Lawrenz, 2000)

Traditional or recitational subject matter knowledge involves the ability to produce specific facts on demand, recognition and use of correct terminology and the correct answer on multiple-choice tests (Kennedy, 1997). In the reform-based view, the recitational subject matter knowledge is not sufficient, rather it must include these five characteristics: (1) a deep conceptual understanding; (2) subject matter structure; (3) nature of discipline; (4) content-specific orientation to teaching; and (5) contextual influences on curricular implementation (Gess-Newsome, 1999).

Conceptual Understanding

In the extant literature, conceptual understanding is defined as, a sense of size and proportion of things (Paulos, 1988), attending to connections and relationships among ideas in a discipline often through the use of a tool such as concept mapping (Lederman, Gess-Newsome, & Latz, 1993; Shymansky, Woodworth, Norman, Dunkhase, Matthews, & Liu, 1993), capacity for a high degree of elaboration including lots of details and examples, and the ability to reason, argue, problem solve, and defend one's solution (Bennet & Carre, 1993; Greene, 1990), and focusing on key ideas (Prawat, 1991,1993).

Subject Matter Structure

For ease of storage and recall, the conceptual knowledge is assumed to be organized in the long term memory in a structured and integrated fashion, unique to the individual and the context (Champagne, Klopfer, Desena, & Squires, 1981; Gagne &

Glaser, 1987; Hiebert & Carpenter, 1992; Roehler, Duffy, Hermann, Conley, & Johnson, 1988). The tension between the structure of the discipline (the philosophical construct) and the cognitive structures in the minds of individuals (the psychological construct) gives rise to various interpretations of the subject matter structure. A representation of this interpretation is the subject matter taught in schools (Beane, 1995). Most novice teachers appear to have fragmented knowledge structures (Gess-Newsome, 1999), whereas experienced teachers are more likely to "hold subject matter structures that are coherently structured and rich in relationships" (Gess-Newsome, 1999, p. 69), making it readily accessible to students (Anderson, 1989; Gess-Newsome, 1999).

Views of the Nature of the Discipline

This includes a "teacher's understanding of the history, philosophy, and sociology of the discipline, as well as the questions asked within the discipline, the modes of inquiry used, the nature of discourse, and the cannons of evidence that characterize accepted answers" (Gess-Newsome, 1999, p. 57). Research shows that most teachers viewed science teaching as a transmission of facts, the rhetoric of conclusions, marked by objectivity, rather than as a powerful form of making meaning of the world that is often tentative and problematic, the stance advocated by the reform view of science education (Gess-Newsome, 1999; King, 1991; Lederman, and Latz, 1995). Even the teachers who had the correct understanding of the nature of science, fail to imlplement it in the classroom, often citing various environmental constraints as the reason (Lederman & Zeidler, 1987)

Content-specific Orientations to Teaching

It is a complex combination of content knowledge, beliefs, and values that have the potential to impact teaching and learning (Gess-Newsome, 1999; Grossman, Wilson, & Shulman, 1989; Gudmundsdottir, 1991). In his research Hashweh (1996) found that secondary science teachers who held constructivist views used a wider repertoire of teaching strategies, including conceptual change model, and were likely to spot students' alternative conceptions. However, well-regarded experienced teachers that taught by traditional methods, and whose students achieved academically, were resistant to adopting reform-based methods (Hollon, Roth, & Anderson, 1991; Wildy & Wallace, 1995).

Contextual Influences on Curricular Implementation

As Talbert, McLaughlin & Rowan (1993) posit, "knowledge, as it is socially and contextually formed, both influences and is influenced by the situations [such as administration, school culture, resources, students, parents etc.] in which it is manifested" (p. 50). Teachers with limited content knowledge or confidence, tend to overly rely on the textbook (Wineburg & Wilson, 1991). Teacher beliefs are powerful determinants of curricular implementation and are highly resistant to change (Hollon et al., 1991).

Pedagogical Content Knowledge (PCK)

Opposed to the traditional view of content and pedagogy as dichotomous constructs, PCK restores the balance between them (Morine-Dershimer & Kent, 1999). PCK is the "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). It is the knowledge teachers use to “provide teaching situations that help learners make sense of particular science content” (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001, p. 289), and represents a science teacher’s ability to convey the subject matter in a manner that makes it accessible to students (Kennedy, 1997; Zeidler, 2002). PCK, as an embodiment of aspects of content most germane to its teachability, includes the most useful forms of representation of ideas in the subject, the most powerful analogies, illustrations, examples, explanations, and demonstrations etc., that make the ideas comprehensible to the students (Shulman, 1986).

A critical amount of SMK and clear conceptual understanding of the subject matter are a prerequisite to bring this to fruition, i.e., to use a metaphor to capture the essence of the original idea. One of the finest examples of PCK is Richard Feynman’s explanation of the size of an atom in his lectures on Physics. It goes, “ if an apple is magnified to the size of the earth, then the atoms in the apple are approximately the size of the original apple” (Feynman, 1963/1995, p.3). This metaphor gives students an immediate sense of how minute the atoms are. “The ability to generate such metaphors is, for Shulman, at the heart of pedagogical content knowledge. And it is, presumably, important for any teacher who aims to teach important ideas rather than lists of facts and procedures” (Kennedy, 1997, p. 10). This clarity, parsimony, and immediate connection to students’ frame of reference contrasts sharply with how the size of the atom is defined in the traditional course/s teachers take in colleges/programs, hence propagate in their own classrooms. In these courses, an atom’s size is typically mentioned as 1 to 2 Angstroms, with an Angstrom being equal to 10^{-8}cm. Ability to recite this fact does not assist the teachers or their students to grasp the meaning of the size of the atom, as the metaphor mentioned earlier does. Therefore, "if PCK is not sufficiently present in teaching, then we may be quite efficient in presenting students with rote memorization" (Zeidler, 2002, p. 7) and continue to perpetuate the fact-driven classroom culture. On the other hand, sufficient presence and good execution of PCK allows the students the opportunity to construct meaning from symbols and images and see the underlying relationships among ideas much like the experts (Kennedy, 1998; Ma, 1999), consistent with the research-based practices that emphasize the development of deep understanding of the subject matter in the students.

Other ways that PCK differs from the traditional methods is that the metaphors used are not only accurate, they are within the zone of proximal development, therefore accessible for understanding, of the targeted audience. As teachers make their PCK explicit, it brings to light the possible problems they may encounter during instruction. Reflecting on these, and coming up with solutions, starts the next iteration of refinement, further enriching their PCK. "PCK is developed (via multiple pathways) by an iterative process that is rooted in classroom practices, implying that prospective or novice teachers usually have little or no PCK at their disposal" (De Jong, Veal, & Van Driel, 2002, p. 371). Through their PCK, the teachers are "representing the character of the subject, just as they represent its ideas through their sentences" (Kennedy, 1997, p. 12). Additionally, the teachers should possess a taxonomy of PCK, ranging from the general PCK that all teachers of science should possess, to those that are subject specific (i.e., specific to Chemistry), to those that are specific to topics within the subject (stoichiometry, acid/base titrations etc.) (Veal & MaKinster, 1999). Therefore, a rich repertoire of PCK needs to be a part of the classroom practice of teachers implementing research-based methods.

There are several "structuralist" (Carlsen, 1999, p. 135) conceptualizations of the components that constitute PCK. These view PCK to be made up of interrelated components such as SMK, GPK, and the contextual knowledge etc. Many examples of this type of model are found in the literature, including several proposed by Shulman and his associates (Grossman, 1990; Grossman, Wilson, & Shulman, 1989; Hashweh, 1987; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986; Tamir, 1988). The three mutually interacting domains, common to all of the above models, that affect each other and the SMK, and in turn are affected by it, are GPK, SMK, and the contextual knowledge. Therefore, these domains are considered in this study. GPK and SMK have already been described earlier in this section. The relevant contextual knowledge will be described in the section entitled 'Urban science classrooms'.

Later, Carlsen proposed a "poststructural view" (Carlsen, 1999, p. 139)of PCK, in which he argued for the rejection of a compartmentalized, fixed, systemic concept of knowledge and its substitution with one that is sociocultural, idiosyncratic, and situated in the community rather than the individual.

Regardless of the two views, at one extreme the PCK can be regarded as an act of integrating knowledge across the three distinct domains of GPK, SMK, and the context. This is how, novice teachers access this construct, i.e., for planning and executing a lesson, they draw from individual domains separately as needed. At the other extreme is the *transformative* view of PCK, obtained through a synthesis of the three fuzzy domains, moving flexibly and seamlessly among the domains, into the "*only* form of knowledge that impacts teaching practice" (Gess-Newsome, 1999, p. 10). The transformative view "signals that PCK is more than the some of its parts, more than simply fitting together bits of knowledge from different domains" (Magnusson et al., 1999, p. 116). Generally, experienced teachers practice this form, arriving at it through reflection, ongoing inquiry, collaboration with peers/guides, active processing etc. "This capacity to transform subject matter knowledge into forms that are pedagogically powerful and adaptive to particular groups of students is at the core of successful science teaching" (Zembal-Saul, Starr, & Krajcik, 1999, p. 243). The characteristics of the two extreme views, integrative and transformative, are compared to those of a mixture and a compound made of the same elements, respectively (Gess-Newsome, 1999).

Neither the college courses nor the traditional professional development programs build a deep knowledge of the three domains separately, much less, how to integrate these to teach a specific lesson to build the teachers' PCK. Effective professional development programs need to do this to promote research-based classroom practices. Also, the teachers need to be exposed to exemplary instances of teaching and be equipped with the tools necessary to progress towards the transformative model, such as informed decision making, use of inquiry, reflection, and collaboration etc. in their preparation/professional development programs. Since teaching is a complex task whose end product cannot be packaged as a 'teachers' bag of tricks' and delivered to the teachers ready for use without adaptation, this reinforcement of tooling will enable them to use their creativity, and problem solving skills to achieve personal growth as teachers and accumulate their own unique PCK, "their own special form of professional understanding" (Shulman, 1987, p. 8), as they implement the 'best practices' in their classrooms. One of the goals of the MCE program is to enable the teachers to build their PCK through modeling exemplary teaching and the capacity to implement the practices in their classrooms (Gess-Newsome, 1999).

As mentioned earlier, apart from teachers' knowledge base, the factor that affects teachers' understanding of PCK and its domains and their implementation in the classroom, is their beliefs (Brickhouse, 1990; Magnusson et al., 1999; Tobin, McRobbie, & Anderson, 1997). Therefore, the role of teachers' beliefs in instruction is described in the next section.

Role of Teachers' Beliefs in Instruction

Beliefs are the dyes that permeate the fabric of SMK, PK, and PCK, and color their use, organization, and retrieval, and are powerful indicators of the affective and evaluative aspects of behavior (Bandura, 1986; Beck & Lumpe, 1996; Haney et al., 1996; Nisbett & Ross, 1980)

However, there does not seem to be a common definition or use of the term 'belief' (Tobin, Tippins, & Gallard, 1994). It has been variously identified with personal or subjective knowledge (Green, 1971), "attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practice principles, perspectives" (Pajares, 1992, p. 309).

Beliefs are described as both evidential and non-evidential, static, emotionally bound, organized into systems that develop episodically (Gess-Newsome, 1999; Nespor, 1987; Pajares, 1992) as opposed to knowledge that is evidential, dynamic, emotionally-neutral, and develops with age (Alexander, Schallert, & Hare, 1991; Hiebert & Carpenter, 1992). According to Tobin, Tippins, & Gallard (1994), "studies… suggest that teacher beliefs are a critical ingredient in the factors that determine what happens in classrooms" (p. 64). Beliefs that enable the teachers to meet their goals are used as a guide for actions and those do not, are not used as referents in those contexts (Tobin & McRobbie, 1996).

The role of belief in the implementation of research-based practices has been well investigated (Batista, 1994; Beck & Lumpe, 1996; Bryan & Abell, 1999; Cornett, Yeotis, & Terwilliger, 1990; Hashweh, 1996; Richardson, 1996; Tobin et al., 1994; Tobin & McRobbie, 1996). "Epistemic beliefs of teachers strongly influence their efforts to bring about educational reform" (Lavonen, Jauhiainen, Koponen, & Kurki-Suonio; 2004, p. 310; Brickhouse, 1990; Clark & Peterson, 1985; McComas, Clough, & Almazroa, 1989). Teachers with traditional beliefs typically transmit knowledge through lectures, their students solve problems from textbooks, and do cookbook type of labs, i.e., activities that do not assist in constructing depth of understanding of scientific concepts (Arons, 1990; Berry & Sahlberg, 1996; Stinner, 1992). On the other hand, teachers subscribing to constructivist beliefs are more likely to detect students' alternative conceptions, have a richer repertoire of teaching strategies, use more effective strategies to effect conceptual change and use these more often, and are likely to evaluate their strategies (Hashweh, 1996; Veal, 2004).

Often, the distinction between teacher knowledge and beliefs is blurred in classroom practice ((Bullough & Baughman, 1997; Grossman, 1990). The transformation of these in action is complex (Fenstermacher, 1994). To acquire new knowledge and beliefs, teachers' current knowledge and beliefs need to be challenged (Borko & Putnam, 1996; Cohen & Ball, 1990), and they need to be provided support, feedback, and opportunities to examine, reflect upon, elaborate, and integrate the new knowledge and beliefs. According to Veal (2004), “A teacher’s personal science background, peers, teachers, and personal traits facilitate a teacher’s transition of beliefs into practice” (p.331). Context, sociocultural, and institutional factors can also constrain the implementation of beliefs into classroom practice (Palmeri, 1995; Roth & Roychoudhari, 1994; Tobin et al., 1990).

What follows is a section that considers the contextual factors, the milieu of practice of the teachers in the present research, influencing their classroom practice, i.e., the urban science classroom.

Science Education in the Urban Context

Although some of the issues underlying the problems faced by schools in urban areas are not uniquely urban, teacher preparation, teacher morale, access to resources, teacher beliefs, student attendance, student self-esteem and achievement, as well as parental/administrative support etc., often coalesce to become uniquely urban concerns (Hewson, Kahle, Scantlebury, & Davis, 2001; Kopetz, Lease, Warren-Kring, 2006).

This section describes the characteristics of the urban setting and the unique challenges it poses for science education. Then, the origins of these challenges and strategies for dealing with them are discussed, with insights from the nascent literature on science education in the urban context.

Introduction

In the past several decades, the urban demographic landscape across the United States has changed considerably and it continues to change (Barton & Tobin, 2001). According to US Census (2000, 2001a, 2001b) over 70% of US population lives in urban areas. Large urban districts educate 25% of all school-age students, 35% of all poor students, 30% of all English-language learners, and nearly 50% of all minority children (Pew Charitable Trust, 1998). Thus, urban areas constitute a widely diverse population, with the largest concentration of ethnic minorities (New York City 57% and Philadelphia 86%), immigrants, and foreign-born residents (Barton, 2001; Barton & Tobin, 2001).

In the SDP, 64.4% of students are African American, 5.6 % Asian, 15.8% Hispanic, 0.2% Indian, and 13.3% white (School District of Philadelphia, 2007). These children attend impoverished schools characterized by high student mobility, inadequate fiscal and other resources, high rates of truancy, and low rates of graduation. Also, their teachers are more likely to be underprepared, and their achievement levels are lower than those of their peers in nonurban settings (Clewell et al., 1995; Kozol, 1991; Linden, 1995; Rury & Mirel, 1997; Rainwater & Smeeding, 2003; Tobin, Seiler, & Walls, 1999; Waxman & Padron, 1995).

The recent wave of reform in science education has been largely concerned with epistemology, cognition, systemic change, policies at various levels, teacher preparation, standards, accountability, curriculum, instruction, and assessment etc. As a perusal of the literature on the subject indicates, challenges facing the science education of urban youth has received scant attention until recently (Barton, 2001; Gabel, 1994). The twin goals of equity and excellence for all the students, espoused by the National Science Education Standards (NRC, 1996), are far from becoming a reality for the urban students due to the needs in four highly interrelated areas: (1) academic achievement; (2) resources; (3) policies and schooling practices; and the (4) culture of schooling (Barton, 2001).

Achievement Gap

"The goal of 'science for all' continues to be unattainable, particularly in the urban setting where science achievement gaps exist between some groups of African American, Latino, Native American, and Asian American students and their white counterparts" (Fraser-Abder, Atwater, & Lee, 2006, p.599; Atwater, 1994). Between 2000 and 2005, the achievement gap between African –American and White students and also between White and Hispanic students, has widened on the 12th grade science test on the NAEP (Cavanagh, 2006). Analysis of science achievement data suggests that an important factor in the creation and maintenance of this gap is the fact that educational system favors the groups in power (Rodriguez, 1998). Tobin, Roth, & Zimmerman (2001) hold the view that "National standards are a component of the hegemony, which maintains the achievement gaps between Whites and African Americans" (p. 961).

The cause for a large part of the gap in scholastic performance has been attributed to the disparities in job opportunities and disadvantaged socioeconomic status of these groups, rather than race (Sowell, 1977, 1995). Data from the turn of the century when White immigrant groups from Europe performed poorly compared to blacks in northern United States, and from many parts of the world support this connection (Benson, 1995; Klich, 1988; Lynn, Hampton, & Magee, 1984; Ogbu, 1978, 1992a, 1992b).

Steele (1999) has suggested that stereotype threat could be one of reasons for the low performance of urban minorities. Reducing the stereotype threat, supporting, and validating the students are some of the ways to improve their performance and reducing the achievement gap (Turner & McCann, 2000). According to Norman et al. (2001, p. 1106) "students who are socioculturally disadvantaged respond to these societal disparities in ways that may impede learning". Due to their own (lack of) preparation, the science teachers perceive these responses as resistance to learning, and turn it into matters for disciplinary action, instead of finding ways to harness these into "cultural capital that will enhance rather than impede learning" (Norman et al., 2001, p. 1106).

One of the causes of disparities leading to the achievement gap is the allocation and activation of resources in urban settings. Attention is devoted to discussing this next.

Resources

Resources available to urban classrooms can be divided into the four categories of temporal, fiscal, intellectual, and social. To facilitate teaching and learning, the resources must not only be available, but be actualized by the teachers and students. It is their agency that converts these resources into learning, the "return" (Knapp & Plecki, 2001, p. 1092) on the investment. Given the meager resources, urban settings require that the administrators utilize their resources creatively to yield a high return on instruction (Spillane, Diamond, Walker, Halverson, & Jita, 2001).

Temporal Resources

Reform-based methods in science advocate the use of inquiry methods. These methods require substantial investment in time to allow the students the opportunity to learn the content. Additionally, adequate allocation of time has a positive impact on student learning (Darling-Hammond, 1999b; Miles & Darling-Hammond, 1998; Newmann & Associates, 1996). In urban settings, the time allocated to science is generally not sufficient to afford a deep engagement with content (Knapp & Plecki, 2001) due to a variety of reasons, some of which are discussed in the section on practices and policies. In many high schools in this study, there were no double lab periods for the subject.

Material and Fiscal Resources

There are both structural and implementation barriers regarding this resource. Urban classrooms are notoriously undersupplied in terms of scientific instruments and lab supplies and their allocation is, often, mismanaged (Fraser-Abder, Atwater, & Lee, 2006; Tate, 2001). NAEP 1999 Trends in Academic Progress found a positive correlation between using scientific equipment and science assessment score (Campbell, Hombo, & Mazzeo, 2000). The best technology-rich experiences students receive, often, occur in extracurricular programs available to a few high achieving students (Tate, 2001). On the other hand, institutions like museums, lab on wheels, colleges, and universities are sometimes within reach, and can be partnered with, but many teachers do not tap into these important resources for a variety of reasons.

Intellectual Resources

Urban children are often taught by underprepared or out-of-field teachers, especially in math and science (Ingersoll, 1999). These teachers lack the subject matter knowledge and the pedagogical content knowledge (Shulman, 1986) required for deep conceptual understanding of the subject. They, therefore, “lack the tools to teach high-level skills or to implement appropriate innovations to support this kind of teaching” (Tate, 2001, p. 1021). This impacts the students’ opportunity to learn science concepts and ultimately student achievement (Darling-Hammond, 1999a). The inadequacy of teacher preparation is exacerbated by the high rate of absenteeism, low attendance at professional development sessions, and lack of relevant and sustained professional development (Tate, 2001). Sometimes, as a result of participating in reform-oriented professional development using inquiry/discovery methods, teachers are enthused and intend to use these in their classrooms. But, due to various constraints described throughout this chapter, they are handicapped in their efforts and fall back into their routine practices (Hewson et al., 2001).

Social Resources

According to Elmore & Fuhrman (1995), shared norms, knowledge, and skills of teachers are the most powerful factors in enhancing student learning and achievement outcomes. Often, there is no common planning time and there is little opportunity for teachers to collaborate and learn from each other. In the school district of Philadelphia, teachers take part in mandatory monthly professional development that covers topics developed centrally, often disconnected to their local needs. Even in situations where time/resources for collaboration are available, there may not be an enthusiastic support/promotion from the administration, or such partnerships are not part of the school culture, i.e., the supportive infrastructure consisting of responsive parents, motivated colleagues, effective administrators, supportive school district policies, a culture of collaboration etc,. that is taken for granted in many suburban contexts is more likely to be absent in urban settings. To add to these, there may be English language learners and students with special needs in the class, with the teachers neither being provided the support nor the training in instructional strategies to impart quality instruction to these students. Also, frequently due to a shortage of substitute teachers, a science teacher may be asked to combine classes, seriously affecting the quality of instruction (Hewson et al., 2001).

Since the allocation and activation of resources are determined by the policies and practices of the institution, these constitute the topics for the next sections.

Policies and Practices

This section is divided into two subsections. The first section describes policies that directly and indirectly impact classroom instruction. The remaining section discusses urban classroom practices that contribute to the low achievement of students.

Policies

Fraser-Abder, Atwater, & Lee (2006) posit that "urban education policies are shaped by issues of power and control, race/ethnicity, culture, language, social class and gender (p. 604; Darden, 1981; Freire, 1971; Giroux, 1981; Kahle, 1998). Additionally, these policies favor the privileged, and the marginalized groups are treated "in a hegemonic way" (Hill, 2005, p. 344; Kivel, 2004).

Policies formulated at several levels (federal, state, district, and school), impact urban science teaching. Teachers generally have no say in their formulation, but are charged with the agency of their enforcement. Some policies directly impact teaching and learning, and the effects of their implementation are all too pervasive, encroaching on all the aspects of teaching and learning. Examples of these policies are:

(1) Policy regarding what is taught in the classroom, how is it taught, and what materials are used is often determined at the district level in the form of a curriculum guide or framework (Knapp & Plecki, 2001). In the case of Philadelphia, the core curriculum based on the state standards, and its plan of daily activities, the planning and scheduling timeline, drive instruction at the classroom level, in every subject in the

district. Teachers are monitored, especially in low performing schools, for adherence to it and reminded to be on track.

(2) Policy regarding what is assessed in the classroom, and therefore is the primary focus of teaching the content and drives the instruction, is also determined at the district and state levels. In SDP, the benchmark tests at the end of each 5-week cycle and PSSA in most grades drive the instruction. Teachers are required to analyze the results of the benchmark tests and reteach the material the students fared poorly in. Many teachers are held accountable by their principals for the performance of their students on the benchmark tests, so are the principals by their regional superintendents. Thus a formative assessment tool assumes the status of a high stakes test dreaded and hated by a large number of stakeholders. Ironically, most teachers do not find the benchmark tests to be aligned to the content, therefore not a good diagnostic tool regarding gaps in instruction. The teachers express the concern that they are asked to implement the assessment, are judged by its outcome, but their suggestions for changes are not considered.

Policies regarding hiring, staffing, assignment of classes, teacher preparation, and professional development indirectly impact classroom instruction. In an urban setting, many factors determine the deployment of teachers, qualification being one of them, and not often the one that takes precedence, resulting in many science classes being taught by unqualified/uncertified teachers (National Commission on Teaching & America's future, 1996). Policies regarding class size (max. 33 in Philadelphia, max. 25 in Upper Dublin) and configuration do not favor quality science instruction (Center for the Study of Teaching and Policy, 1998).

In sum, the prevalent policies form a teaching policy environment (Center for the Study of Teaching and Policy, 1998) that, in an urban setting, is characterized by a lack of coherence, comprehensiveness, and stability, resulting in little guidance or professional support from the district and colleagues and is inadequate in addressing the needs of teachers (Knapp & Plecki, 2001).

Practices

The dominant pattern of discourse in an urban classroom is teacher monologue and triadic dialog (Lemke, 1990). Students are, generally, passive recipients rather than active participants. Student response is limited to answering recall type questions, rather than those requiring higher order skills (Haberman, 1991). Student talk is viewed as disruption and is discouraged. To deal with large classes and little equipment many urban teachers use whole-class instructional techniques, and the ‘pedagogy of poverty’ (Haberman, 1991), such as lectures, class readings, completing worksheets, textbook assignments (Barton & Darkside, 2000; Nieto, 1994), rather than the reform-based science teaching methods including open-ended discussion, project work, and activities, in which the learners assume responsibility for their learning (Knapp & Plecki, 2001).

Students' opportunity to learn (Carroll, 1963), the amount of time required to learn a concept, is seriously encroached upon by two practices (elaborated upon in the last section) that the teachers cannot escape from. These are; curriculum pacing schedule, set by the central office which demands that only a predetermined amount of time be spent on a given topic, and the NCLB driven standardized test oriented pedagogical strategies (Olson, 2001; Tate, 2001). About 60% of teachers whose classes had a high number of minorities indicated going over test-taking skills (significantly more than in classes without sizeable minorities), teaching topics known to be on the assessment, emphasizing tested content, and beginning test preparation more than a month before the assessment (Madaus, West, Harmon, Lomax, & Viator, 1992), and the climate of standards and assessments continues to fail to prepare the students meaningfully (Seiler, Tobin, & Sokolic, 2003; Shepard & Dougherty, 1991). Overall, the quality of science instruction available to many students is restricted due to the tracking practices in many urban schools (Oakes, 1990; Oakes, Gamoran, & Page, 1992).

Science education in urban settings typically reflects middle class experiences and views of knowing and doing science. It excludes the lives of marginalized students (Atwater, 1998; Brickhouse, 1994; Lee & Fradd, 1998; Moses, Kamii, Swap, & Howard, 1989).

This (conscious or unconscious) exclusion leads to students' disengagement and opposition to learning science (Bourdieu, 1977; Brickhouse & Porter, 2001; Holland, Lachicotte, Skinner, & Cain, 1998).

Inside the school, learning and achieving in science requires being able to memorize the answers and reproduce these correctly in the exam, whereas in the real world sociocultural context, "learning is a dynamic and recursive process of constructing meaning" (Fusco, 2001, p. 861; Rogoff & Chavajay, 1995; Vygotsky, 1978). This lack of correspondence between learning inside the school and in the outside world of the students' community minimizes the relevancy of school learning (Lave & Wenger, 1991; Nieto, 1994; Resnick, 1987; Saxe, 1990; Sleeter & Grant, 1991).

The next section elaborates on this disconnect and its consequences.

Culture of Schooling

According to recent studies, urban students and students of color have exceptionally negative attitudes towards school science and their futures in the field, with feelings of boredom, anxiety, confusion, and frustration, especially in the high school (Atwater, Wiggins, & Gardner, 1995; Ayers & Price, 1985; Basu & Barton, 2007; Bohardt, 1975; Cannon & Simpson, 1985; Disigner & Mayer, 1974; Haladyna & Shaughnessy, 1982; Hill, Atwater, & Wiggins, 1995; Ormerod & Duckworth, 1975; Randall, 1975; Simpson & Oliver, 1990). This attitude appears to be affected by the students' interest levels in science, their abilities in school science, the curriculum and learning climate, their access to extra curricular experiences, their family, teachers, their own self concept, and their peer groupings (Cannon & Simpson, 1985; Fouts & Myers, 1992; George and Kaplan, 1998; Hansen, 1999; Simpson & Oliver, 1990; Simpson & Troost, 1982; Wang & Waldman, 1995).

Further, identity is a strong determinant of what one participates in and how (Brickhouse et al., 2000; Carspecken & Apple, 1992). Most urban students envision science to be the realm of Einstein, lab coats, and goggles that is far removed from their own identities (Boullion & Gomez, 2001; Brickhouse, 1994; Burkham, Lee, & Smerdon, 1997). These issues arise since the nature of science and what it encompasses remains narrow, intact, and exclusionary, a far cry from the context and experience of the students (Atwater, 1996; Barton, 1998a; Delpit, 1995; Fusco, 2001; McShane & Yager, 1996; Moses, Kamii, Swap, and Howard, 1989; Nespor, 1987; Rodriguez, 1997, 1998).

Boullion & Gomez (2001) express this disconnect very succinctly as, "Schools are *in* communities but often are not *of* communities" (p. 878; Fraser-Abder, 2001).

According to Vygotsky, learning is mediated by sociocultural factors. Patterns of activity that students take part in outside of the school are, often, well articulated compared to those within schools. This is a source of disconnect, that leads to student disengagement.

Schools need to bridge the world of science classroom and the children's community-based experiences and find ways to enrich each in meaningful ways in order to make the world of science relevant to students' lives (Boullion & Gomez, 2001; Lee, 2003; Moll & Greenberg, 1990). Activities such as integrating science learning across the curricular areas, social interaction with outside experts/mentors, using other community-based resources, tapping in to science-related 'funds of knowledge' existing in different contexts and communities, using students' lived experiences in the context of science etc. help to 'decenter' science (Barton, 1998c; Moll & Gonzalez, 1992; Gonzalez, Moll, & Amanti, 2005).

Making such connections is part of the vision of science education for all, as expressed by the following statements from the National Science Education Standards: "teaching for understanding requires responsiveness to students, so activities and strategies are continuously adapted and refined to address topics arising from student inquiries and experiences, as well as school, community, and national events" (NRC, 1996, p. 30) and "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 31).

Since the student inquiries, experiences, understandings, and communities in a culturally diverse setting are inherently different from the mainstream science that currently drive the curricula, if these culturally diverse students are to find science relevant, science teaching "must respond to and emerge from the life experiences, questions, and interests of all learners" (Fusco, 2001, p. 874), such that the students perceive science as something important to their lives outside of school (Eisenhart et al., 1996). There are several instances in the literature where students show a great deal of involvement and ownership in after-school, community-based programs that provide opportunities for students to explore, give expressions to their creativity, be authors and creators of knowledge rather than mere recipients, and does not marginalize their culture (Fusco, 2001). The same level of participation needs to occur in urban science classrooms, which seems to be elusive so far.

This now leads into the vision of urban classrooms where the goals of equity and excellence need to be realized for *all* the groups of students.

Urban Science Education - A Vision

As stated earlier, the literature on inclusive urban science education practices is still in its infancy. However, it is clear that to realize the goals of equity and excellence for all, rethinking is required in the following areas; 1) the nature of scientific knowledge, 2) the role of teachers and other experts, 3) the relationship of the learner to the knowledge presented, and 4) the context of teaching and learning (Barton, 1998c).

The view of science as an objective, positivist body of knowledge needs to be abandoned. It needs to be replaced by the post-colonial view that regards science as a product of the Western culture (Aikenhead, 1997, 2001; Aikenhead & Lewis, 2001) and teaching science as a transmission of this subculture (Heath, 1982; Ogawa, 1995; Phillips, 1983; Spindler & Spindler, 1997). Recent reform efforts in science, described extensively in the earlier sections of this chapter, envision students as active constructors of meaning rather than passive recipients of knowledge. However progressive this view is, it still does not go far enough to embrace the pedagogical needs of students from different sociocultural backgrounds to achieve the goals of equity and excellence, since it only deals with 'how' science is learned, leaving 'what' is learned untouched (Atwater, 1996; Barton, 1998b; Bianchini & Kelly, 2003; Carter, 2006, 2007; Cross, 1997; Cunningham & Helms, 1998; Lee, 1999; Lemke, 2001; McNay, 2000; McShane & Yager, 1996; Ninnes, 2001; Rodriguez, 2001; Settlage & Meadows, 2002; Wong, 2001; Zacharias & Barton, 2004). To include the perspectives and experiences of diverse groups of students, meaningful reflection and dialog must occur and the confines of Western science need to expand to make room for indigenous science (Atwater, 1996; Barton, 1998b; Collins & Pinch, 1993; Hammond, 2001; Harding, 1998; Jasanoff et al., 1995; Knorr-Cetina, 1995; Paty, 1999; Seiler, 2001; Snively & Corsiglia, 2001). This will lead to a new definition of scientific knowledge as "any systematic attempt to produce knowledge about the natural world including local knowledge systems, ethnosciences, and science as a local cultural practice" (Carter, 2007, p.3, 2004, 2005). As these experiences are included and valued, definitions of what constitutes science and who can participate in it are bound to change resulting in a more or less seamless transition for urban youth as they negotiate the two cultural strands, find relevancy and meaning in school science, as opposed to silencing their cultural perspective in order to participate in school science (Barton, 2000, Fine, 1991; Fusco, 2001; Roychoudhury, Tippins, & Nichols, 1995; Siegel, 2002; Stanley & Brickhouse, 2001).

In such a classroom, the role of the teachers will change from the transmitter of western science to that of a cultural broker communicating with various voices. As Aikenhead (1996, 1997) put it succinctly, the teachers must be 'tour guides' assisting students with border crossings (between their culture and culture of western science). As teachers are better equipped to navigate the cultural interface zones, classrooms will become places of cultural cooperation, rather than of cultural conflict (Giroux, 1992; Norman et al., 2001).

Teachers need to learn to harness the cultural capital students come to class with, e.g., African American students' extensive orality, communalism, and rhythm, towards social construction of scientific knowledge, rather than labeling these as elements of resistance to learning (Seiler, Tobin, & Sokolic, 2001; Tobin, 2000; Tobin, Seiler, & Walls, 1999) and punishing the students. Teachers can reshape the classroom discourse and gain insights into their own pedagogical approaches through cogenerative dialog (Tobin, Elmesky, & Seiler, 2005) and negotiated agreements (Bodley, 2000) with the students.

As Tobin, Elmesky, & Seiler (2005) express it so clearly, "teachers need to ask difficult questions about their own practice and beliefs towards developing a more reflective and inclusive pedagogy. Improving urban science education begins with our own individual beliefs and practices" (p. 37).

Change and Its Implementation

Change in the present study is defined as "teachers doing something that others (in this case, national science standards) are suggesting they do. A critical feature is that someone outside the classroom decides what changes the teachers will make" (Richardson, 1990, p. 11). However, the change is centered on the individual teachers.

Some assumptions about change posited by Hord, Rutherford, Huling, and Hall (2006), are utilized in the present research:

> Change is a process, not an event. It occurs over time, usually a period of several years.
> Change is accomplished by individuals. Therefore, individuals must be the focus of attention in implementing a new program.
> Change is a highly personal experience. Therefore, different responses and interventions will be required for different individuals.
> Change involves developmental growth in terms of feelings and skills, by those involved in the process.
> Change is best understood in operational terms. By addressing the concerns of those involved in change in concrete, practical terms, communication can be improved and resistance to change decreased.
> The focus of facilitation should be on individuals, innovations, and the context.
> The real meaning of change lies in its human, not material, component. (p. 6-7)

Barriers to the Implementation of Change

Implementation of new ways of thinking and practice usually necessitate some organizational changes, particularly in the roles and role relationships of the members directly involved with putting the changes into practice. Problems inevitably arise during the attempt to implement the changes, often, resulting in the implementation not occurring at all, or, in ways not intended (Fullan and Pomfert, 1977). As discussed in the literature, lack of success of the implementation of many research-based practices has been attributed to several factors. These factors fall into three general categories; teacher characteristics, organization, teacher self-efficacy. Some of the factors related to teacher characteristics are; resistance to change (Duffy & Roehler, 1986; McLaughlin, 1987), beliefs and perceptions (Roehrig & Kruse, 2005), lower level of rational and analytic abilities (Lortie, 1975), lack of use of scientific or objective measures in assessing student growth (Jackson, 1968), and intuitive and non-technical behaviors (Berlak & Berlak, 1981; Feiman-Nemser & Floden, 1986). Some organization related factors that enable or hinder implementation of change by teachers are; the norms of collaboration, collegiality and experimentation (Hatton, 1985; Little, 1987), instructional coordination (Rosenholz, Bassler, & Hoover-Dempsey, 1986), and significant cues from the environment (March & Simon, 1958). Lastly, self-efficacy factors such as teachers' beliefs (e.g., about how students learn and how they should learn etc.), attitude, knowledge, goals, concerns about student engagement and performance, knowledge and experience gained from the professional development, and orientation to specific contextual concerns impacted by the implementation of change (Bryk, 1988; Doyle & Ponder, 1977; Guskey, 1988; Hargreaves, 1984; McLaughlin & Yee, 1988; Mitchell, Ortiz, & Mitchell, 1987; Stern & Keislar, 1977; Tobin, 1987).

Implementation of Change and Teacher Concerns

Adoption and implementation of change requires that the culture of reform-based practices become the culture of classroom practice of the affected teachers (Hatton, 1985). Although the objective characteristics of an innovation are important, the perceptions of teachers who will implement it are even more so, for a successful realization of its intent. The meaning realized during the process of implementation is central to its successful implementation (Fullan, 1993; Nias, 1996). The meaning finds expression through the concerns teachers express as they practice the new culture.

"Although personalized interventions can facilitate change, in the end individuals determine for themselves whether or not change will occur" (George, Hall, & Stiegelbauer, 2006, p.9). Therefore, to understand the implementation of new ways of thinking and practices in classrooms, it is imperative that a great deal of attention be paid to how the teachers construe their new role, to understand their subjective realities, and to have an awareness of their concerns and experiences that will ultimately determine their behavior and the success or failure of implementation (Fuller, 1969; Hall, George, &

Rutherford, 1977; Richardson, 1990). Here, concerns refer to the questions, uncertainties, the composite representation of the feelings, preoccupations, thoughts, and considerations, and possible resistance that teachers may have in response to new situations and/or changing demands (van den Berg & Ros, 1999). Hall et al. (1977) describe concern as "an aroused state of personal feelings and thoughts about a demand as it is perceived" (p.5).

Procedures for Assessing Concerns

Three procedures are, generally, used for assessing concerns of teachers implementing new practices. "These provide a framework from which to understand the personal side of the change process" (George et al., 2006, p.2). The three are: (1) an informal; one-on-one interview with appropriate questions to elicit the concerns and feelings of the respondents. This method is appropriate in individual cases; (2) responding in complete sentences and sufficient detail, to open-ended questions/statements. This is a more formal approach, appropriate for groups (Newlove & Hall, 1976); and (3) responding to the Stages of Concern Questionnaire. Again, this is a formal approach, suitable for groups of teachers. There are several strengths of the SoCQ approach. It identifies concerns by quantitative scores for each stage, eliminating the need for inferring concerns from verbal or written statements. It can be used to provide a pattern of concerns. Pattern of concerns for individuals can be compared. By administering the SoCQ several times to a person, the changes in the pattern of concerns can be recorded. In this study, a SoCQ will be used to determine the concerns of teachers as they implement the reform-based methods and depth of content experienced in the MCE program in their classrooms, for all the strengths, except the last one, stated above.

Three SoCQs will be considered for the purpose, with their prominent features, method of analysis, available instrument statistics, and pros and cons of using each. A rational will be provided for the chosen instrument and its characteristics and method of analysis will be described in detail.

Van den Berg's SoCQ - The Dutch Model

Based on research done in the Netherlands, Belgium and other European countries, van den Berg's team revised Hall's SoCQ (Hall et al., 1979; van den Berg & Ros, 1999; van den Berg and Sleegers, 1995; van den Berg, Sleegers, & Geijsel, 2001).

There are seven distinct stages of concern in this model: (1) Awareness; (2) personal concern/need for information; (3) consequences for pupils; (4) management; (5) collaboration; (6) refocusing on the basis of experiences with pupils; and (7) refocusing.

Awareness (7): Teacher knows very little about the innovation, or has little/no interest in it.

Personal Concern/Need for Information (12): The teacher is interested in the changes that may occur in his/her personal work, would like the opportunity to study and discuss about the innovation.

Consequences for Pupils (5): The teacher would like some indication of the value and necessity of innovation for his/her students.

Management (10): The teacher's attention is focused on daily tasks, and solving practical problems arising regularly.

Collaboration (8): The teacher is concerned with collaboration with colleagues to better implement the innovation.

Refocusing on the Basis of Experiences with Pupils (5): Teacher is geared towards revising the innovation based on students' reactions and assessments.

Refocusing (5): The teacher sees clear alternatives to the innovation and would like to replace it, when necessary.

These stages are clustered around three dimensions, Self-concern (Awareness, Personal Concern/Need for Information, and Consequences for Pupils), Task concern (Management), and Other concern (Collaboration, Refocusing on the Basis of Experiences with Pupils, and Refocusing). There are 52 items in this SoCQ, with a Likert-type response on an 8 point scale (0-7). The number of items to assess each stage is different. The number of items for each stage is indicated beside the stage headings above, i.e., there are 7 items pertaining to the Awareness stage. Inclusion in a scale was done on the basis of the item (statement) loading highest on that factor and some degree of correspondence between the interpretation of the factor and the meaning of the particular scale. Additionally, the questionnaire asked for the demographic information from the participants. The SoCQ was administered to K-12 teachers involved with implementation of innovations. Based on the factor analysis of this data, internal consistency of the scales was developed by calculating Cronbach's alpha coefficient. These ranged from .55 to .95 and the results were very similar with 4 other studies using this SoCQ. These studies have shown this SoCQ to be a reliable and valid instrument (van den Berg, 1993; van den Berg & Sleegers, 1995).

Depending on the research questions to be answered, the method of data analysis varies. The first method requires summing the scores of items pertaining to a stage, converting this number to a percentile and plotting the percentiles of all the stages to obtain a profile of the stages of concern. The next method requires using ANOVA or MANOVA to compare the questionnaire data for various groups and find if the results were significant.

Although this is the most detailed of the 3 SoCQs examined with 52 items spread over 7 stages to explore the concerns of teachers implementing an innovation, it was not used in the this study due to the following reasons: (1) The construct validity of data from the SoCQ was not examined by confirmatory factor analysis (Cheung, Hattie, & Ng, 2001); (2) While preserving the construct of teacher change progressing through a developmental series of concerns, the model suggests that the nature and sequence of concerns is less universal than implied originally (Anderson, 1997); (3) There is no literature about its use in studies conducted in the United States. It has been used in some western European, mainly Scandinavian, countries therefore it may suffer from cultural bias. The original instrument is in Dutch, with English translation available; (4) It has been used for some very large studies, none as small as this one, hence data on its versatility is not available, and (5) some of the statements in the questionnaire are too specific and may not apply to this study.

Cheung's SoCQ - The Hong Kong Model

Cheung used Hall's (1979) SoCQ to collect data on the teacher concerns when a large scale curriculum innovation was implemented in Hong Kong. As a result of exploratory factor analysis of this data, only 22-items were retained clustered around five stages of concern. The alphas of the five stages ranged from .75 to .84 (Cheung, Hattie, & Ng, 2001). Two years later, using data from the introduction of a high level chemistry course in secondary school, this SoCQ evolved to the present 25-item questionnaire, clustered around 5 stages with different labels. These are: (1) evaluation; (2) information; (3) management; (4) consequence; and (5) refocusing (Cheung and Yip, 2003).

Evaluation (5): The teacher feels uncertain about the worth, fairness and feasibility of the innovation.

Information (5): The teachers concerns focus on rationale, requirements of use, and moderation mechanism, as well as the type of support and his/her role in the innovation.

Management (5): In this stage, the concerns are about the tasks and process involved in implementation, efficiency, and time demands for planning assessment tasks.

Consequence (5): The teachers are concerned about the impact of the innovation on student learning and are eager to cooperate with other teachers for greater effectiveness.

Refocusing (5): The teachers are keen on refining the strategies learned during implementation and explore, institute alternatives.

Consisting of 25 items only clustered around 5 categories, this is the most economical questionnaire examined in this study that captures the essential information. The items are randomly arranged and an 8 point Likert-type response format is used (scale of 0-7). All the items were in Chinese originally, however, English translation is available. Reliability tests of items show that the total correlations ranged from 0.4 to 0.7. Further confirmation on reliability is provided by the Cronbach's alphas of the five subscales, that ranged from 0.68 to 0.84. Data were analyzed through various quantitative methods to suit the research question. As for the earlier model, the hypothesized sequence of the five SoC constructs is not evidenced. Therefore the five stages need to be regarded as 5 categories, rather than sequential stages of concern (Cheung & Yip, 2004). The psychometric properties of this SoCQ were explored most thoroughly of the three instruments considered here. Using this questionnaire, the peak concerns of science teachers in Hong Kong were identified as they implemented school-based science curricula and professional development to address their needs was provided (Cheung, 2005).

This questionnaire was not used in the present study for the following reasons: (1) Although this SoCQ was used to examine the concerns of teachers involved in one of the largest curriculum change efforts in Biology and Chemistry in Hong Kong, it has not been tested on a variety of sample sizes for its feasibility of use in a small sample as is the case in this research study; (2) There may be possible cultural biases in the questionnaire that have not been explored, limiting its use to Southeast Asia; (3) and by the authors' own admission, the SoCQ may be innovation specific and needs to be tried in a variety of situations to improve its versatility (Cheung, 2002; Cheung, Hattie, & Ng, 2001).

Hall's SoCQ

Hall's SoCQ is one of the tools of the Concerns Based Adoption Model (Hall & Hord, 1987; Hall & Loucks, 1978, 1979). The concept of Stages of Concern was based on the work of Fuller (1969), who studied the concerns of teachers as they implemented a curricular innovation. Early researchers hypothesized the developmental characteristic of the concerns and delineated their 7 stages (Hall, Wallace, & Dossett, 1973). These were later modified and named: (0) Awareness, (1) Informational, (2) Personal, (3) management, (4) Consequence, (5) Collaboration, and (6) Refocusing (Hall et al., 1979).

Awareness (5): The teacher expresses little concern or involvement with the innovation.

Informational (5): The teacher expresses interest in learning about the general characteristics, effects and requirements for use.

Personal (5): The teacher is uncertain about the demands of the innovation, his/her ability to fulfill them, and his/her role with it. Some additional concerns may be about his/her role in decision making, conflicts with existing structures, and other commitments.

Management (5): The teacher is focused on tasks and processes of using the innovation, such as efficient use and management of resources, schedule, organizational features etc.

Consequence (5): The teacher is concerned about the relevance and impact of the innovation on his/her students, evaluation of students' competencies, and the changes needed to improve student outcomes.

Collaboration (5): The teacher is focused on coordinating and cooperating with others regarding the use of innovation.

Refocusing (5): The teacher explores ways to improvise the innovation to benefit all, by making changes/replacements/introducing alternatives etc.

These stages are grouped in to three dimensions: (1) self; (2) task; and (3) impact. Self concerns include the stages of awareness, informational, and personal. Task concerns include the management stage, and impact concerns include the stages of consequence, collaboration, and refocusing. These stages of concern are distinctive but not mutually exclusive. A teacher may have concerns at all the stages simultaneously with varying intensities.

The questionnaire has 35 items, 5 items per stage, that are distributed randomly in the questionnaire. The response format is a 0-7 point Likert-type scale.

Validity of SoCQ was established by examining how the scores on the seven stages related to one another and to other variables suggested by concerns theory (Cronbach, & Meehl, 1955). Several methods, such as intercorrelation matrices, judgments of concerns based on interview data, and confirmation of expected group differences and changes over time, were used to establish the validity of SoCQ scores. The internal consistency for each of the seven stages of concern as measured by Cronbach's alpha ranged from 0.64 to 0.83 (Hall, George, & Rutherford, 1979).

Hall's SoCQ, with the addition of 3 open-ended questions at the end of the 35 items (Appendix F), was the instrument used in the present research to examine the concerns of chemistry teachers as they implement the depth of conceptual understanding and practices experienced in the MCE program, in their high school classrooms. This instrument was chosen for the following reasons:

(1) Although the 2 instruments mentioned above have some desirable characteristics regarding internal consistency data and the number of items to respond to, they have been used on a small number and variety of samples. Hall's SoCQ has been the most widely used instrument for measuring teachers' concerns for 30 years. Its validity and reliability have been established through application to a vastly greater variety of contexts and sample sizes.

(2) The ease of using, scoring, and displaying the data. Data can be displayed either graphically or through a variety of tables.

(3) Availability of a thorough, well developed literature on the interpretation of data.

Using and Scoring the SoCQ

The SoCQ has 4 parts: (1) the cover letter; (2) the introductory page; (3) thirty-five statements on two pages with numbers 0-7 beside each statement; and (4) the last page with 3 open-ended questions (see Appendix F).

Classroom Observation Instrument

Introduction

In recent times many groups have focused on what reform-based classroom practices in math and science education entail (AAAS, 1990, 1993; Adamson, Banks, Burtch, Cox III, Judson, Turley, Benford, & Lawson, 2003;Aldridge, 1989; Grouws & Schultz, 1996; National Committee on Science Education Standards and Assessment, 1992; National Council of Teachers of Mathematics, 1989, 1991; National Research Council [NRC], 1996, 2000).

Reform-based (also referred to as standards-based) practices emphasize a constructivist view of learning and teaching such as supporting inquiry and problem solving, engaging students in their own learning, encouraging discourse among students, emphasizing conceptual understanding of content, and connecting the content to real life situations etc. (Morrell, Flick, & Wainwright, 2004)

However, these documents are silent on *how* these practices manifest themselves in terms of observable teaching and learning behaviors in the classroom. There are no agreed upon classroom teaching and learning behaviors that represent or exemplify the standards espoused in these documents. This leaves the subject of standards-based practices to multiple interpretations, e.g, engaging students in inquiry can be associated with a number of different activities or combinations of activities. The challenge of designing reform-based classroom observation instruments is, then, to distil the intent of the standards into a number of associated statements representative of reform-based teaching and learning behaviors (Sawada, Piburn, Judson, Falconer, Turley, Benford, & Bloom, 2002; Wainwright, Flick, & Morrell, 2003).

Classroom Observation Instrument as an Evaluation Tool

The most common approach to evaluating the implementation of reform-based instructional practices in science classrooms is the use of an observation instrument (also referred to as a protocol). In essence, an observation instrument requires a trained observer to rate the happenings in a classroom during a lesson as they complete items regarding the methods utilized for instruction, content of the lesson, and the prevalent classroom culture. The observers respond to a set of statements representative of reform-based practices by indicating the degree to which the elements of the lesson matched the statements. All the protocols described below were adapted from, or derived from, or were influenced by the Horizon Research Inc.'s Local Systemic Change (LSC) Classroom Observation Protocol and measure the construct 'reform-based (standards-based) classroom practices of math and science teachers' (HRI, 1999, 2000, 2005). The instruments were developed primarily for two reasons: (1) to evaluate the implementation of (standards-based) LSC programs; and (2) to improve reform-based teaching in undergraduate teacher preparation courses. Some commonly used classroom observation instruments are now described.

Horizon Research's Local Systemic Change (LSC) Classroom Observation Protocol (1997, 2000, & 2005)

This instrument consists of a composite of sub-categories which include lesson design, implementation, math/science content, and classroom culture. Seven to ten statements, illustrative of reform-based practices, are organized under each of the sub-categories. The observer rates the statements based on a seven point Likert scale, ranging from 'not at all' to 'to a great extent'. Observer also gives an overall rating to the categories, the lesson, and combines these ratings with post observation teacher interview to derive a composite picture of the lesson. The face validity of the instrument was established through several iterations of review and revision by a group of sixty math and science educators, till a broad agreement on item content as well as integrity and completeness of the protocol was reached. Ninety two percent of a trained group of observers rated a set of videotaped lessons within one point of the norming group's rating key (HRI, 2000), which attests to a high degree of interrater reliability of the instrument.

CETP-Core Evaluation Classroom Observation Protocol (CETP-COP) (2001)

In this instrument the observer provides a rating for twelve statements illustrative of reform-based practices, on a seven point Likert scale, ranging from 'not applicable' to 'to a great extent'. Additionally, the observer is required to keep a record of the type of instruction, student engagement, and cognitive activity at 5-minute intervals using an extensive coding system. Field notes, pre and post observation teacher interviews, as well as results of a student survey feed into creating a total picture of the lesson and its evaluation. To ensure the face validity of the instrument, items were chosen from a variety of sources and reviewed by external experts, pilot tested and revised. Reliability was ensured by a thorough training and communication with other observers leading to reconciliation (Lawrenz, Huffman, Appeldoorn, & Sun, 2001; SSI, 2000).

In addition to the features mentioned above, this instrument utilizes a checklist, a pre-observation teacher interview, student input, and recording of the status of the type of activity, student cognitive activity, and engagement every five minutes to evaluate the extent of reform-based practices implemented in the class.

OCEPT Classroom Observation Protocol (O-TOP) (2001)

In this instrument, the observer responds to ten statements, each on a five point Likert scale ranging from 1 to 5 based on a 'not observed/observed frequently/very frequent' response format. Each statement focuses on a reform-based practice with examples of teacher/student behaviors illustrative of the practice. These responses, in conjunction with the field notes and teacher interview generate a descriptive profile of the happenings in the classroom, whose rating determines the degree of alignment of the lesson with reform-based practices. To achieve face validity of the instrument, it was examined, discussed, and revised by a team of six researchers. Interrater reliability was established among seven observers of a videotaped lesson and was found to be 100% on most of the statements (Wainwright, Flick, & Morrell, 2003).

Reformed Teaching Observation Protocol (RTOP) (2000)

RTOP was developed as an observation instrument to provide a standardized means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed (MacIssac & Falconer, 2002; Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000). The observer responds to twenty-five statements, clustered around three domains: (1) lesson design and implementation (5 items); (2) content (10 items); and (3) classroom culture (10 items). The response format is a five point Likert-type scale ranging from 0 to 4, encompassing 'never occurred' to 'very descriptive'. The sum of all the scores on the 25 items produces the overall score, which, in turn, determines the degree of lesson's alignment with reform-based practices. A high value exemplifies a lesson utilizing standards-based practices to a great degree.

The scores on the statements in each domain are added to produce a domain score. Maximum possible scores in the lesson design and implementation, content, and classroom culture domains are 20, 40, and 40 respectively.

Of the currently available observation instruments, RTOP is the only one that satisfies all of the following criteria (MacIssac, Sawada, & Falconer, 2001):

> 1) Focused on math and science; 2) aimed at classroom K-20; 3) focused exclusively on reform rather than general characteristics such as classroom management, lesson closure etc.; 4) brief to administer; 5) very high interrater reliability; 6) factor analyzed for construct validity; 7) proven predictive validity; and 8) readily available training and reference manuals. (p. 1)

RTOP (Appendix G) is also the instrument used by MCE program to evaluate the alignment of teaching practices of its instructors with reform-based practices. Therefore, it was used to evaluate the extent to which the teachers in this study were implementing reform-based practices emphasized in the MCE program, in their own classrooms.

Chapter Summary

The purpose of this chapter was to examine the literature related to the present research. First, the literature was reviewed to ascertain the characteristics of traditional and research-based classroom practices in the domains of lesson design and implementation, content, and classroom culture (Sawada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002).

In the traditional classroom practice, little consideration is given to the exploration of students' preconceptions and their active engagement. Science is delivered to students as facts with heavy reliance on textbooks, emphasis on memorization/ coverage of material rather than on understanding, and it is dominated by teacher talk rather than communication for understanding among students and the teacher (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Fosnot, 1996; Lampert & Ball, 1995; Tobin & McRobbie, 1996; Weiss, 1997). On the other hand, research-based practices lay emphasis on examining students' ideas and address these in a variety of ways with a view to building scientific understanding of concepts, explore student generated questions, content and skills are geared towards developing depth of understanding of the subject, connections are made to other disciplines and to the real world, and students are allowed to actively interact, collaborate, and communicate with each other and in investigating their ideas (AAAS, 1990; Alexopoulou & Driver, 1996; Borko & Putnam, 1995; Bransford, Brown, & Cocking, 2000; Brooks & Brooks, 1993; NRC, 1996; Pearsall, Skipper, & Mintzes, 1997; Trowbridge, Bybee, & Powell, 2000). Then, a rationale for switching to research-based practices is presented, with key findings drawn from two streams of recent research. These are; psychological aspects of learning, e.g., the works of Piaget, Ausubel, Vygotsky and Bruner etc., and how the brain functions (Alexander & Murphy, 1998; DeBoer, 1991; Donovan & Bransford, 2005; Lambert & McCombs, 1998; Michael, 2006). The constructivist approach to learning undergirds these findings. Therefore, constructivism is the theory underlying this study and is considered next.

The section on constructivism begins with a very brief historical account to underscore the point that the idea has been around for millennia, although it has gained currency lately with strong support from research. According to this theory, knowledge is constructed in the mind of the learner rather than transmitted by an outside agent (Bodner, 1986; Eisner, 1993). "Meaning is not given to us in our encounters, but it is given by us, constructed by us, each in our own way, according to how our understanding is currently organized" (Duckworth, 1987, p. 112). A variety of shades of constructivism is found in literature, with some common themes. Three of these varieties, the theories of Piaget, von Glasersfeld, and Vygotsky are considered and elaborated upon with respect to epistemology, role of the teacher, and the role of the learner.

Piaget's cognitive constructivism has a stage dependent part, the four stages of cognitive development that humans go through (sensorimotor, preoperational, concrete operations, and formal operations), and a stage independent part consisting of the processes of organization and adaptation and their resolution through the process of equilibration utilizing the mechanisms of assimilation and accommodation. The most important role of the teacher is to organize the environment to facilitate learning (Brainerd, 1978; Rieber, 1995). The most important role of the student is to actively participate in the activities organized by the teacher, reflect, ask questions, offer explanations, communicate with peers and the teacher to promote understanding, and be metacognitive (Jakubowski, 1995).

Von Glasersfeld's radical constructivism maintains that the constructed knowledge is different from the reality, which is not knowable in our experiential world. What is important about the constructed knowledge is its viability, given the constraints of the experience. There may be many viable constructions that fit an experience, with none matching it, just as many keys can open a lock, with none matching the lock (Bettencourt, 1995, Bodner, 1986; von Glasersfeld, 1992). The teacher's role is to act as a guide, co-ordinator, facilitator, resource advisor, tutor or coach. Here also, the students are regarded as responsible 'sense makers' (Gergen, 1995; Mayer, 1996, von Glasersfeld, 1996).

The fundamental difference between Vygotsky's sociocultural theory and those of Piaget and von Glasersfeld is that the unit of analysis is not the individual, rather, it is the sociocultural activity of which the individual is a part (Rogoff, 1990). Two important concepts in Vygotsky's epistemology are the development of higher (uniquely human) mental processes and the zone of proximal development (zpd). The uniquely human higher psychological functions differ from the psychological processes of animals by virtue of their cultural mediation (Cole, 1990). Human cognition is the transformation from the lower processes to the higher psychological functions mediated by more mature members of the society via the tools, signs and symbols of culture. Through the active agency of the student and the intersocial interactions, the methods, processes, representations, and tools of the culture are appropriated, uniquely transformed and ultimately internalized by the student (Davydov & Kerr, 1995; Kozulin, 1990; Moll, 1990; Wertsch, 1985, 1990). Development of scientific concepts in children from the concepts based on their everyday experiences, mediated by competent teachers, using language, symbols, representations, instruments, and equipments, is an example of the development of higher psychological functions, hence human cognition (Vygotsky, 1987). Children's cognitive development can be potentially advanced in the zpd (Gillani

& Relan 1997). ZPD is the “distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). The role of the teacher is to facilitate the movement of the student across the zpd, often using an instructional technique called scaffolding. Scaffolds are the supports/interventions teachers use in their teaching. As the student becomes progressively more independent, the scaffolds are slowly withdrawn (Hammond, 2002; Mercer, 1995). The role of the students is to participate collaboratively with the teacher and peers, be reflective, engage in dialog and discourse (Finkel & Monk, 1983; Mercer, 2000; Whipple, 1987), and take increasing responsibility for their learning (Rogoff & Gardner, 1984; Wertsch, McNamee, McLane, & Budwig, 1980).

Both, Vygotsky’s sociocultural theory and research-based classroom practices, emphasize exploration of students’ preconceptions and the teachers’ facilitation towards transforming these into scientific concepts, probing deeper and connecting with other disciplines, and the important role of a variety of classroom interactions in building the understanding of concepts. Due to this alignment of the salient features of the two, Vygotsky’s theory is the theoretical perspective chosen to inform this study.

In this research, adults participate in a professional development program to learn the research-based practices and then implement these in their classrooms. Therefore, the next section sheds light on the characteristics of adult learning, beginning with a brief historical introduction. This is followed by a description of four of the theories of adult learning found in the literature; McCluskey’s Theory of Margin, Illeris’s Three Dimensional Learning Model, Jarvis’s Learning Process, and Knowles’ Andragogy. Due to a paucity of research, the first three theories are rejected. Knowles' Andragogy is a learner centered process model of adult learning (as opposed to pedagogy, the teacher centered practices) that emphasizes the learners' prior knowledge/experience, desire/motivation to learn, and the "procedures and resources for helping learners acquire information and skills" (Knowles et al., 2005, p. 115), similar to the research-based classroom practices. Six assumptions are at the core of Knowles' model of Andragogy, flexibly applied to situations by taking into account contextual factors, such as individual differences and the goals and purposes of learning (Henschke, 1998; Hiemstra, 1993; Knowles, 1980a; Knowles, Holton, & Swanson, 2005; Merriam & Caffarella, 1999; Reischman, 2000; Savicevic, 1999; Schugurensky, 2005; Zmeyov, 1998).

The six assumptions of Andragogy are: (1) The learner's need to know- The primary need that drives the adults to enroll in programs (such as the MCE). Educators can tap into this need by collaborating with the adult learners in designing their learning (Knowles et.al, 2005);

(2) Self-directed Learning-Adults take the ownership of their learning. Therefore, working in their zones of proximal development will lead to the teachers 'becoming independent and self-regulating learners and problem solvers' (Candy, 1991);

(3) Prior experience of learners- The wealth of experiences adults bring with them, needs to be tapped into as scaffolds, to build new learning (Savery & Duffy, 1996).

(4) Readiness to learn- The preparedness and levels of commitment may differ among adults and may need different kinds and amounts of support (Pratt, 1988);

(5) Orientation to learning- Adults prefer a problem-solving orientation to learning as opposed to a subject-centered orientation to learning. They prefer to test their

learning against new experiences and learn further as a result of the interaction (Kolb, 1984); and

(6) Motivation to learn- Adults are more likely to be driven by internal rewards than external, such as learning something of value and enjoyment of learning (Wlodowski, 1985).

The learning undertaken by adults (the teachers) in this study occurs in a 26-month long graduate professional development (MCE) program. Therefore, the next section commences with a definition of professional development as an ongoing process geared towards improving their performance. Then, the needs for professional development are discussed. Some of the needs cited are; improvement in the scientific literacy of the students (as members of the future workforce) as it impacts the economy, increase in students' science test scores, improvement in teacher qualification/preparedness, and promotion of research-based practices (Cavanagh, 2006; Darling-Hammond & Berry, 2006; Darling-Hammond, Berry, Haselkhorn, & Fideler, 1999; Gardner, 1993; Goldhaber & Brewer, 2000; NCTAF, 2007; Schmidt, McKnight, Houang, Wang, Wiley, & Cogan, 2001; Simmons, Emory, Carter, Coker, Finnegan, & Crockett et al. 1999; Singer, Hilton, & Schweingruber, 2005; Sparks & Hirsh, 2000).

A vast majority of traditional programs of professional development are shallow rather than coherent, of brief duration rather than sustained, emphasize skill development rather than depth of understanding, are taught in the traditional manner by 'experts' with teachers as passive recipients, and measure their success by the satisfaction of the recipients (Cohen & Hill, 2000; Collinson, 1996; McDiarmid & Corcoran, 2000; Desimone, 2002; Elmore, 2002; Feiman-Nemser, 1983; Loucks-Horsley, Hewson, Love,

& Stiles, 1998; O'Day & Smith, 1993; Sparks, 1995; Supovitz, 2003). These professional developments are steeped in the traditional practices of "knowledge as facts and skills, teaching as telling, and learning as remembering" (Thomson & Zeuli, 1999, p. 353), resulting, at best, in the teachers tinkering at the fringes of their current knowledge and practice, leaving the bulk of these untouched, with no perceptible change on any meaningful measure affecting classroom practice (Fullan & Steigelbauer,1991; Huberman, 1995; Joyce & Showers, 1988, 1995; Little, 1993; Sparks & Hirsch, 2000). A plethora of research-based suggestions have been proposed to improve the design of the professional development programs to make them more effective. Bulk of this research emphasizes five core principles, all of which resonate with the research-based classroom practices, Vygotsky's sociocultural theory, and the principles of andragogy. These are:

1) New knowledge is built upon one's existing knowledge and skills, 2) reflection on one's thought and behaviors is essential for knowledge growth, 3) it is important to address teachers' beliefs, purposes, contexts of work, and identity issues, 4) learning proceeds through developmental stages, and 5) both social and individual processes impact learning (Alexander & Murphy, 1998; Hawley & Valli, 1999).

Based on a large body of research, Loucks-Horsley et al. (1998) have compiled a list of 7 characteristics of effective professional development programs to promote research-based practices in science education.

1) Using inquiry skills, investigations, and problem solving, 2) providing opportunities for teachers to develop deep content knowledge and pedagogical content knowledge, 3) modeling with teachers the strategies they are expected to use in their classrooms and providing enough time for exploration, collaboration, and reflection, 4)

building a learning community where teachers learn together, 5) supporting teachers to be leaders and change agents, 6) linking and integrating the professional development with other school district initiatives, 7) continuously assessing the impact of professional development on teaching and learning and making changes as needed (Corcoran & Goertz, 1995; Guskey, 1989; Hollingworth, 1989; Little, 1993).

The last part of the section on professional development exposes the readers to some exemplary professional development programs that have made an impact on the classroom practices of its participants.

Cohen & Hill (2000), working with California's mathematics teachers found that sustained professional development situated in the curriculum aligned to standards improved their classroom practice.

Using data from Local Systemic Change initiative, Supovitz & Turner (2000) showed that the teachers who participated in 80 or more hours of research-based practices were strongly inclined to use these practices in their classrooms and this shift occurred significantly for teachers who attended 160 hours of professional development. Some other studies have also reported the impact of sustained, intensive, research-based professional development on the use of these practices in the classroom and improvement in student achievement (Corcoran, McVay, & Riordan, 2003; Garet, Biman, Porter, Desimone, Herman, &Yoon, 1999; Harcombe, 2001; Irving, Dickson, & Keyser, 1999; Radford, 1998; Supovitz, Mayer, & Kahle, 2000).

An important finding of this analysis was that the teachers' content preparation (and beliefs) have a powerful influence on the use of inquiry methods and investigative classroom culture, the cornerstone of research-based methods (Supovitz & Turner, 2000).

The section on professional development concludes with a detailed description of the MCE program, the professional development that the teachers in this study participated in.

The next section explores teachers' knowledge base and beliefs that impact the implementation of research-based practices.

Teachers' knowledge base and practice affect each other reciprocally, and beliefs influence all the decisions teachers make regarding their practice as well as advance or hinder their knowledge base (Carlsen, 1988, 1991, 1999; Gess-Newsome & Lederman, 1995; Gess-Newsome, 1999; Grossman, 1990; Hauselien, Good, & Cummins, 1992; Nespor, 1987; Smith & Neale, 1991; Veal, 2004).

Traditionally, the teachers' knowledge base is developed in teacher preparation programs dealing with either content courses that emphasize vocabulary and facts over depth of content, or methods courses that focus on generic classroom management and teaching strategies. Both the teaching methods and content courses provide teachers with "an array of noncontextualized, unconnected activities, concepts, and demonstrations" (Mason, 1999, p. 277), never achieving an integration and coherence of content and methods required for effective teaching. Several knowledge bases relevant to teaching with research-based methods have been proposed. These are organized into four common domains; 1) general pedagogical knowledge, 2) subject matter knowledge, 3) pedagogical content knowledge, and 4) the knowledge of the teaching context (Carlsen, 1999; Schulman, 1986, 1987; Zeidler, 2002).

1) General pedagogical knowledge is teachers' knowledge of *generic variables* that impact the classroom instruction, independent of the subject matter. Important

among these are, effective classroom management and organization best suited to high level engagement of students and the context, a repertoire of teaching strategies that promote problem solving with a focus on cooperative and productive interactions in the classroom, and a variety of classroom discourse techniques including scaffolding strategies (Brown, 1997; Brown & Campione, 1990, 1994; Everton & Harris, 1992; Evertson, 1997; Gess-Newsome, 1999, p. 32; Joyce, Weil, & Showers, 1992; Kagan, 1992; Morine-Dershimer & Reeve, 1994; Palincsar & Brown, 1984; Tobin, 1990).

2) Subject matter knowledge of a science teacher refers to his/her quantity, quality, and organization of information, conceptualizations, and underlying constructs in the subject and its field of specialization. It consists of five characteristics: 1) a deep conceptual understanding, 2) presence of subject matter structure, 3) knowledge of the nature of discipline, 4) content-specific orientation to teaching, and 5) contextual influences on curricular implementation (Gess-Newsome, 1999; Green, 1990; Grossman, 1990; Hashweh, 1996; Hiebert & Carpenter, 1992; Lederman, & Latz, 1995; Talbert, McLaughlin & Rowan, 1993).

3) Pedagogical content knowledge is best expressed in the words of Schulman (1987) as the “special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding” (p. 8). It represents a science teacher’s ability to present the subject matter through representations, analogies, illustrations, examples, explanations, and demonstrations etc., so that it is comprehensible to the students. Good execution of PCK allows the students the opportunity to construct meaning from symbols and images and see the underlying relationships among ideas much like the experts (Kennedy, 1997, 1998; Shulman, 1986; Zeidler, 2002). A teacher’s

pedagogical content knowledge should typically include a taxonomy of this knowledge pertaining to the subject (science), the field of study (chemistry), and the topics (e.g. stoichiometry) within the field (Veal & MaKinster, 1999).

4) Beliefs, variously described as teachers' attitudes, values, perceptions, dispositions, internal mental processes, action strategies, and action principles etc. powerfully influence teachers' actions in the classroom (Pajares, 1992; Tobin, Tippins, & Gallard, 1994). Beliefs that enable the teachers to meet their goals, guide their actions (Tobin & McRobbie, 1996). Reciprocally, actions influence beliefs (Gess-Newsome & Lederman, 1995).

In classroom practice, the distinction between teachers' knowledge and belief is blurred (Bullough & Baughman, 1997; Grossman, 1990). To change the teachers' classroom practices from traditional to research-based approaches, their knowledge and beliefs must be challenged, supported by opportunities to examine, reflect upon, provide feedback, elaborate, and integrate (Borko & Putnam, 1996; Cohen & Ball, 1990). Beliefs pertaining to classroom practices are colored through the lenses of contextual, sociocultural, and institutional factors (Palmeri, 1995; Roth & Roychoudhari, 1994; Tobin et al., 1990). Therefore, the next section will elaborate on the context of practice, the urban science classroom.

The urban schools consist of a highly diverse population, with a high percentage of children from the lowest rungs of socioeconomic stratum, such as minorities, immigrants, English language learners, and poor. Some of the problems plaguing the urban schools are, inadequacy of resources, high rates of truancy and student mobility, low rates of graduation, underqualified teachers, and low achievement of students compared to their suburban counterparts (Fraser-Abder, Atwater, & Lee, 2006; Clewell et al., 1995; Darling-Hammond, 1999b; Kozol, 1991; Linden, 1995; Miles & Darling-Hammond, 1998; Tobin, Seiler, & Walls, 1999; Waxman & Padron, 1995).

In addition to the above mentioned factors, the requirement to follow the scripted district mandated curriculum, without adequate opportunity to learn via inquiry/ investigative methods hinders the implementation of research-based practices in urban classrooms (Knapp & Plecki, 2001). Some other impediments to the implementation of these practices are the frequent district (Benchmark) and federally (NCLB) mandated testing of students with a large amount of time spent in preparing for the tests, as well as the entrenched classroom practices, such as frequent use of worksheet, asking questions that primarily require information recall, repetitiously teaching low-level skills etc., characterized as the 'pedagogy of poverty' (Haberman, 1991).

A serious problem for science education of urban youth is their strongly negative attitude towards the subject as it is taught in urban classrooms (Atwater, Wiggins, & Gardner, 1995; Ayers & Price, 1985; Basu & Barton, 2007). Some of the causes underlying the negative attitude are identified as; the disconnect between the cultures of students' communities and the science classrooms, the marginalization of minorities in the science classroom through exclusionary teaching practices, and students' inability to identify with the stereotypical images of the practitioners of the subject (Boullion & Gomez, 2001; Brickhouse, 1994; Brickhouse et al., 2000; Carspecken & Apple, 1992; Fraser-Abder, 2001; Fusco, 2001).

To engage the urban students in science education, it is suggested that the definition of science be broadened to include the 'funds of knowledge' from other cultures, teachers become facilitators of communication among students from different cultures and 'western' science, students be given opportunities to contribute to science knowledge rather than just be its recipients, and that the teachers be reflective of their practice and reshape classroom discourse through cogenerative dialog with their students (Aikenhead, 1997, 2006; Norman et al. 2001; Seiler, Tobin, & Sokolic, 2001; Tobin, 2000; Tobin, Elmesky, & Seiler, 2005; Tobin, Seiler, & Walls, 1999).

In the urban environment, the teachers in the study plan to implement the changes in their classroom practices, to which they were exposed to in the intensive professional development (MCE) program. This study utilizes the following assumptions about change. Change is a highly personal experience, accomplished by individuals, and is a developmental process, not an event. Additionally, change is best understood by addressing the concerns of the teachers implementing the change (Hord, Rutherford, Huling-Austin, & Hall, 2006). Several barriers may hinder its implementation or result in its inadequate implementation. These barriers are teachers' resistance, attitudes, beliefs, concerns about students' engagement and performance, norms of collegiality and experimentation, instructional coordination etc. (Duffy & Roehler, 1986; McLaughlin, 1987; Rosenholtz, Bassler, & Hoover-Dempsey, 1986). The meaning realized by the teachers as they implement change is expressed by their thoughts, questions, uncertainties, feelings, etc., collectively referred to as teacher concerns (Hall et al., 1977, 1979; van den Berg & Ros, 1999).

Literature mentions three ways of assessing the concerns of practitioners. These are; conducting a one-on-one interview, responding to open-ended questions, and responding to the questions on the Stages of Concern Questionnaire (SoCQ). In this study, the SoCQ will be used for its ease of use and the quantitative data yield. Three SoCQs were considered for this study. These were; Van den Berg's, Cheung's , and Hall's. The first two instruments were not suitable, since they were not used in the US and not used in a small case study such as this study (Cheung, Hattie, & Ng, 2001; van den Berg & Ros, 1999; van den Berg & Sleegers, 1995; van den Berg, Sleegers, & Geijsel, 2001). The instrument of choice was Hall's SoCQ, for its extensive use in a variety of studies and easy availability in the U.S. It has 35 items, divided equally among 7 stages of concern, with a response format of 0-7 on a Likert type scale. Three open-ended items were added to the SoCQ to gauge the specific concerns of teachers as they implemented the program. The 7 developmental stages of concern are; 1) awareness-teacher is not involved with implementing the research-based practices, 2) informational-teacher seeks more information about it, 3) Personal-teacher concerns are about the ability to handle the responsibility, his/her role in implementation, 4) management-teacher is preoccupied with the tasks, processes, management of resources, schedule, organization etc., 5) consequence-teacher is concerned about its relevance, impact on student skill level, and achievement, 6) collaboration-teacher is interested in cooperating and collaborating with other teachers, 7) refocusing- teacher explores ways to improve the innovation by making changes, replacements, and suggesting alternatives (Hall, Wallace, & Dossett, 1973).

The internal consistency for each of the seven stages of concern, as measured by Cronbach's alpha, ranged from 0.64 to 0.83 (Hall, George, & Rutherford, 1977, 1979).

Both the standards documents in science education, NSES and Benchmarks for Science Literacy delineate the characteristics of constructivist, research-based 'reform' practices to be followed in the classroom (AAAS, 1990, 1993; Adamson, Banks, Burtch, Cox III, Judson, Turley, Benford, & Lawson, 2003; Aldridge, 1989; Grouws & Schultz, 1996; National Committee on Science Education Standards and Assessment, 1992; National Research Council [NRC], 1996, 2000).

Horizon Research's Local Systemic Change Classroom Observation Protocol was the first classroom observation instrument to *operationalize* these characteristics in to observable teaching and learning behaviors to rate a classroom for the occurrence of constructivist, research- based practices by distilling the intent of the standards into a number of associated statements. Four reform-based classroom observation protocols were considered in this study. These were: 1) Horizon Research's Local Systemic Change (LSC) Classroom Observation Protocol (HRI, 1997, 1999, 2000, & 2005), 2) CETP-Core Evaluation Classroom Observation Protocol (CETP-COP) (SSI, 2000), 3) OCEPT Classroom Observation Protocol (O-TOP) (Wainwright, Flick, & Morrell, 2003), and 4) Reformed Teaching Observation Protocol (RTOP) (Judson & Sawada, 2001).

The RTOP was chosen for use in this study due to reliable statistics, readily available online training, and its use by the MCE program to evaluate its instructors (MacIssac, Sawada, & Falconer, 2001). There are 25 statements in the protocol, with 5 statements in the lesson design and implementation domain, and 10 each in the domains of content and classroom culture. The response format is a five point Likert-type scale ranging from 0 to 4, ('never occurred' to 'very descriptive'). One can find domain scores for lesson design and implementation, content, and classroom culture, as well as the overall score that determines the degree of lesson's alignment with research-based 'reform' practices.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

Overview

This chapter describes the research design and the qualitative and quantitative research methodologies employed in this study. The unit of analysis, rationale and details of the research design (including methods of data collection and analyses), issues of verification, and validity constitute the other important sections of the chapter.

This study focused on how the chemistry teachers in the School District of Philadelphia (SDP), who graduated from the MCE program, implemented its practices as a group in their classrooms, and how the implementation of these practices differed among the teachers. This study also probed the concerns the teachers had regarding the factors that promoted and inhibited its implementation.

As described in Chapter 2, MCE program is a 26-month long, content intensive professional development program for in-service teachers. Its goal is to improve the teacher participants' knowledge of chemistry and research-based instructional practices. The teachers in this study have graduated from the program for 1-6 years.

In this study the examination of classroom practices of teachers was confined to the three domains of 'lesson design and implementation', 'content', and 'classroom culture' consisting of communicative interactions and student/teacher relationships (Sawada et. al, 2002).

For the purpose of this study, the construct classroom practices was defined as research-based teaching practices modeled in the MCE program (henceforth referred to as MCE program practices, or just practices), consonant with the recommendations of National Science Education Standards (NRC, 1996). Teaching practices included the following; active student engagement, probing student preconceptions, encouraging the students to seek alternate solutions, promoting deep conceptual understanding, connecting with other disciplines and the real world, promoting a variety of representations of the phenomena, predicting outcomes and devising plans to test them, students discussing and communicating their ideas, encouraging divergent thinking, encouraging interpretation of evidence, and the teacher acting as a facilitator and resource person etc. (see Appendix A for a complete list).

To explore the phenomenon and derive an understanding of the implementation of research-based teaching practices, the teachers were administered a concerns survey first. Then the researcher observed three chemistry classes of each of the six teacher participants in this study over a period of 12-15 weeks. Teacher generated lesson plans (See Appendix H for a sample) and handouts, if any, were collected on the days of observation. At the end of this duration, the teachers completed a survey and were interviewed individually. These sources provided quantitative, qualitative, and both quantitative and qualitative data to answer the research questions.

Research Questions

This study answered the following research questions.

Question 1

How does graduation from a twenty-six month content intensive professional development program for high school teachers, whose goal is to improve the teachers' knowledge of research-based instructional practices (in the domains of lesson design and implementation, content, and classroom culture), affect the classroom practices of the group of teachers in an urban environment?

Three contributory questions assisted in answering this research question.

Contributory Question 1a

To what extent do the group's lesson design and implementation reflect the research-based instructional practices?

Contributory Question 1b

To what extent are the group's content knowledge and application of supportive procedures exhibited during their classroom instruction?

Contributory Question 1c

To what extent does the group of teachers promote a student-centered classroom culture, consistent with the research-based practices?

Question 2

How are the teachers' classroom practices (in the domains of lesson design and implementation, content, and classroom culture) different from each other when implementing the research-based MCE program practices?

Three contributory questions assisted in answering this research question.

Contributory Question 2a

To what extent are the teachers' designed and implemented lesson plans different from each other when implementing the practices?

Contributory Question 2b

To what extent are the teachers' content knowledge and application of supportive procedures exhibited during their classroom instruction different from each other?

Contributory Question 2c

To what extent is the teachers' promotion of a student-centered classroom culture different from each other, consistent with the research-based practices?

Question 3

What concerns do teachers express as factors that enable the implementation of the MCE program practices in their classrooms?

Question 4

What concerns do teachers express as the factors that hinder the implementation of the MCE program practices in their classrooms?

Rationale for a Multi-site Exploratory Case Study Research Design

There are many characteristics of a case study design that apply to this study. According to Yin (2003), "In general, (exploratory) case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over the events, and when the focus is on a contemporary phenomenon within some real-life context" (p. 1) or "a case study is an empirical inquiry that investigates a contemporary phenomenon, within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13). The primary question explored in this investigation was, *how* does graduation from the MCE program, that stressed the conceptual understanding of content and modeled research-based practices, affect the group of teachers' own classroom practices? The investigator had no control over any event pertaining either to the professional development of the teachers or their classroom practices. It is a real life phenomenon, currently taking place in the SDP.

As Yin (2003) proffers, "the case study's unique strength is its ability to deal with a full variety of evidence-documents, artifacts, interviews, and observations" (p. 8). In this study the sources of data included questionnaire, survey, observation, interview, and teacher generated lesson plans. All of these sources strongly support the case study design. Since the primary purpose of this research was to inquire into how the group of teachers implemented the practices (modeled in the MCE program) in their classrooms, how these practices differed among the teachers, and the factors that enabled and inhibited their implementation, it is an exploratory study. In this process, the researcher heard stories, described happenings, acquired insights, and interpreted the findings in an attempt to deepen her understanding of individual meaning (Patton, 1990). Since these can only be realized in context (Creswell, 1998; Ritchie, 2003), the researcher immersed herself in the classroom environment of the teachers (Kelly & Lesh, 2000), and asked many questions to elicit rich descriptions of the teachers' milieu (Cline & Mandinach, 2000). Wolcott (1992) describes a case study as an "end-product of field-oriented research" (p. 21). The immersion of the researcher in the field of the classroom yielded data whose findings were used to produce a "thick rich" description (Geertz, 1973, p. 420) and answer the research questions. Thus this study fits both the process and product definitions of a case study.

Case studies reveal "understanding of humans as they engage in action and interactions within the contexts of situations and settings" (Collins & Noblit, 1978, p.

160). This researcher administered a concerns questionnaire to the teachers whose sole purpose was to ascertain the concerns, reactions, feelings, and thoughts of the teachers in this study regarding the implementation of the practices in their classes.

The quintessential defining characteristic of the case study is the case, the unit of study and its being an inherently bounded system (Smith, 1978). Stake (1995) describes the case as "an integrated system" (p.2). For Merriam (1998) it is something that can be "fence(d) in" (p. 27). Miles and Huberman (1994) posit that "the case is a phenomenon of some sort occurring in a bounded context" (p. 25). In this study, the unit of study was the group of six teachers who graduated from the MCE program and were teaching Chemistry in the SDP. The two common factors that united this group of teachers and bound them together with one thread were; their graduation from the MCE program and their current assignment as teachers of chemistry in the SDP. This study was temporally (all the participants were currently teaching), spatially (although spread over many schools, all the teachers worked in the same school district), and most importantly, conditionally (all satisfied the same two conditions of participation) bound. Since the teachers were working in different schools, it made this study a multi-site single case study. The same research question was addressed in all the settings and the same data collection and analysis procedures were used in all the settings. A multi-site (exploratory) case study "consciously seeks to permit cross-site comparisons without necessarily sacrificing within-site understanding and strengthens the ability to generalize while preserving in-depth description" (Herriott and Firestone, 1983, p. 14). However, in this study, 'multi-site' was used in the literal sense of subunits of a case being situated in different locations, rather than in the 'classical sense' defined in the above quotation.

This study used sampling logic, rather than replication logic for the subunits (Yin, 2003), the classrooms of teachers. In this study, teachers' classroom practices were examined in depth. Then a comparative analysis of the teachers' practices was offered in the domains of lesson planning, content, and classroom culture and the factors that promoted and hindered the implementation of the practices.

Thus, the nature of this study called for a design that was responsive to the unique perspectives and situations of the participants and was coincident with the essential features of a multi-site exploratory case study design as shown above.

Rationale for Quantitative and Qualitative Methodologies

According to Yin (2003), "case studies can be based on any mix of quantitative and qualitative evidence" (p.15). Further, in comparing the two terms, qualitative and quantitative, Merriam (1998) states, "quantitative research takes apart a phenomenon to examine component parts (which become the variables of the study), [and] qualitative research can reveal how all the parts work together to form a whole" (p.6). The goal of this research was to arrive at a deep understanding of how the practices of MCE program were being implemented by the group of teachers in the classrooms, how were these practices different among the teachers, and what factors promoted and inhibited their implementation. Achievement of this goal required both, pulling apart the happenings and examining the component parts, as well as piecing together the component parts into a meaningful whole. All the means that supported this endeavor were employed. Therefore, the use of a variety of data sources was the most pragmatic course of action for this study, resulting in both qualitative and quantitative categories of data. This diversity of data sources only served to strengthen this study "because qualitative and quantitative methods involve differing strengths and weaknesses, they constitute alternative, but not mutually exclusive, strategies for research" (Patton, 2002, p. 14).

In addition, Creswell (1994) reports five purposes to combine the two approaches, as proposed by Greene, Caracelli, & Graham (1989). These five purposes are; "to seek convergence in findings, each may reveal a different facet of the phenomenon, one method informs the other, contradictions and fresh perspectives emerge, and adding breadth to the study" (p. 175). This study used a number of sources of data that fell under quantitative and/or qualitative methods and every effort was made to ensure that all of the above purposes of combining the two methods were met, leading to a robust study.

Next, the sources of data used in the quantitative and qualitative phases of this study are described.

Quantitative Phase

In general, quantitative research "is used when one begins with a theory (or hypothesis) and tests for confirmation or disconfirmation of that hypothesis" (Newman & Benz, 1998, p.3). However, this research is a qualitative study that utilized some of quantitative data gathering techniques, such as questionnaire and survey research and structured observations (Bogdan & Biklen, 1998). The purpose of the quantitative phase of data collection was not to test a hypothesis. In fact, the researcher entered the field of observation with as much of a 'clean slate' stance as possible and let any patterns, propositions, or theories arise from the unbiased (as far as possible) observations. Any propositions and theories (that she had) were held in abeyance and data was allowed to speak for itself. Only after data spoke for itself, was it related to established theories.

Theories did not hold sway *before or during* observation and description. Therefore, even in the quantitative phase of data, no theory was tested.

In this case study, the quantitative data was primarily generated from three sources, the SoCQ (Stages of Concern Questionnaire- Appendix F), RTOP (Reformed Teaching Observation Protocol - Appendix G), and the RTOPTS (RTOP Teacher Survey- Appendix I). The SoCQ and the RTOP Teacher Survey were completed by the teachers, hence represented their perspectives. RTOP was recorded by the researcher. An advantage of quantitative data is that they are “succinct, parsimonious, and easily aggregated for analysis” (Patton, 2002, p.20). These data were “summarized, organized and simplified” (Gravetter & Wallnau, 2000, p.8) by using descriptive statistics. In particular, following descriptive statistics were calculated from the data gathered from these three instruments; mean, standard deviation, frequency counts and percentages. Inferential statistics was not an appropriate quantitative method for this small sample. Therefore, it was not applied.

Qualitative Phase

Qualitative research is “an inquiry process of understanding a social or human problem, based on building a complex, holistic picture, formed with words, reporting detailed views of informants, and conducted in a natural setting” (Creswell, 1994, p.2-3; Taylor & Bogdan, 1984). In this research, three types of qualitative data informed the process of understanding how the group of teachers implemented the practices of the MCE program in their classrooms, how did the implementation differ among the teachers, and the factors that helped and hindered the process. These sources were field notes collected during teacher observations, teachers’ responses to 3 open-ended questions added to the SoCQ (see above) and the semistructured interview (Appendix J). These sources represented multiple perspectives to aid in the deep understanding of the problem. Some of these data were quantified through the generation of descriptive statistics, when possible. Details are discussed in the data analysis section.

Researcher's Background

The researcher is a teacher, turned administrator, who has taught science and mathematics at various levels, ranging from middle school to undergraduate. She has been involved with public education in various capacities for the past 21 years, mainly in the SDP and a neighboring suburban school district. She started her career in the SDP as a teacher of Physics and Chemistry and taught in schools similar to those described in the study for 10 years. Then she moved towards the administration side of public education, serving as the roster chair and assistant principal in a large neighborhood high school. She also served as the department head of science in a neighboring suburban high school, before joining her current position as an administrator in the Office of Assessment in the SDP, responsible for coordinating and professionally developing stakeholders about many large scale (NCLB and other) mandated assessments. She has kept in touch with science education via her position as an adjunct professor who trains aspiring high school science teachers in a local university.

Roles of the Researcher

In this study, the researcher was committed to spending one 12-15 week semester in the field making 3 observations of a chemistry course, of every teacher in this study. These observations of classroom practices were roughly 4-5 weeks apart. At the beginning of the semester, the teachers completed the SoCQ. At the end of the semester, the teachers completed a survey and the researcher conducted one interview with each teacher. For the completion of the questionnaire and the survey, the researcher just sent and received these documents to the teachers via e-mail or inter-office mail. However, to observe, collect lesson plans, and interview the teachers, the researcher played two interactive roles, that of an (almost) “complete observer” (Gold as reported in Merriam, 1998) and an interviewer respectively. These required the researcher to be in the presence of the teacher and/or interact directly with him/her. To prepare for these situations, the researcher met with every teacher in this study individually at least once prior to the commencement of this research. At these meetings, the purpose and design of the study, their roles, and researcher’s expectations were explained to them and their questions/concerns were responded to. Since then, the researcher contacted the six teachers via telephone and e-mails, and most importantly, acted as a resource person by providing them with chemistry resources for their classes. These interchanges and some of the binding factors between the researcher and the teachers, such as, working for the same school district (although in different positions), being aware of and having faced the challenges of teaching chemistry in the district, served to establish a sense of collegiality, rapport, and trust between them. This relationship stood in good stead as the researcher assumed the roles of an observer and an interviewer to collect the data for this study. Now, these two roles are described in detail.

Observer

Gold (1958) suggests that a complete observer is that role assumed when “the researcher is hidden from the group (for example, behind a one way mirror) or in a completely public setting such as an airport or a library” (p. 101). In this study, the researcher entered the classroom before the students and occupied an empty seat on the periphery (either in the back or on the side) of the classroom. The researcher stayed, as inconspicuously as possible, in the same location in the classroom for the entire duration of the class. There was no attempt to communicate with the teacher or the students during the teaching of any class. Although the researcher was in close proximity of the students and the teacher in the class, the intent of this researcher was to observe the classroom setting unobtrusively (short of being hidden) in the stance of as close to a complete observer as possible. The role and activities of the researcher were not disclosed to the teacher and the students. According to Merriam (1998), “the interdependency between the observer and the observed may bring about changes in both parties’ behaviors. Finally, the mere presence of the observer in the setting can affect the climate of the setting, often effecting a more formal atmosphere than is usually the case” (p. 103). Merriam (1998) adds that "the researcher must be sensitive to the effects one might be having on the situation and account for those effects" (p. 104). With this acknowledgement, the researcher's impact on the classroom interactions were not examined in this study.

As an almost complete observer, the researcher documented the classroom interactions in the domains of lesson planning and implementation, teachers’ content knowledge and application of supportive procedures, and the classroom culture, using the instrument RTOP. The classroom interactions for each of the RTOP domains were further elaborated upon in the researcher's field notes, as needed. The field notes also include student, school, and teacher characteristics, such as type of school, diversity of student body, resources, and teaching experience.

Being a former chemistry teacher, the researcher brought a well-informed subjectivity to the whole exercise. This subjectivity could be a double edged sword. It could be viewed as “a necessary and vital element of the inquiry process” (Mehra, 2001, p.81) as well as a potential source of bias. Awareness and acknowledgement of the subjective stance of the researcher was noted.

Co-observation

The researcher observed one lesson of a teacher with a colleague, who was also trained in using the RTOP, had experience using it, and was quite familiar with the research-based practices. After the observation, the researcher and the expert colleague scored the lesson independently, then discussed the score on each indicator and resolved the differences, to arrive at a consensus. This procedure insured that the subjectivity of scores was in check.

Interviewer

Since “as a good hammer is essential to fine carpentry, a good tape recorder is indispensable to fine fieldwork” (Patton, 2002, p. 380), the interview was taped. Tape-recording was *one* of the means of collecting the data. As Patton (2002) says, “the use of the tape recorder does not eliminate the need for taking notes” (p. 380).

However, it allowed the interviewer freedom to focus on the content, on taking strategic and focused notes, key phrases, words in quotation marks, and major points that facilitated her to better capture the flavor of the respondents’ language.

In the role of the interviewer, the researcher began the interviews by asking basic descriptive information about the teachers and their experiences of the MCE program. The interviewer followed this by asking probing questions that required exploration, explanation, clarifications, and insights regarding any piece of data that may lead to answering the research questions (DeSimone & LeFloch, 2004). Examples of questions asked to achieve this purpose were; ‘What do you mean?’, ‘I am not following you’, ‘Could you explain that’, ‘Can you give an example of that?’ The researcher was “captive to the larger goal of the interview-understanding-not to the devices, gimmicks, questions, or the like that were invented as strategies and techniques of obtaining information. The researcher must always be prepared to let go of the plan and jump on the opportunities the interview situation presents” (Bogdan & Biklen, 1998, p. 97). Therefore, any lead that had the potential to answer the research questions, i.e., how did the group of teachers implement the practices of the MCE program in their classrooms, how were these practices different among the teachers, and the factors that enabled and inhibited their implementation, were pursued, even if these deviated from the set of written questions, since “the actual stream of questions in a case study interview is likely to be fluid rather than rigid” (Rubin & Rubin, 1995), as quoted in Yin (2003, p. 89).

Since, “the interview is the main road to multiple realities” (Stake, 1995, p.64), the interviewer listened to what the teachers had to say attentively and was its repository. The interviewer, perhaps, improved the quality of data derived from the interview by communicating personal interest, nodding her head, and using appropriate, encouraging expressions to elicit teachers’ responses.

Research Setting

Classes in the Schools

This study ascertained how the group of teachers, who graduated from the MCE program, implemented the practices learned in the program in their classrooms. In addition, this study also explored how this implementation differed among the teachers and the factors that promoted and inhibited the process. The six teachers in this study were teaching chemistry in six different high schools spread throughout the SDP, the fifth largest urban school district in terms of the size of student population. Four of the teachers were teaching in special admission/criteria-based schools, where the students had to pass an examination and/or meet set criteria to be admitted. The other two teachers were teaching in comprehensive neighborhood high schools. The classes of these teachers were scheduled at different times during the school day, between 8 am to 3 pm. The duration of classes ranged from 45 minutes to 90 minutes. The number of students in a class varied approximately in the range of 20-30 students. Students of all the participating teachers, except one, were juniors. The exceptions were sophomores. Chemistry is, typically, a third year mandatory course taken to fulfill the science requirement for graduation. The student population was overwhelmingly African-American in two schools and was a mixture of African-American, White, Asian, and Hispanic in the other four.

In every school, the classroom instruction occured at least 4 of the 5 days of the week. On the 5^{th} day, the students took part in a double or single period lab activity, aligned to the content taught previously. At the teacher’s discretion, the lab periods were, often, used for instruction also.

Teachers were asked to submit their weekly lesson plans by the beginning of the week to the department head/lead teacher. It was apparent that there was no accountability regarding this submission. Also, the format of the lesson plan varied among the teachers. There were two curricular features common to all the schools in the system. These were; a requirement to follow the core curriculum with a pacing schedule determined by the district's curriculum office, and benchmark assessments at the end of every 5-week cycle of instruction.

Sample

As Patton (2002) states,

> Sample size depends on what you want to know, the purpose of inquiry, what is at stake, what will be useful, what will have credibility, and what can be done with available time and resources. The validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information richness of the cases selected and the observational/analytical capabilities of the researcher than with sample size. (p. 244)

The participating teachers in this study comprised a "purposeful sample"(Patton, 2002, as cited in Maxwell, 2005, p. 88) of teachers, deliberately chosen, who met the following three criteria; (1) graduation from the MCE program for 1-6 years, (2) currently teaching chemistry, and (3) employment in the SDP. Only seven teachers in the entire district met the three criteria. All, except one, agreed to participate in this study. Therefore this is a case study, not of a sample, but almost the whole population of teachers who graduated from the MCE program, and were teaching chemistry in the SDP in 2007-8.

Data Collection Procedures and Protocols

A case study admits of the widest possible array of data collection (Creswell, 1998). According to Yin (2003), six important sources of data are; documents, archival records, interviews, direct observation, participant-observation, and artifacts. According to Yin (2003),

> some overriding principles are important to any data collection effort in doing case studies. These include the use of (a) multiple sources of evidence (evidence

> from two or more sources, but converging on the same set of facts or findings), (b) a case study database (a formal assembly of evidence distinct for the final case study report) and (c) a chain of evidence (explicit links between the questions asked, the data collected, and the conclusions drawn). The incorporation of these principles into a case study investigation will increase its quality substantially. (p. 83)

(a) In this study, five sources of evidence (questionnaire, classroom observation, survey, interview, and the lesson plan) were used to explore the research questions, how did the group of teachers implement the practices of the MCE program in their classrooms, and how did these practices differ among the teachers? Two sources of data, the two open-ended questions added to the questionnaire and the interview, informed the research questions what factors enabled and inhibited the implementation of the program. This variety of data collection procedures guarded against the threat of systematic bias inherent in a given method and it had the potential to lead to a deeper and more secure understanding of the issues under investigation, an aspect of triangulation (Maxwell, 2005; Fielding & Fielding, 1986).

(b) A collection of evidence was coded into various categories as the information was interpreted and the final report was written.

(c) The data analysis section of this chapter provides a link between the research questions, data collected, and possible conclusions.

Finally, data collection, in case studies, is a flexible process (Eisenhardt, 2002). The most flexible of all the data sources in the present study was the (semistructured) interview, followed by the open-ended questions on the questionnaire. The questions in the interview protocol were adjusted before and during the interview with every teacher to allow for exploration of emergent themes, follow a line of inquiry, or to take advantage of a situation, always keeping in mind the goal of optimizing the yield to be able to answer the research questions in sufficient breadth and depth. This flexibility of data collection procedure can be characterized as "controlled opportunism in which researcher takes advantage of the uniqueness of the specific case and the emergence of new themes to improve resultant theory" (Harris & Sutton, 1986, p. 16-17).

Direct (Classroom) Observation Protocol

In order to acquire an understanding of the classroom practices actually employed by the teachers in their chemistry courses, observations of classes constituted an important source of the data collection. Since the course was not created for the purpose of this research and all the conditions in the environment, e.g., the course structure, content, and materials etc. preexisted, data obtained through direct observation was most appropriate. There are six advantages to the method of direct observation as enumerated by Patton (2002). All of these applied to this study. First, it better enabled the researcher to capture the context within which people interacted since "understanding context is essential to a holistic perspective" (Patton, 2002, p. 262). Second, first hand experience like direct observation allowed the researcher to be open, discovery oriented and inductive without being hindered by prior conceptualization. A third strength of direct observation was that the researcher noticed things that might routinely escape the participants' attention, hence might not have been captured in interviews and surveys. Fourth, it afforded the researcher a chance to witness and learn things that participants might be uncomfortable talking about. Fifth, direct observation afforded the researcher an opportunity to move away from the selective perspectives of the interviewee. However, the researcher's perspective merged with the data to arrive at a unique, possibly holistic, view of the observation. Finally, reflection on the experience and the impressions created by it assisted in the interpretation and analysis stage of this study. Keeping these advantages in mind, the researcher acted as an (almost) complete observer and collected data in the "natural field setting" (Merriam, 1998, p.94) of the classroom. The researcher's experiences as a chemistry teacher, head of science department in a high school, and an administrator were an integral part of this process.

The researcher observed three complete classes of a chemistry course of every teacher in this study. The three observations occurred approximately in the beginning, middle, and at the end of a 12-15 week semester. This time spent in the field was sufficient to record the information delineated above.

According to Patton (2002), "Fieldwork should last long enough to get the job done-to answer the research questions being asked and fulfill the purpose of the study" (p. 274). Merriam (1998) says that

> there is no ideal amount of time to spend observing, nor is there one preferred pattern of observation. For some situations observations over an extended period of time may be most appropriate, for others, shorter periodic observations make the most sense given the purpose of the study and the practical constraints. (p. 98)

Since every effort was made to be unobtrusive, and create the least amount of perturbation in the natural setting, the classroom observations were not tape recorded or videotaped.

Direct observation data consisted of two components. The first component, the field notes, aided in creating a rich, "thick" (Geertz, 1973, p. 420; Denzin, 2001) description and interpretation of the observations. Information on the six elements that are "likely to be present in any setting" (Merriam, 1998, p. 97) were the source of data for this component. These elements were related to physical setting, participants, activities and interactions, conversations, subtle factors, and observer comments. The second component of classroom observation was the evidence of the use of research-based practices by the teachers, collected through the instrument RTOP (Piburn et al., 2000- Appendix G). This instrument was used as a "means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed" (Adamson et al., 2003, p.941). The reader is reminded that information on RTOP can be found in the 2nd chapter and the instrumentation section of this chapter (Piburn et al., 2000).

Teacher Interview Protocol

According to Yin (2003), "one of the most important sources of case study information is the interview" (p. 89). Further, Patton (2002) posits that

> We interview people to find out from them those things that we cannot directly observe. The issue is not whether observational data are more desirable, valid, or meaningful than self-report data. The fact is that we cannot observe everything. We cannot observe feelings, thoughts, and intentions. We cannot observe behaviors that took place at some previous point in time. We cannot observe situations that preclude the presence of an observer. We have to ask people questions about those things. The purpose of interviewing, then, is to allow us to enter into other person's perspective. Qualitative interview begins with the assumption that perspective of others is meaningful, knowable, and able to be made explicit. We interview to find out what is in and on someone else's mind, to gather their stories. (p. 340-341)

In this study, the collection of teachers' stories began with the administration of a concerns survey, the SoCQ (with 35 multiple–choice items and 3 open-ended items added by the researcher), at the commencement of the 12-15 week observation period. The two major sources of questions for the "semistructured" (Merriam, 1998, p.74) interview were the concerns questionnaire and the classroom observations.

One semistructured interview was conducted with every teacher after the completion of his/her classroom observations. The interviews were audiotaped by the researcher and transcribed by an independent source. A copy of the transcript was mailed to the participating teachers to affirm accuracy and receive their feedback. Although the researcher had some structured and open-ended focus questions (see Appendix J), there was enough flexibility during the interview process to mold or change the questions into those that succeeded in eliciting meaningful responses and insights from individual teachers. Therefore, a part of the interview protocol was generalized and the other part was customized to the needs of individual teachers. This method of data gathering shed light on the gaps in data obtained from other sources and, therefore, assisted in answering the research questions, i.e. how did the group of teachers in this study implement research-based practices in their classrooms, how did these practices differ among teachers, and what factors helped and hindered the process? Another function of the information generated from interview questions was to inform, corroborate, or dispute what was known from other sources of data collection (Seidman, 1991). The interview data helped cement certain findings and revealed new ones, in either case enriching this study.

Documents Protocol

According to Bogdan and Biklen (1998),"document refers to materials such as photographs, videos, files, memos, letters, diaries, clinical case records, and memorabilia of all sorts that can be used as supplemental information as part of a case study" (p. 57). Merriam defines the word more broadly, referring to documents as "any communication" (Merriam, 1998, p. 112) that can be used as a source of data and is not gathered through observations and interviews. Only document procured for this study was the teacher generated lesson plans. A sample can be found in Appendix H.

Since the lesson plans were not produced for the purpose of this research, but happened to be present in the field, often these were not readily useful (Merriam, 1998). However, this document was a good source of data for qualitative case study, since it "lends contextual richness and help ground an inquiry in the milieu of the writer" (Guba & Lincoln,1981, p. 234).

As Creswell (2003) and Yin (2003) enumerate, there are several advantages and limitations to using documents in case study research. The advantages are; being an unobtrusive source of information, convenience of access, enabling the researcher to obtain the language and words of the participants, work that was created thoughtfully with participants careful attention, an existing written evidence that does not need transcribing, a source of clues for further investigation, and its potential to provide specific details to corroborate information from other sources. The limitations are; it may require a great deal of time from the researcher to search out the necessary information in hard-to-find places, it may be incomplete, and it may not be accurate. As the researcher examined the teacher generated lesson plans, she was cognizant of the advantages and limitations of document examination.

According to Yin (2003), "because of their overall value, documents play an explicit role in any data collection in doing case studies. The most important use of documents in case studies is to corroborate and augment evidence from other sources" (p.87).

Keeping this in mind, as the researcher examined the lesson plans, she looked for evidence of how well aligned these documents were with the research-based practices of lesson design and implementation, content, and classroom culture. In addition, how the documents generated by different teachers supported or did not support the research-based practices were noted and recorded.

Self-Administered Protocols

"Self-administered questionnaires (surveys) are instruments used to collect information from people who complete the instrument themselves. The stimulus in such questionnaires is exclusively visual" (Borque & Fielder, 2003, p. 2). The self-administered protocols (a survey and a questionnaire) were both e-mailed and sent through inter-office mail of the SDP to the teachers. The teachers had a choice of returning the completed instrument via either of the above modes. They completed two self-administered protocols in this study, outside the presence of the researcher. These protocols were: RTOP Teacher Survey (RTOPTS-Appendix I) and the Stages of Concerns Questionnaire (SoCQ- Appendix F). There are several advantages to using self-administered protocols. Some of these are: they work well with a literate population that is interested in the research, subjects can respond at their convenience, when one wants to ask a large number of items that are in a similar form, advantageous when dealing with sensitive items or items that require time to think over, the research question asks about the present rather than the past or the future, and lack of interviewer bias (Bourque & Fielder, 2003; Fowler, 2002; Frankel & Wallen, 2003; Gilham, 2000).

Both the self-administered protocols used in this study employed dual formats of closed and open-ended responses. The closed-ended items were easy to use, score, and required a response along a 5 or 7 numbered continuum, the number of categories most respondents can handle meaningfully for rating tasks (Fowler, 1995; Frankel & Wallen, 2003).

Instrumentation

The instruments used in this study were: SoCQ with 3 open-ended questions to measure teachers' self-ratings of implementation and concerns regarding factors that enabled/inhibited the implementation; RTOP to record the teachers' use of research-based practices in the domains of lesson design and implementation, content, and classroom culture and the researcher's notes regarding the classroom environment; teachers' lesson plans on the days they were observed; RTOPTS to gauge teachers' perceptions of the extent of implementation in the domains of lesson design and implementation, content, and classroom culture; and the semistructured interview to explore in-depth the teachers' concerns regarding implementation and the enabling and inhibiting factors, as well as their thoughts on lesson design and implementation and depth of content knowledge. This instrument yielded quantitative data that was analyzed as described in the data analysis section.

SoCQ with Three (3) Open-ended Questions

This instrument consisted of two parts. Part one had 35 closed ended items, each requiring a response on a 7 point Likert-type sacle (0=irrelevant, 1-2=not true for me, 3-4somewhat true of me now, and 5-7=very true of me) according to how truly the item described the teachers' perceptions/concerns with respect to the implementation of MCE program practices in their classrooms. Each of the items was identified with one of seven different Stages of Concern/perception (Awareness, informational, personal, management, consequence, collaboration, and refocusing) related to the implementation.

With permission from the publishers, throughout the questionnaire, the word innovation was replaced by the word MCE program to accommodate this research. This was the only change made to the instrument. This part of the instrument yielded quantitative data and had strong reliability estimates ranging from .65 to .86 and internal consistency with alpha coefficients ranging from .64 to .83 (George et al., 2006). Part two had three open-ended questions. The first question asked the teachers to rate their level of implementation on a scale of 0-10 and also describe it as non-user, novice, intermediate, old-hand, or past-user. The second and third questions asked them to describe the factors that enabled and inhibited the implementation, respectively (see Appendix F for a copy). The first question yielded quantitative and qualitative data, while second and third questions yielded qualitative data. The methods of analyses of both the quantitative and qualitative data are described in the data analysis section of this chapter. This instrument was e-mailed and sent via inter office mail to the teachers at the beginning of the 15-week semester of data collection, before the classroom observations began. The teachers had one week to return their completed questionnaires.

RTOP

Using the instrument RTOP, this researcher rated the classroom observations of the teachers for alignment with research-based practices. RTOP's 25 indicators (statements) are clustered around the domains of lesson design and implementation (5 statements), content (10 statements), and classroom culture (10 statements). The rating of each of the indicators ranges from 0 (never occurred) to 4 (very descriptive) on a Likert-type scale. This instrument produced total and domain quantitative scores. The analysis of scores is described in the data analysis section. RTOP also requires a narrative account of the lesson from the observer.

Face validity of the instrument was established by six researchers as a result of several iterations of using, analyzing, revising, and refining it and arriving at a consensus. A trained team of observers achieved an exceptionally high interrater reliability for both the overall score and the subscales (between 0.85 and 0.95). Additionally, two researchers rated the same sixteen lessons. Data from these were used for obtaining estimates of reliability by doing a best-fit linear regression on one set of observations vs. the other. The proportion of variance accounted for by the best-fit line was 0.954, an exceptionally high value. Reliability estimates for the subscales were high also, ranging in value from 0.67 to 0.945.

Internal consistency determined by Cronbach's alpha for the individual RTOP scales and subscales are reported between 0.80 and 0.93 (Sawada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002). The reliability of the instrument, based on observations of various science and math classes, ranged between 0.9 and .954, and it had a high degree of face, construct, and predictive validity (Piburn & Sawada, 2000).

RTOPTS

This instrument consisted of 25 statements that mimicked the RTOP's 25 statements, except that many of the RTOPTS statements were in the first person singular, to reflect the perceptions of the teachers regarding their classroom practices. The teachers responded to each statement on a 0-4 Likert-type scale (0=Never occurred, 4-Very descriptive). Similar to RTOP, the first five statements in RTOPTS occurred under the domain of lesson design and implementation, next ten statements under the content domain, and the last ten statements under the classroom culture domain. RTOPTS was e-mailed and sent via interoffice mail to the teachers towards the end of the 15 week semester of data collection, with a response time of one week. Quantitative data obtained through RTOPTS was analyzed according to the method described in the data analysis section.

Lesson Plan

Since there was no prescribed format for writing the lesson plan, the lesson plans submitted by the six teachers, on the days of observation, were in a variety of formats and addressed different aspects of lesson planning. This instrument also yielded qualitative data, whose method of analysis is described in the data analysis section.

Semistructured Interview

The culminating piece of data was collected from the teachers when they were individually interviewed with a semistructured interview instrument consisting of a set of flexible questions, and a set of fixed questions (see Appendix J). The flexible questions probed into the individual concerns of teachers and the questions arising from their classroom observations by the researcher. Therefore, flexible questions were customized to the concerns of the individual teacher and the unique aspects of his/her classroom practice as noticed by the researcher during classroom observations. There were three fixed questions towards the end, that inquired into how the teachers planned their lessons and how did they impart depth of understanding to the students. These questions were termed fixed, since all the teachers were asked exactly the same three questions. Responses to both sets of questions provided qualitative data. These data were analyzed similarly, but separately, as described in the data analysis section.

Procedure

At the commencement of a 15-week semester, the researcher administered the concerns questionnaire to the six teachers in this study and collected the completed questionnaire within a week of its issuance. During the 15 week semester, the researcher observed 3 classes of the same course taught by a teacher. Every effort was made to space the 3 observations evenly during the semester. To the extent possible, a similar schedule was followed for all the teachers in this study. RTOP teacher observation protocol was completed during each observation. Prior to the observations, the researcher and a qualified colleague were self-trained in using the RTOP by viewing a set of 3 video taped lessons, rating the lessons with the instrument and reconciling any differences. Interrater reliability was established by the researcher and the colleague observing and rating one lesson of a teacher in this study, and coming to a consensus regarding the score on each of the 25 statements (indicators). At the end of the semester, the teachers completed a survey consisting of 25 modified RTOP statements, and were individually interviewed. Teacher prepared lesson plans were collected on each of the days he/she was observed. In addition, the core curriculum, teaching and scheduling timeline, benchmark assessments, textbook, and ancillary materials were available for review.

Data Analysis

Data analysis is the most difficult step in the case study research (Gee, Michaels, & O'Conner, 1992; Yin, 2003).

Qualitative Aspect

According to Merriam (1998), "The analysis begins with the first interview, the first observation, first document read. Emerging insights, hunches, and tentative hypotheses direct the next phase of data collection, which in turn leads to the refinement or reformulation of questions, and so on" (p.151). However, it is helpful to use the following six "analytic manipulations" to organize the data prior to analysis as described by Miles and Huberman (1994) and cited in (Yin, 2003),

(1) Putting information into different arrays
(2) Making a matrix of categories and placing the evidence within such categories
(3) Creating data displays- flowcharts and other graphics-for examining the data
(4) Tabulating the frequency of different events
(5) Examining the complexity of such tabulations and their relationships by calculating second-order numbers such as means and variances
(6) Putting information in chronological order or using some other temporal scheme. (p. 110-111)

The first step in data analysis in case study consists of writing a detailed, rich "thick" (Geertz, 1973, p.420), description of the case and its context (Creswell, 1998). In this study rich descriptions of the case and its contexts were compiled from teachers' responses to the SoCQ's open-ended questions (numbers two and three), and responses to the interview questions on lesson design and helping and hindering factors. After this step, according to Stake (1995), there are "two strategic ways that researchers reach new meanings about cases. These are; "direct interpretation of the individual instance and through aggregation of instances until something can be said about them as a class. Case study relies on both of these methods" (p.74). In categorical aggregation, the researcher looks for a collection of corroborating incidents or disconfirming ones as well, that impart meaning to the case. "In direct interpretation, …the case study researcher looks at a single instance and draws meaning from it without looking for multiple instances" (Creswell, 1998, p.154). In this study, both of these ways were used as appropriate.

Quantitative Aspect

Bogdan and Biklen (1998) emphasize the sensitization of a qualitative researcher to a quantitative perspective on “hard data” (p. 155). They posit that “ quantification has the potential to make that which was once taken for granted salient and make that which was once amorphous concrete” (p. 154). Also, “counting can shape what people consider important and meaningful and designate particular activities as expedient” (p.155). In this study, the researcher quantified the qualitative data that could be quantified, and summarized these through descriptive statistics of frequency counts, percentages, mean, and standard deviation as suitable.

Combination of Qualitative and Quantitative Aspects

Creswell (1994) adds that “the process of data analysis is eclectic; there is no “right way” (Tesch, 1990, p. 152). It also requires that the researcher be open to possibilities and see contrary or alternative explanations for the findings” (p.153). In keeping with these suggestions, this researcher systematically searched and arranged all the qualitative and quantitative data (only descriptive statistics) to improve her understanding of the evidence. Additionally, following the strategies employed by several authors (Bogdan & Biklen, 1998; Dey, 1995; Stake, 1995; Stake & Easley, 1978; Creswell, 1998; Miles & Huberman, 1994), she “fractured” (Strauss, 1987, p. 29) the data into manageable units through coding, reconstituted them in a more meaningful way, and searched for patterns.

As Stake (1998) elaborates further,

> sometimes, we will find significant meaning in a single instance, but usually the important meanings will come from reappearance over and over. Both categorical aggregation and direct interpretation depend greatly on the search for patterns.

> Often, the patterns will be known in advance, drawn from research questions, serving as a template for the analysis. Sometimes, the patterns will emerge unexpectedly from the analysis. (p. 87)

Elucidating meaning leads to interpretation of the findings (Patton, 2002).

However, as Patton (2002) cautions, there is guidance but no formula for the transformation of data into findings. The "findings emerge like an artistic mural created from collage-like piece that make sense in new ways when seen and understood as part of a greater whole" (Patton, 2002, p. 432). The findings that emerged from the analysis of data provided a naturalistic generalization to this exploratory case study.

Data Analysis for Relevant Data Sources

The five sources of data for this study were: SoCQ with 3 open-ended questions; RTOP; teachers' lesson plans; RTOPTs; and the semistructured interviews. In this section the method of data analysis from each of these five sources is described.

SoCQ with Three (3) Open-ended Questions

SoCQ's 35 items provided quantitative data. Using the Stages of Concern Quick Scoring Device (Appendix K), the raw scores of items belonging to each of the seven stages of concern were added to give the total raw score for each of the seven stages (George et al., 2006). The total raw scores for the seven stages were then converted to percentile scores using a conversion table. This was done for every teacher. Then, the data was analyzed in two ways: first by creating a table of the percentile scores of the top two and the bottom concern of every teacher, then by creating a concerns profile for every teacher by plotting the percentile scores of their seven stages of concern (Appendix L). This data source was utilized in answering research question 4.

Open-ended Question 1a provided qualitative and quantitative data. Teachers' descriptive responses (Non-user, Novice, Intermediate, Old-hand, Past user) were quantified by assigning a numerical value of 0-4 to these in order. Then the mean of these values was calculated and used to describe the group's level of implementation. This data source assisted in answering research questions 1 and 2.

Open-ended Question 1b provided quantitative data. The mean and standard deviation of teachers' self-reported level of implementation scores were calculated. To analyze the results, a continuum of the levels of implementation corresponding to scores 0-10 was devised and the mean was placed on the continuum to determine the level of implementation of the group of teachers. This data source assisted in answering research questions 1 and 2.

Open-ended Questions 2 and 3 provided qualitative data. Teachers' transcribed responses to the questions were reviewed many times independently by the researcher and a highly-experienced colleague. Independently they created categories and subcategories (enabling factors) to be parsimonious and inclusive of all the teachers' responses to this question, followed by the placements of all the teachers' responses under corresponding enabling factors till exhaustion. To achieve this, if necessary, more enabling factors were added. Final codes and placements were arrived at through discussion and reconciliation between the researcher and the colleague. Then frequency of response for each enabling factor was tabulated. The same procedure was followed with the responses to question 3 to code and enumerate the evidence of hindering factors. Data from the open-ended questions 2 and 3 were used in answering research questions 3 and 4 respectively.

RTOP

RTOP provided a source of quantitative data. The total RTOP score for each observation was obtained as a percentage by adding the scores of 25 statements, since the maximum possible total score was 100. Mean and standard deviation were calculated for each observation for the six teachers as a group, and also for each teacher's three observations independently.

Since the maximum possible scores for the three domains were different (lesson design and implementation=20, content=40, and classroom culture=40), the domain scores were normalized by calculating the percentage score for each domain (referred to in this research as weighted percentage). For example, a domain score of 5 in the lesson design and implementation domain would yield a percent domain score of (5÷20) 100 = 25%. Mean and standard deviation of the % domain scores in each domain, for all the teachers, was calculated for each observation. Also, the mean and standard deviation of the percent score (the weighted percentage) in each domain was calculated for the three observations of each teacher. RTOP data was utilized in answering research questions 1 and 2.

Teachers' Lesson Plans

This source yielded qualitative data that was quantified as follows. RTOP's 25 statements were the codes. Statements in the teacher generated written lesson plans that aligned to these codes were recorded and counted. A frequency count of these aligned statements pertaining to the three RTOP domains calculated and tabulated. To establish interrater reliability, the researcher and an experienced colleague conducted the alignment independently, then negotiated to arrive at a final version. Information provided by the lesson plans was utilized in answering research questions 1 and 2.

RTOPTS

RTOPTS provided a source of quantitative data. The method of analysis for calculating the RTOPTS Total and Domain Scores followed the same procedure used for RTOP (i.e., computing the mean and standard deviation) described above. However, since teachers completed the survey once, the teachers' mean and standard deviations of percentage total score and percentage domain scores were computed only once. RTOPTS data was utilized in answering research questions 1 and 2.

Semistructured Interview (henceforth referred to as interview)

Responses to both the flexible and fixed questions on the interview provided qualitative data. The general procedure of analysis was the same for these two question types (e.g., coding the statements into various categories), however there were some differences as the analyses of data for each type of question continued.

Data analysis for responses to 3 Questions on lesson design and content (fixed questions)

All the teachers were asked the same three questions, the purpose was to probe their perceptions of lesson design and implementation, and the delivery of content. The researcher and her colleague independently looked for teachers' responses that aligned with the intent of the 25 statements of RTOP (e.g., the expressed characteristics of research-based practices). Responses that were aligned with an RTOP statements were placed under it and the process was continued till all the relevant responses were placed under one of the 25 RTOP statements. The researcher and colleague resolved placement differences through discussion and arriving at a consensus. Then, a frequency count was computed for the responses aligned with statements in the following four areas; (1) whole of RTOP, (2) lesson design and implementation domain, (2) content domain, and (3) classroom culture domain. Further, percentage of each teacher's responses in agreement with the statements in above four areas was also calculated. This data was utilized in answering research questions 1 and 2.

Data analysis for the responses to the rest of the questions (flexible questions) The data analysis for these responses followed the procedure for SoCQ's Open-ended Questions 2 and 3 described earlier in this section. However, many categories and subcategories (enabling or hindering factors) were different for this source of data. In this case also, the qualitative data were quantified through the creation of tables of frequency counts. This data was utilized in answering research questions 3 and 4.

The reader is directed to Appendix M for a graphical display of data flow, sources of data and the research questions addressed by each data source.

Methods of Verification

Yin (2003) describes four methods of verification as relevant to case studies. These are; construct validity, internal validity, external validity, and reliability. For Merriam (1998), "ensuring validity and reliability in qualitative research involves conducting the investigation in an ethical manner" (p. 198). Since this exploratory case study used both qualitative and quantitative methods, it was essential to address these issues. In the following subsections, the issues of construct validity, internal validity, external validity, reliability, and ethics are discussed.

Construct Validity

Gall, Gall, & Borg (1999) posit that construct validity is the extent to which the case study can be shown to measure a particular hypothetical construct. To establish construct validity one must establish "correct operational measure for the construct being studied" (Yin, 2003, p.34). This required that the researcher succinctly identify and communicate the phenomenon being investigated, i.e., classroom practices of chemistry teachers, in this study.

To guard against misinterpretation, the researcher employed redundancy of data gathering and procedural challenges to explanations. "For qualitative casework, these procedures generally are called triangulation" (Goetz & LeCompte, 1984 as reported in Denzin & Lincoln, 2005, p. 148; Denzin, 1989). The researcher included member checks in the triangulation process.

Denzin (1978) has identified four basic types of triangulation. Two of these, data source triangulation and methodological triangulation, were applicable to this study. "For data source triangulation, we look to see if the phenomenon or case remains the same at other times, in other spaces, or as persons interact differently" (Stake, 1995, p. 112). In this study the data source triangulation was ensured by looking at the same phenomenon, teaching practices of chemistry teachers, at three different times for every teacher and at multiple sites.

For methodological triangulation, "a rich variety of methodological combinations can be employed to illuminate an inquiry question. Some studies intermix interviewing, observation, and document analysis" (Patton, 2002, p. 248). This study employed classroom observation, teacher interview, concerns questionnaire, teacher survey, and lesson plan analysis conducted during a 15-week semester to meet the condition of methodological triangulation. Thus, using “an arsenal of methods that have non-overlapping weaknesses in addition to their complementary strengths” (Brewer & Hunter, 1989, p. 17) ensured the validity of the construct, ‘classroom practices of chemistry teachers’, in this study.

Internal Validity

According to Merriam (1998), “internal validity deals with the question of how research findings match reality” (p. 201). Merriam (1998) offers several strategies to enhance the internal validity of an (exploratory) case study. Four of the strategies applicable in this study were; triangulation, member checks, long-term observations, and researcher’s bias. As explained in the previous section, triangulation involved using multiple sources of data and multiple methods to confirm the emerging findings. Member checks were accomplished by reporting the findings and interpretations of the researcher back to the teachers and colleagues, and soliciting their feedback. Long-term observation at the research site is the repeated observations of the same phenomenon and the attendant gathering of data over a period of time (Merriam, 1998, p. 204). In this study the researcher spent 15-weeks in the field, making 3 complete observations, in the beginning, middle, and end of this duration, of every teacher in this study in the act of teaching chemistry. The same observation protocol (RTOP) was utilized for all the teachers in this study. The researcher made her biases explicit in this study. In this way, the researcher made “an effort to understand situations in their uniqueness as part of a particular context and the interactions therein. This understanding is an end in itself” (Merriam, 1998, p. 6).

External Validity

According to Merriam (1998), "external validity is concerned with the extent to which the findings of one study can be applied to other situations" (p. 207). Often the word 'generalization' is associated with external validity. In case study research, the word 'generalization' is reframed to reflect the assumptions underlying qualitative inquiry. Some of the reconceptualizations of generalization (Lincoln & Guba, 1985, as quoted in Merriam, 1998) include,

> (1) Working hypothesis: "When we give proper weight to local conditions, any generalization is a working hypothesis, not a conclusion (Cronbach, 1975, pp. 124-125). "Working hypotheses not only take account of local conditions, they offer the educator some guidance in making choices" (Merriam, 1998, p. 209).
> (2) Naturalistic generalizations: These provide "full and thorough knowledge of the particular" that allows one to see similarities in "new and foreign contexts". This process of naturalistic generalization is arrived at "by recognizing similarities of objects and issues in and out of context and by sensing the natural covariations of happenings, develop from experience, and guide a person's actions" (Stake, 1995, p.6).
> (3) Reader or user generalizability: This involves leaving the extent to which a study's findings apply to other situations up to the people in those situations (Merriam, 1998). Called case-to-case transfer by Firestone (1993), "it is the reader who has to ask, what is there in this study that I can apply to my own situation, and what clearly does not apply?" (Walker, 1980, p.34). According to Kennedy (1979) and Lincoln & Guba (1985) the responsibility for generalizing rests with the reader rather than the researcher. However, "the researcher has an obligation to provide enough detailed description of the study's context to enable readers to compare the "fit" with their situations. (p. 211)

(1) Generalization as a working hypothesis occurred in this study, when the researcher fully explored and described how each teacher implemented the practices in his/her classroom context, taking into consideration all the factors that impinged on this phenomenon, that enabled or did not enable the implementation of the practices.

(2) Naturalistic generalization occurred in this study, when the description mentioned above was placed in relation to a continuum of similar studies and the similarities and differences among 'similar' studies were made explicit.

(3) The researcher provided a "thick rich" (Geertz, 1973, p.420) description of this study that was detailed enough in all the necessary aspects for the reader to draw his/her own conclusions about its generalizability.

According to Merriam (1998), there are two strategies to improve the chances of generalizability of a qualitative inquiry that serve the three conceptions described above. These are; providing a rich, thick description of the case, and using a multi-site design, especially that maximizes diversity in the phenomenon of interest. With the data collected over a 15-week semester, the researcher was able to provide the readers a thick rich description of the classroom practices of the teachers and contexts associated with the chemistry classrooms studied. The six teachers in this study were teaching in six different high schools. They constituted the (almost) entire population of teachers who graduated from the MCE program *and* were teaching chemistry in their chosen urban setting. This inclusion of (almost) all the teachers ensured maximum possible diversity for the group in this study.

Reliability

According to Merriam (1998), "reliability refers to the extent to which research findings can be replicated" (p. 205). Lincoln & Guba (1985, p. 288) suggest that reliability in qualitative research needs to be conceptualized as 'dependability' or 'consistency' of the results obtained from the data. "The question then is not whether the results will be found again but whether the results are consistent with the data collected"

(Merriam, 1998, p. 206). Again, Merriam (1998) suggests that the following techniques can be used to ensure reliability of the descriptive case study.

(1) *The investigator's position*: The research should explain the assumptions and theory behind this study, the basis for selecting the participants, their descriptions, and their context (LeCompte & Preissle, 1993).

(2) *Triangulation* in terms of using multiple methods of data collection and analysis:

For the assumptions and theories underlying this study, the reader is referred to chapter 2.

The researcher did not have any positional relationship with the teachers in this study. However, both were employed in the same school district. This information, along with the teachers' descriptions, why were they chosen for this study, and their professional context was made explicit in the report of this research. As stated earlier, triangulation was achieved through the use of a variety of data sources, e.g., classroom observations, teacher interviews, concerns questionnaire, survey, and teacher made lesson plans.

Interrater Reliability

Interrater reliability was addressed in two different manners. Per RTOP's creator, ACEPT (Arizona Collaborative for Excellence in Preparation of Teachers), this researcher and a highly qualified colleague well versed in research-based practices, observed 3 videotaped lessons of 20 minutes each from ACEPT (Arizona Collaborative for Excellence in Preparation of Teachers), the originators of RTOP. These lessons were observed together by the two raters, and scored independently using RTOP. On an average, the scores on the 25 indicators of RTOP matched between the two raters in 90%

of the cases. Then, the two raters reconciled the variability in their scores on the remaining 10% of the cases through discussion and arriving at a consensus.

The RTOP was utilized once again in the classroom setting, where the researcher and the same colleague co-observed a lesson of a teacher in this study. Interrater reliability was established as the researcher and co-observer rated the lesson independently, after which differences in scores were resolved through discussions. This procedure is in direct compliance with ACEPT's protocol.

Interrater reliability was also established for teachers' responses to open-ended questions on survey and interview questions. In these cases, following Miles and Huberman (1994), categories and subcategories (factors) were created and the evidence was placed under these. Also, the frequency counts of the evidences were computed. Above processes were first carried out independently by the researcher and a highly qualified colleague, then100% agreement between the two was arrived at through discussion and consensus.

Ethical Considerations

This researcher acknowledged the bias that she brought to this study, arising from her multiple roles as an educator for over 20 years. As a result, this study's data collection, analysis, interpretation, and report were colored through multiple perspectives. Most notable among these perspectives were; those of a former chemistry teacher, administrator, and a research assistant. This subjectivity was viewed and noted as "a necessary and vital element of the inquiry process" (Mehra, 2001, p.81).

In addition, the researcher observed at least two classes and some labs in every one of the ten courses in the MCE program for one year. This first hand witnessing of the rigor of content the teachers were exposed to and the classroom practices modeled in the MCE program afforded her a unique perspective and a valid reference for comparison.

The researcher was aware that “the nature of data collected will, to some extent, be dependent on the role and perspective of the observer. Just as the presence of the observer can affect people observed, so too the observer can be affected” (Patton, 2002, p. 329).

Again, “because qualitative methods are highly personal and interpersonal, because naturalistic inquiry takes the researcher into the real world where people live and work, and because in-depth interviewing opens up what is inside people-qualitative inquiry may be more intrusive and involve greater reactivity than surveys, tests, and other quantitative approaches” (Patton, 2002, p. 407). This researcher dealt with such issues with sensitivity.

Following Merriam’s (1998) suggestion, this researcher preserved the confidentiality of all the documents and anonymity of the teachers in this study. In order to maintain accepted ethical standards, the rules and regulations of the institutions where the teachers worked were followed and the research was used for its intended purpose only.

The Office of Research and Evaluation of the SDP granted permission to the researcher to conduct this study in six schools (Appendix N). The researcher abided by the conditions imposed by this office. In addition, the researcher obtained written permission from the six Principals (Appendix O) and signed consent forms from the six teachers before conducting this study (Appendix P).

CHAPTER 4

CONTEXT OF THE STUDY, DATA ANALYSIS, PRESENTATION, AND FINDINGS

Introduction

In this chapter the findings on the contexts of the research study, for the group and for each teacher, are described first. This is followed by the data analysis and presentation of the findings, including discussion, for each research question utilizing various sources of data.

Contexts of the Study

To frame the contexts of the study, relevant findings regarding the teachers, courses taught, students, and school characteristics are presented first for the group of teachers, followed by similar information for individual teachers. The sources of this data were: researcher's notes taken during classroom observations; information available on the School District of Philadelphia's (SDP) website; and the information made available to the researcher by the MCE program administration.

The teachers in this study graduated from the first five cohorts of the MCE program in the years 2002 - 2006. At the time of the study (2006-8), these teachers were the only graduates of the MCE Program in their respective schools who were teaching chemistry. Some of the schools in the study had other graduates of this program, but they were not teaching chemistry at the time of the study. There were no other teachers in their schools with this qualification. Their years of teaching experience in the SDP ranged from 5-15 years, and the levels of chemistry courses taught, and observed in the present study, varied from the 'regular' level delineated in the core curriculum, for all the students, to accelerated courses such as Advanced Placement (AP) and International Baccalaureate (IB). The class periods of individual teachers were 50-55 minutes in duration and met between 2 to 6 times per week. Only one teacher (16.7%) had assigned double laboratory periods every week in his/her roster. The teachers in the study taught a great variety of topics in chemistry during the observations. Two of the teachers (33.3%) were teaching accelerated courses (AP or IB), therefore did not follow the SDP's core curriculum in chemistry. Of the remaining four teachers (66.7%) that followed the core curriculum, three (50.0%) were behind the pacing schedule and one (16.7%) was on track in the observed classes. The number of students in the observed classes ranged from 21 to 29. In the two accelerated courses observed, the representation of African American students (one each) was disproportionately low compared to their overall distribution in the two schools. Students in these courses were overwhelmingly White and Asian. The sizes of total student populations in the schools varied from under 300 to over 2000, with students drawn primarily from the neighborhood, to those from all parts of the city. The diversity in terms of racial distribution, English language learners, students with special needs, gifted students, and students receiving free and reduced lunch (an indicator of poverty) was widespread. The standardized test (PSSA-Pennsylvania System of School Assessment) scores on reading and math varied from 10.0% proficiency to over 90.0%. Now, the above characteristics are described for individual teachers in the study.

Teacher A

This teacher was a member of the second cohort of MCE Program participants and graduated from the program in the summer of 2003. He/She has taught high school level science courses in the SDP for 15 years, including all levels of chemistry, from regular to accelerated.

For this research, three classes of an accelerated course were observed. This course was taught 2 days per week and there were no double laboratory periods assigned to the course. Each class period was 53 minutes long.

The purpose of this course was to review curricular material for the examination in the accelerated course. Therefore, a wide range of topics were covered in the observed classes. These included bonding theories, hydrocarbon nomenclature, rates of reaction, activation energy, catalysis, stoichiometry problems, chemical equilibrium and application of Le Chatelier's principle, enthalpy and heat of reaction, electronegativity and its variation across the periodic table, drawing structural formulae of organic compounds, greenhouse effect, global warming, water purification by ion exchange, bond angle, bond energy, specific heat problems, gas laws problems, and oxidation/reduction etc.

In any class of this course that the researcher observed, there were 23-29 students in attendance. Further, there was only one African American student in the course, quite unlike the overall diversity of the school (see below). The rest of the students in the course were almost equally divided between White and Asian. The students were a mix of juniors and seniors.

The school where teacher A taught is one of the large (over 2000 students) comprehensive high schools in a desirable neighborhood in the city, with students drawn from all over the city. The student population is quite diverse (~37.0% African-American, ~40.0% White, ~12.0% Asian, and ~10.0% Hispanic). Adding to the ethnic diversity of the student body are ~17.0% students with special needs, ~9.0% of English language learners, and ~8.0% mentally gifted students. A little over 46.0% of students are eligible for free or reduced cost lunch, an indicator of the level of poverty in the student body (in the city ~75.0% of students are eligible for free or reduced lunch). About 36.0% and 33.0% of the 11^{th} grade students scored proficient or better in the state's reading and math assessments (PSSA) respectively, only slightly above the city levels and well below the state levels in both the subjects.

Teacher B

This teacher was a member of the first cohort of MCE Program participants and graduated from the program in the summer of 2002. He/She has taught high school level science courses in the SDP for 6 years. Among the courses taught are, regular chemistry and physical science.

For this study, three classes of a regular chemistry course were observed. Teacher B taught this course 5 days per week, and there were no double laboratory periods assigned to the course. Each class period was 51 minutes long. Since most of the students were planning for non-science careers, this was their last science course needed to fulfill the science requirements for graduation from high school.

The topics covered in the three observed classes were: drawing the structures of polyatomic ions and molecules with double/triple bonds, reviewing post lab questions on classifying chemical reactions (for an impending exam), solving problems by substitution in various formulae on gas laws.

In any of the three observed classes, there were 21-26 students in attendance. The diversity in the students in the course was quite similar to the overall diversity of the school's student population (see below). All the students taking the course were juniors. The school where teacher B taught is a small (under 700 students) special admissions school where only students who fulfill certain criteria are admitted, drawn from all over the city. The student population is quite diverse (~44.0% African-American, ~42.0% White, ~5.0% Asian, and ~7.0% Hispanic). Adding to the ethnic diversity of the student body are ~4.0% with special needs, ~2.0% of English language learners, and ~21.0% mentally gifted students. A little over 44.0% of students are eligible for free or reduced cost lunch. In the 11^{th} grade, approximately 80.0% and 70.0% of students scored proficient or better in the state's reading and math assessments (PSSA) respectively, well over the city and state levels in both the subjects.

Teacher C

This teacher was a member of the first cohort of MCE Program participants and graduated from the program in the summer of 2002. He/She has taught high school level science courses in the SDP for 12 years. Among the courses he/she has taught are chemistry at all levels, from regular to AP, and physical science.

The researcher observed 3 classes of an accelerated course taught by teacher C. This course met 6 times per week and there were no double laboratory periods assigned to the course. Each class period was 50 minutes long. All the students in the course were sophomores. Most students in the school take more than the minimum number of courses required for graduation and apply to the best colleges in the nation. Therefore, this was one of a few science courses that they take at this accelerated level.

The topics covered in the observed classes were: vapor pressure, application of Clausius-Clapeyron equation, phase diagram, equilibrium and Le Chatelier's principle, using the specific heat formula, relationship between boiling point and intermolecular forces, bond energy, rates of reaction, applying the formula for equilibrium constant, and finding the solubility product of a reaction etc.

In any of the three observed classes, there were 25-26 students in attendance. There was only one African American student in the course, quite unlike the overall diversity of the school (see below). The rest of the students in the course were almost equally divided between White and Asian.

The school where teacher C taught is a large (over 2000 students) special admissions school where only students who fulfill certain criteria are admitted, drawn from all over the city. The student population is quite diverse (~32.0% African-American, ~33.0% White, ~26.0% Asian, and ~8.0% Hispanic). Adding to the ethnic diversity of the student body is ~1.0% with special needs, ~3.0% of English language learners, and ~44.0% mentally gifted students. A little over 43.0% of students are eligible for free or reduced cost lunch. In the 11^{th} grade, a little over 97.0% and 96.0% of students scored proficient or better in the state's reading and math assessments (PSSA) respectively, considerably above the city and state levels in both the subjects.

Teacher D

This teacher was a member of the second cohort of MCE Program participants and graduated from the program in the summer of 2003. He/She has taught high school level science courses in the SDP for 13 years. Among the courses taught are, regular and honors chemistry and physical science.

For this study the researcher observed three classes of a regular chemistry course. Teacher D taught 6 classes of this course per week, including a double laboratory period. Each class period was 52 minutes long. For a majority of the students this was their last science course needed to fulfill the science requirements for graduation from high school.

The topics covered in the observed classes included writing total and net ionic equations, explanation of dissociation of solids in liquids, stoichiometry problems, plugging into formulae on gas laws to find the unknown, carrying out the distillation of a mixture (student lab), intermolecular forces and boiling points, behavior of substances on lowering ambient pressure (teacher demonstration) etc.

In any of the observed classes, there were 21-22 students in attendance. The diversity of the class reflected the overall diversity of the school (see below). Vast majority of students in the class were juniors.

The school where teacher D taught is a small (under 600 students) special admissions school where only students who fulfill certain criteria are admitted, drawn from all over the city. The student population is quite diverse (~56.0% African-American, ~18.0% White, ~12.0% Asian, and ~13.0% Hispanic). Adding to the ethnic diversity of the student body are ~2.0% with special needs, ~1.0% of English language learners, and ~20.0% mentally gifted students. A little over 60.0% of students are eligible for free or reduced cost lunch. In the 11th grade, about 84.0% and 75.0% of students scored proficient or better in the state's reading and math assessments (PSSA) respectively, well over the city and state levels in both the subjects.

Teacher E

This teacher was a member of the fifth cohort of MCE Program participants and graduated from the program in the summer of 2006. He/She has taught high school level science courses in the SDP for 5 years, including regular chemistry and physical science. Three classes of teachers E's regular chemistry course were observed by the researcher. These classes met everyday, and there were no double laboratory periods assigned to the course. Each class period was 55 minutes long.

The topics covered in the observed classes were: calculating the percentage composition of a compound, finding the empirical formula of a compound, substituting in various gas law formulae and finding the unknown, and applying ideal gas law and combined gas law to solve problems.

In any one of the observed classes, there were 25-26 students in attendance. Further, there was only one Asian student in the course, quite similar to the lack of diversity of the overall student population (see below). A vast majority of the students were juniors.

The school where teacher E taught is one of the large (over 2000 students) comprehensive high schools, in one of the poorer sections of the city, with students drawn from the neighborhood. The student population is not at all diverse (~98.0% African-American, and each of the other groups, i.e., White, Asian, and Hispanic under 1.0%). There are ~15.0% students with special needs, less than 1.0% of English language learners, and ~1.0% gifted students. A little over 71.0% of students are eligible for free or reduced cost lunch. Roughly 15.0% and 10.0% of the 11th grade students scored proficient or better in the state's reading and math assessments (PSSA) respectively, well below the city and state levels in both the subjects.

Teacher F

This teacher was a member of the third cohort of MCE Program participants and graduated from the program in the summer of 2004. He/She has taught high school level science courses in the SDP for 11 years including regular and honors chemistry and physical science.

Three classes of a regular chemistry course were observed by the researcher for this study. The course met 5 times per week, with no double laboratory periods. Each class period was 52 minutes long.

The topics covered in the observed classes included: listing evidence of chemical reactions, translating a chemical equation into words, classifying chemical reactions, balancing chemical equations, developing explanation for bond dissociation, given the reactants predict the products, identify the type of reaction, write the chemical equation, and balance the equation.

In any of the three classes that this researcher observed, there were 26-27 students in attendance. Further, all the students were African American, quite similar to the overall lack of diversity in the student population (see below). All the students were juniors and this was their last science course needed to fulfill the science requirements for graduation from high school.

The school where teacher F taught is a small (under 300 students) special admissions school where only students who fulfill certain criteria are admitted, drawn from all over the city. The student population is not at all diverse (~97.0% African-

American, ~1.0% White, less than 1.0% Asian, and ~1.0% Hispanic). Additionally, there were ~2.0% students with special needs, ~7.0% mentally gifted students, and no English language learners. A little over 59.0% of students are eligible for free or reduced cost lunch, an indicator of the level of poverty in the student body. In the 11th grade, ~42.0% and ~10.0% of students scored proficient or better in the state's reading and math assessments (PSSA) respectively, well below the state levels in both the subjects and above the city level in reading only.

Overview of Data Analysis

The purposes of this study were: to ascertain the extent that six high school chemistry teachers implemented research-based practices, learned during an intensive 26-month professional development, in their respective urban classrooms. The extent of implementation was examined, first for the group and then for the individual teachers, with respect to three aspects of the research-based practices: (1) lesson design and implementation; (2) content; and (3) classroom culture (Sawada et al., 2002). Also, this study ascertained how the implementation of research-based practices differed among the six teachers. Furthermore, this study determined the concerns of the teachers regarding the factors that helped or hindered the implementation of research-based practices in their respective classrooms.

To answer the research questions multi-source data were utilized at various times throughout the 12-15 week long study. The data sources included:

(1) Survey of Concerns Questionnaire (SoCQ) with 3 open-ended questions added by the researcher;

(2) Reformed Teaching Observation Protocol (RTOP);

(3) Teachers' Lesson Plans;

(4) Reformed Teaching Observation Protocol Teacher Survey (RTOPTS); and

(5) Semi-structured Interview.

In this chapter, information from the appropriate and relevant data sources are reported, summarized, analyzed, and discussed in relation to each research question. The findings for research question 1 are based on the analyses of data from the five sources for the teachers as a group. The findings for research question 2 are based on the same data sources used in research question 1, but this time the analyses are reported for the individual teachers. For research questions 3 and 4, both group and individual teachers' data from two sources (amended SoCQ and the semistructured interview) are reported and analyzed.

Findings for Research Question 1

Research Question 1: How does graduation from a twenty-six month content intensive professional development program for high school teachers, whose goal is to improve the teachers' knowledge of research-based instructional practices (in the domains of lesson design and implementation, content, and classroom culture), affect the classroom practices of the group of teachers in an urban environment?

In order to ascertain the level of implementation of MCE program practices of the six teachers when considered as a group, three contributory questions guided separate analyses of the group's responses to SoCQ's first open-ended question, RTOP, teachers' lesson plans, RTOPTS, and the teacher interview data. The contributory questions were:

(1) To what extent do the group's lesson design and implementation reflect the research-based instructional practices?

(2) To what extent are the group's content knowledge and application of supportive procedures exhibited during their classroom instruction?

(3) To what extent does the group of teachers promote a student-centered classroom culture, consistent with the research-based practices?

Each of the contributory questions targeted the group's level of implementation of MCE Program practices, on a global scale, with respect to one of three domains: (1) lesson design and implementation; (2) content; and (3) classroom culture.

For research question 1, the following data sources were used:

1) Open-ended questions 1a and 1b amended to the SoCQ;
2) RTOP;
3) Teachers' lesson plans;
4) RTOPTS; and
5) Three (3) interview questions related to lesson planning and content

Open-ended Questions 1a and 1b Amended to Survey of Concerns Questionnaire (SoCQ): Groups' Level of MCE Program Practices Implementation Self-Rating Results

The reader is reminded that a copy of the SoCQ and open-ended questions appears in Appendix F. Also, descriptions of the SoCQ and the open-ended questions, as well as their respective scoring procedures, appear in Chapter 3.

Question 1a asked the teachers, "In your use of the MCE program practices, do you consider yourself to be a/an; Non-user, Novice, Intermediate, Old-hand, or Past user?" In order to compute the descriptive statistics for the group's perception of their implementation characteristic, the five descriptors (Non-user, Novice, Intermediate, Old-hand, and Past-user) were assigned a numerical value from 0 to 4, in the order presented above (Non-user=0, Past-user=4). Results revealed that the average self-reported implementation characteristic score for the group was 1.7. Furthermore, the group's self-reported implementation of MCE program practices characteristic fell between the Novice and Intermediate levels.

Question 1b asked the teachers, "On a scale of 0 to 10, where do you place your level of implementation of the MCE program practices?" Descriptive statistics were computed for the group using each member's self-reported level of implementation of the MCE program practices scores. For the group, analysis revealed a mean self-reported level of MCE Program implementation group practices score of 4.5 (SD=3.6).

As the range of possible implementation of practices scores for this self-reported response was from 0 to 10, a level of implementation continuum was created to continue this analysis. Scores of '0' and '10' were indicative of the absence of implementation of the MCE Program practices (ABSENT) and complete implementation of MCE program practices (MCE PROGRAM INTENTION), respectively. These scores and categories established the endpoints of the continuum. Scores that fell within a range that was 'greater than 0, and up to and including 5' were considered a low level of implementation of the MCE program practices (LOW LEVEL), whereas scores that were 'greater than 5 but, less than 10' were indicative of a high level of implementation of the MCE program practices (HIGH LEVEL). These four categories and their associated scores and/or range of scores are presented in Table 1.

Table 1. *Level of Implementation of MCE Program Practices Categories vs. Teacher's Self-rating Scores*

Level of Implementation Category	Self-rating Score
ABSENT	0
LOW LEVEL	$0 < S \leq 5$
HIGH LEVEL	$5 < S < 10$
MCE PROGRAM INTENTION	10

In extending the above analysis using Table 1, the mean of the group's implementation of MCE program practices self-rated score (M=4.5, SD=3.6) falls within the 'LOW LEVEL' of implementation category.

Discussion

The analyses conducted suggest that there is a low degree of implementation of the MCE Program practices reported by the group of six teachers. These results are compatible with other studies where the teachers' self-reported scores were classified as low to moderate levels of implementation of professional development practices exercised in their respective classrooms (Geijsel, Sleegers, van den Berg, & Kelchtermans, 2001; Dutro, Fisk, Koch, Roop, & Wixson, 2002; Basista & Mathews, 2002). Geijsel, et al. (2001) found in their study that "the average scores show that the teachers implement the principles underlying the relevant educational innovation into actual teaching practice less than they agree with principles" (p. 156). Similar results of low degrees of classroom implementations have been reported by several researchers

(Elmore, 1996; van den Berg & Vandenberghe, 1986), including a reform-based curriculum in high school chemistry (Roehrig & Kruse, 2005).

Reformed Teaching Observation Protocol (RTOP) Results

In order to explore the group's overall level of implementation of the MCE program practices, this researcher first assigned RTOP scores (in compliance with the instrument-scoring procedures identified in Chapter 3) to each of the three classroom observations on the four instrument-related measures (Total, Lesson Design and Implementation, Content, and Classroom Culture). Then, the group's average total scores and domain scores were computed. The reader is reminded that a copy of the RTOP can be found in Appendix G, and a detailed description of the instrument's domains and statements appear in Chapter 2.

RTOP Total Scores and Domain Scores for the Group's Classroom Observations

Table 2 contains the summary results for the group's mean RTOP total scores and mean RTOP domain scores for each of the three classroom observations made by the researcher.

Table 2 indicates the group's mean RTOP total scores were 40.7 (SD=13.2) and 40.7 (SD=10.3) for the first and the third classroom observations, respectively. The mean RTOP total score for the group for the second observation was 43.5 (SD=14.5), which was only slightly higher than the means of the other two classroom observations.

For the first classroom observation, Table 2 indicates that the group's content domain score (M=47.5, SD=13.8) was the highest. Table 2 also reveals that the group's classroom culture domain score (M=39.6, SD=18.4) was higher than the lesson design and implementation domain score (M=29.2, SD=16.3).

Table 2. *Mean and Standard Deviation of the RTOP Total Scores and Domain Scores for Three Classroom Observations for the Group*

RTOP	RTOP Domain*	Observation 1		Observation 2		Observation 3	
		M	SD	M	SD	M	SD
Total		40.7	13.2	43.5	14.5	40.7	10.3
	Lesson Design and Implementation	29.2	16.3	38.3	18.0	29.2	12.0
	Content	47.5	13.8	50.4	11.3	48.8	6.0
	Classroom Culture	39.6	18.4	39.2	20.0	38.3	20.3

*RTOP Domain scores are expressed as weighted percentages.

For the second classroom observation, the group's content domain score (M=50.4, SD=11.3) was the highest. Further, the classroom culture domain score (M=39.2, SD=20.0) for the group was higher than the lesson design and implementation domain score (M=38.3, SD=18.0).

For the third classroom observation, the group's content domain score was the highest (M=48.8, SD=6.0). Additionally, the group's classroom culture domain score (M=38.3, SD=20.2) was higher than the lesson design and implementation domain score (M=29.2, SD=12.0).

The results show that the group's content domain scores were the highest for each of the three classroom observations. The results also show that the group's classroom culture domain scores were higher than the lesson design and implementation domain scores for each of the three classroom observations.

As described in Chapter 2, the maximum range of possible RTOP scores was from 0 to 100. The reader is also reminded that there exists no agreed upon demarcations within this range to gauge the level of implementation of research-based and/or reform-based practices. Using the maximum RTOP score range, RTOP-related literature and relevant research described in Chapter 2, this researcher created a continuum to ascertain the level of implementation of MCE program practices for the group of teachers.

In this continuum, scores 'equal to and greater than zero and less than 25' were indicative of the absence of the implementation of MCE program practices (ABSENT). Scores 'equal to and greater than 25 and less than 50' represented a low level of implementation of the MCE program practices (LOW LEVEL), whereas scores in the range 'equal to and greater than 50 and less than 75' represented a high level of implementation of MCE program practices (HIGH LEVEL). Scores 'equal to and greater than 75 and less than or equal to 100' represented the full implementation of MCE program practices (MCE PROGRAM INTENTION). These four levels of implementation and their corresponding ranges of RTOP scores are presented in Table 3.

This continuum was utilized to analyze the group's average RTOP total scores, and the average RTOP domain scores (see chapter 3 for a discussion of weighted percentages). It is apparent that the group's average RTOP total scores assigned by this researcher (see Table 2), indicative of the overall level of implementation of MCE program practices, fell within the ‘LOW LEVEL’ implementation category in Table 3 for each of the three observations.

Table 3. *Level of MCE Program Practices Implementation vs. RTOP Scores*

Level of Implementation Category	RTOP Score
ABSENT	$0 \leq S < 25$
LOW LEVEL	$25 \leq S < 50$
HIGH LEVEL	$50 \leq S < 75$
MCE PROGRAM INTENTION	$75 \leq S \leq 100$

*RTOP Scores are expressed as percentages

It is evident that all of the group’s average RTOP domain scores across the three classroom observations (see Table 2) fell within the implementation category of ‘LOW LEVEL’ in Table 3, with the exception of the group’s average RTOP content domain score for the second observation, which lied within the level of implementation category of ‘HIGH LEVEL’ in Table 3.

Discussion

RTOP Total Scores for the Group of Teachers:

Analyses of the classroom observations suggested that the group of teachers implemented the research-based practices in their classrooms to a low extent. In other words, a total score of less than 45 is indicative of “traditional high school physics lecture with student questions” (MacIssac & Falconer, 2002, p. 482). In studies of the classroom practices of randomly selected high school science teachers (including both beginning and experienced teachers), the average RTOP total score ranged from 41.4 to 43.5 (Judson & Sawada, 2001; Sawada et. al, 2002). In this present study, the average RTOP total score earned by the group is typical of beginning or experienced high school teachers implementing the ‘traditional’ lecture type of lesson with student questions, focused on transmitting content knowledge rather than using the most appropriate instructional practices (Chang, 1998). Furthermore the scores of similar lessons sometimes differ within 5 points of each other, as was the case in this present study where the group scores ranged from 40.7 to 43.5.

RTOP Domain Scores for the Group of Teachers:

Analysis shows that the group’s average RTOP domain score was consistently the highest in the content domain, followed by classroom culture. Furthermore, the domain lesson design and implementation received the least average score.

In the literature, the scores in the three domains are distributed in different ways for different groups of teachers. For some groups of teachers, the order of domain scores (from the highest to the lowest score) was the same as obtained in this study, i.e., content, classroom culture, and lesson design and implementation (Falconer, Wyckoff, Joshua, & Sawada, 2001; Judson & Sawada, 2001). These results suggest that the lessons of the teachers in the study are “coherent with respect to content but are lacking in the other dimensions of reform” (Falconer, Wyckoff, Joshua, Sawada, 2001, p.15). This distribution of scores among the domains is in alignment with two of the stated goals of the MCE program, i.e., to impart the depth of understanding of content of chemistry and to promote inquiry-based methods. The lowest score in the lesson design and implementation domain points to the, relative, lack of explicit emphasis on lesson design and implementation or modeling of this aspect of reform-based practices.

However, in other studies, for two different groups of teachers, the average score in the classroom culture domain was the highest, followed by that in the content domain, and then the lesson design and implementation domain (Judson & Sawada, 2001). In yet another study, using an instrument similar to RTOP, the domains classroom culture and lesson design and implementation had similar scores, followed by the content domain score (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Therefore, the relative scores of the three domains are germane to the group of teachers being observed.

Results of the Analysis of Teachers' Lesson Plans

The teachers were asked to provide their lesson plans on the days they were observed. Surprisingly, only 39% of the lesson plans were provided to the researcher on the days of observation, while 61% of the lesson plans were sent via inter-office mail or electronic mail, several days later after repeated requests and reminders. As a result of this researcher's observations of the individual lesson plans, it became apparent that the teachers did not adhere to a set format for the written lesson plan. Examples of what was noted by this researcher included: lists of tasks for students; notes on the content to be covered, Microsoft PowerPoint™ on the main topic; test items that the teacher planned to review; and lists of assignments (in-class and homework) that students were to complete. Since there were no common elements among the lesson plans, this researcher decided not to include further analyses of the lesson plan data in this research. The reader is directed to Appendix H for a sample of a lesson plan that was submitted by one of the teachers in this present study.

RTOPTS Results

In order to determine the overall level of implementation of the MCE program practices by the group, the teachers were asked to rate their own lessons taught using a five point Likert-type scale (0=never occurred, 1= occurred at least once, 2= occurred more than once, 3=occurred frequently, and 4=occurred pervasively or very descriptive of the lesson) for each of the 25 statements constituting the RTOPTS. From the self-reported scores given by the individual teachers, descriptive statistics were computed for the group. The descriptive statistics consisted of the mean RTOPTS total score for the group as well as the mean RTOPTS domain scores (lesson design and implementation, content, classroom culture) for the group. The reader is referred to chapter 2 for a description of the RTOPTS instrument and to Appendix I for a copy of the instrument.

RTOPTS Self-Reported Total Score and Domain Scores for the Group

Table 4 contains the summary statistics of means and standard deviations for the group's self-reported RTOPTS total score and RTOPTS domain scores.

Table 4 indicates the average self-reported RTOPTS total score of the group to be 79.2 (SD=3.1).

Table 4 shows that the mean content domain score (M=85.0, SD=3.5) was the highest among the three domains. Further, Table 4 reveals that the mean classroom culture domain score (M=80.0, SD=5.7) was higher than the mean lesson design and implementation domain score (M=67.5, SD=9.4).

Table 4. *Mean and Standard Deviation of RTOPTS Total and Domain Scores for Group*

RTOPTS	RTOPTS Domain*	Self-reported Score	
		M	SD
Total		79.2	3.1
	Lesson Design and Implementation	67.5	9.4
	Content	85.0	3.5
	Classroom Culture	80.0	5.7

*RTOPTS Domain Scores represent weighted percentages (see chapter 3)

The continuum devised in Table 3 was used to evaluate the group's level of implementation of MCE program practices for the average self-reported RTOPTS total and domain scores. It is evident that the mean self-reported RTOPTS total score of the group fell within the 'MCE PROGRAM INTENTION' category. Further, the group's mean self-reported RTOPTS domain scores for the content and classroom culture domains fell within the 'MCE PROGRAM INTENTION' category, and the group's mean self-reported RTOPTS score for lesson design and implementation domain belonged in the 'HIGH LEVEL' category.

Discussion

The self-reported scores of the teachers in this study were consistent with a national survey result of chemistry teachers, where 81-97% of teachers self-rated their lessons very highly on statements similar to those on the RTOPTS, indicative of highly accomplished practitioners of reform-based methods (Smith, 2002). Some other studies have also reported high self-reported scores (Fishman, Marx, Best, & Tal, 2003; Truxaw, Grgieveski, & DeFranco, 2008).

Total scores approaching 80 and beyond, as self-reported by the group of teachers in this study, were "typical of college instructors who have embraced reformed pedagogy" (Judson & Sawada, 2001, p. 23).

The average self-reported RTOPTS total score (79.17) for the group was similar to the range of total scores (66-79) of six observations of a college Physics course implementing reform-manner of teaching (Falconer, Wyckoff, Joshua, & Sawada, 2001). Also, the self-reported average RTOPTS domain scores for the teachers in this study (lesson design and implementation = 67.5, content = 85.0, classroom culture = 80.0) were similar to the domain scores of the observations (N=6) of the above mentioned Physics course implementing reform-based practices (lesson design and implementation = 65.9, content = 77.5, and classroom culture = 72.9) (Falconer, Wyckoff, Joshua, & Sawada, 2001).

Semi-Structured Interview's Open-ended Questions on Lesson Planning and Content: Group's Level of MCE Program Practices Implementation Response Results

In order to explore the group's level of implementation of the MCE program practices, the teachers' views of their individual levels of implementation of these practices in their respective classrooms with respect to lesson planning and content were ascertained via their responses to three open-ended questions. The questions were:

(1) How do you plan your lesson?

(2) What is important to you when you are planning your lesson and do you have a certain format for it?

(3) What do you do to make sure that students develop a depth of understanding of the content?

For a copy of the semi-structured interview questions, the reader is referred to Appendix J.

To analyze the teachers' responses to these questions, statement codes representing the 25 RTOP statements were created. These statement codes were grouped under their respective domains of lesson design and implementation, content, and classroom culture respectively. Teachers' responses were examined independently by the researcher and a co-rater, and placed under the statement codes they best fit as the evidence of a statement code. Differences in the placements of responses, between the researcher and the co-rater, were reconciled. Some statement codes had no evidence among the responses. These were indicated as 'No Response'. All the RTOP statement codes and a sample teacher response for each are listed in Appendix Q.

A summary of the percentages of the group's responses that aligned with the RTOP statements overall, and with the statements in each of the three domains, is presented below in Table 5. The construction of a rich, thick description emanating from the teachers' responses to the three interview questions on the topic of lesson planning is deferred until the next research question.

Overall, the results indicated that 36% of the group's responses to the three interview questions addressed the possible 25 RTOP codes. Further, 43% of the group's responses agreed with the 5 statements in the domain of lesson planning and implementation, 32% of the group's responses agreed with the 10 statements under the content domain, and 37% of the responses agreed with the 10 statements pertaining to the classroom culture domain.

Table 5: *Group's Response to 3 Interview Questions in Percentages*

3 Interview Questions	RTOP Domain	Percentage of Group's Responses in Agreement with RTOP Statements
Total		36
	Lesson Design and Implementation	43
	Content	32
	Classroom Culture	37

In continuing the analysis, Table 3 was utilized to rate the group's level of implementation of MCE program practices based on responses to the three interview questions. It is evident that the group's total responses, as well as, the responses in the three domains of lesson design and implementation, content, and classroom culture fell within the category of "LOW LEVEL" of implementation.

Discussion

The overall low ratings of the implementation of MCE program practices, as well as the low ratings in the domains of lesson design and implementation, content, and classroom culture are consistent with the findings of the national study called 'Inside the Classroom' (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Based on the observations of math and science classrooms, the study found 59% of the lessons taught to be of overall low quality in terms of their effectiveness. Further, in the national study, the modal ratings of the domains lessons design and implementation, and content were 2 out of 5, whereas the modal rating for the classroom culture domain was between 2 and 3 out of 5 (on a Likert-type scale, with 1=none at all, to 5=to a great extent).

The findings for research question 1 and its three contributory questions derived from four data sources (SoCQ, RTOP, Interview Questions, RTOPTS) are summarized in Table 6 on the following page.

Findings for Research Question 2

Research Question 2: How are the teachers' classroom practices (in the domains of lesson design and implementation, content, and classroom culture) different from each other when implementing the research-based MCE program practices?

In order to ascertain the differences in implementation of MCE program practices among the teachers who participated in the study, three contributory questions guided separate analyses of teachers' responses to SoCQ's first open-ended question, RTOP, RTOPTS, and the teacher interview data. The contributory questions were:

(1) To what extent are the teachers' designed and implemented lesson plans different from each other when implementing the practices?

(2) To what extent are the teachers' content knowledge and application of supportive procedures exhibited during their classroom instruction different from each other?

(3) To what extent is the teachers' promotion of a student-centered classroom culture different from each other, consistent with the research-based practices?

Each of the contributory questions targeted the teachers' implementation of MCE Program practices, on an individual basis, with respect to one of three domains: (1) lesson design and implementation; (2) content; and (3) classroom culture.

Table 6: *Summary of Findings from Data Sources (SoCQ, RTOP, Interview Questions, RTOPTS) for Research Question 1 and Three Contributory Questions (1a, 1b, 1c) for the Group of Teachers*

Data Source	Data Source Domains	Level of Implementation			
		Absent	Low	High	Full*
SoCQ (Appendix F)					
Open-ended Question 1a			X		
Open-ended Question 1b			X		
RTOP (Appendix G)					
	Total (Three Domains Below)		X		
	Lesson Design & Implementation		X		
	Content		X		
	Classroom Culture		X		
Interview Questions (Appendix J)					
	Total (Three Domains Below)		X		
	Lesson Design & Implementation		X		
	Content		X		
	Classroom Culture		X		
RTOPTS (Appendix I)					
	Total (Three Domains Below)				X
	Lesson Design & Implementation			X	
	Content				X
	Classroom Culture				X

* Full designates the MCE Program Intention

Following data sources were used for the research question 2:

(1) Open-ended questions 1a and 1b amended to the SoCQ;

(2) RTOP;

(3) RTOPTS; and

(4) 3 interview questions related to lesson planning and content

For the purpose of this research, the differences that were noted among the teachers were limited to the extent that the coded, individual teacher responses and scores differed from the coded responses and scores of the other teachers in the group (see Chapter 3). Born of this investigation which focused on differences among the teachers' implementation of MCE program practices, similarities of the teachers' practices emerged.

Open-ended Questions 1a and 1b Amended to Survey of Concerns Questionnaire (SoCQ): Individual Teachers' Level of MCE Program Practices Implementation Self-Rating Results

In order to examine the differences in the implementation of MCE program practices among the teachers in this study, individual teachers rated their level of implementation of MCE program practices in terms of a characteristic (NON- USER, NOVICE, INTERMEDIATE, OLD-HAND, and PAST USER) on question 1a. On question 1b, the teachers were asked to provide a score using an eleven-point Likert-type scale (0=no implementation and 10=full implementation). The reader is referred to Appendix F for questions 1a and 1b. Table 7 summarizes the teachers' (N=6) self-reported characteristic (question 1a) and numerical score (question 1b) of the level of implementation of MCE program practices (hereafter referred to as level of implementation).

Table 7: *SoCQ Open-ended Questions 1a and 1b Self-Reported Characteristics for Level of Program Use and Program Implementation Score for the Teachers (N=6)*

Self-Reported Characteristics	Teacher					
	A	B	C	D	E	F
Level of Program Use	I	NU	I	I	I	I
Program Implementation Score	5.0	0.0	0.0	7.0	8.0	7.0

I=Intermediate; NU=Non-user

It is evident that the self-reported level of program use characteristic among the teachers (N=6) was split into two categories: INTERMEDIATE (83.3%) and NON-USER (16.7 %). Specifically, teachers A, C, D, E, and F rated their level of implementation of MCE program practices as INTERMEDIATE, whereas teacher B rated his/her level of implementation as NON-USER.

Using the continuum developed in Table 1 as part of research question 1, it is apparent that the self-rated level of implementation scores of three teachers (50.0%) fell in the category 'HIGH LEVEL' and one teacher's (16.7%) score was at the 'LOW LEVEL'. Furthermore, two teachers' (33.3%) scores were designated as 'ABSENT'.

Specifically, scores of teachers D, E, and F were designated at a 'HIGH LEVEL', and teacher A's score represented a 'LOW LEVEL'. Teachers B and C's scores were classified as 'ABSENT '.

Discussion

Five out of six teachers (83.3%) characterized their levels of the use of MCE program practices as Intermediate. One teacher (16.7%) did not use the practices in his/her classroom at all, characterizing himself/herself as a Non-user.

Among four out of six teachers (66.8%) who admitted to implementing the MCE program practices, 75.0% perceived a high-degree (teachers E, D, and F) and 25.0% perceived a low-degree (teacher A) of implementation in their respective classrooms. All other teachers (teachers B and C) felt they were not implementing the practices.

Reformed Teaching Observation Protocol (RTOP) Results

As explained in research question 1, in order to determine the level of implementation of MCE program practices by individual teachers, this researcher observed three lessons of each teacher and computed RTOP scores: (1) total; (2) lesson design and implementation; (3) content; and (4) classroom culture. Since the observed lessons of teachers were different and admitted of a wide variety of topics, the analyses of scores was not warranted. Rather, average RTOP scores for the total and domains were computed for each teacher. Table 8, on the following page, summarizes the average RTOP total and domain scores for each teacher.

In continuing the analysis, Table 8 is used in conjunction with Table 3 to categorize the average RTOP scores in terms of levels of implementation. The continuum established in Table 3 was utilized to analyze all the RTOP scores (see chapter 3 for a discussion of weighted percentages).

Table 8: *Average Total and Domain RTOP Scores for Each Teacher (N=6)*

RTOP	RTOP Domain	Average RTOP Score for Teacher Observations					
		A	B	C	D	E	F
Total		32.3 (0.6)	48.0 (6.9)	25.0 (1.0)	40.3 (6.7)	58.3[1] (8.9)	45.7 (3.2)
	Lesson Design and Implementation	26.7 (10.4)	38.3 (14.4)	13.3[2] (5.8)	33.3 (5.8)	51.7[1] (10.4)	30.0 (17.3)
	Content	53.3[1] (1.4)	53.3[1] (9.5)	38.3 (1.4)	40.0 (12.5)	60.0[1] (8.7)	48.3 (5.8)
	Classroom Culture	14.2[2] (5.2)	47.5 (8.7)	17.5[2] (2.5)	44.2 (5.8)	60.0[1] (8.7)	50.8[1] (3.8)

RTOP Domain scores are expressed as weighted percentages.
( ) Designates standard deviation
Scores are at the LOW LEVEL of implementation unless indicated otherwise;
[1]Designates score at the HIGH LEVEL of implementation;
[2]Designates score at the ABSENT level of implementation.

Average RTOP Total Score

Specifically, the results indicated that teacher E received an average RTOP total score (M=58.3, SD=8.9) that was at the HIGH LEVEL. Scores for teacher A (M=32.3, SD=0.6), teacher B (M=48.0, SD=6.9), teacher D (M=40.3, SD=6.7), teacher F (M=45.7, SD=3.2), and teacher C (M=25.0, SD=1.0) were at the LOW LEVEL. The range of the average RTOP total scores was 25.0 – 58.3.

The average RTOP total score for one teacher (16.7%) was categorized as HIGH LEVEL, whereas the scores for the remaining five teachers (83.3%) were at the LOW LEVEL of implementation.

Average RTOP Domain Scores

Lesson Design and Implementation Domain:

Results revealed that the average RTOP domain score for teacher E (M=51.7, SD=10.4) was at the HIGH LEVEL. Scores for teacher A (M=26.7, SD=10.4), teacher B (M=38.3, SD=14.4), teacher D (M=33.3, SD=5.8), and teacher F (M=30.0, SD=17.3) indicated a LOW LEVEL, and teacher C's (M=13.3, SD=5.8) score designated the ABSENT level of implementation. The range of average RTOP lesson design and implementation domain scores was 13.1-51.7.

The average RTOP lesson design and implementation domain score for one teacher (16.7%) was categorized as HIGH LEVEL, whereas the scores of four teachers (66.6%) were at the LOW LEVEL. The score of one teacher (16.7%) was at the ABSENT level.

Content Domain:

The results yielded that the average RTOP content domain scores for teacher A (M=53.3, SD=1.4), teacher B (M=53.3, SD=9.5), and teacher E (M=60.0, SD=8.7) were at the HIGH LEVEL. Furthermore, the scores of teacher C (M=38.3, SD=1.4), teacher D (M=40.0, SD=12.5), and teacher F (M=48.3, SD=5.8) represented the LOW LEVEL of implementation. The range of average RTOP content domain scores was 38.3-60.0. The average RTOP content domain scores for three teachers (50.0%) were designated as HIGH LEVEL, whereas the remaining teachers (50.0%) scored at the LOW LEVEL.

Classroom Culture Domain:

The results showed that the average RTOP classroom culture domain scores of teacher E (M=60.0, SD=8.7) and teacher F (M=50.8, SD=3.8) denoted the HIGH

LEVEL, and the scores of teacher B (M=47.5, SD=8.7) and teacher D (M=44.2, SD=5.8) represented the LOW LEVEL of implementation. Further, the scores of teacher A (M=14.2, SD=5.2) and teacher B (M=17.5, SD=2.5) fell in the ABSENT level of implementation. The range of average RTOP classroom culture domain scores was 14.2-60.0.

The average RTOP classroom culture domain scores of two teachers (33.3%) were characterized as HIGH LEVEL, and the scores of two teachers (33.3%) were designated as LOW LEVEL. The remaining two teachers (33.4%) scored at the ABSENT level of implementation.

Discussion

The teachers' overall observed extent of implementation was split between two categories. Only one teacher (16.7%) was observed to be practicing the methods of the MCE program to a high degree. Five of the six teachers (83.3%) were observed as implementing the practices to a low extent. Furthermore, these five teachers differed considerably in how they implemented the practices in their urban classrooms. One teacher's level of implementation was close to non-existent, whereas the level of implementation of another teacher was very close to the high level. The other three teachers implemented the MCE program practices very typical of the median behavior for the low level.

In the area of lesson design and implementation, there were wider differences in the observed extent of implementation among the teachers. Only one teacher (16.7%) was observed to be implementing the practices in substantial measure whereas one teacher (16.7%) did not apply any of the practices in her/his classroom teaching. Four teachers

(66.6%) were using the practices in their classrooms to a small degree. The extent of implementation among these four teachers differed greatly, varying from almost non-existent to presence of some elements of reform practice.

The teacher, whose observed practices in lesson design and implementation were aligned to a high degree with the reform-based recommendations, consistently provided detailed lesson plans to the researcher *before* the lessons were observed, while the rest of the teachers' lesson plans were, often, incomplete and submitted after the observations and some prodding.

Three teachers (50.0%) exhibited a high level of Chemistry content knowledge and application of supporting procedures, in a manner consistent with the methods of reform-based practices. This outcome is not surprising, given the intent of the MCE program as the development of deep conceptual understanding of Chemistry using inquiry-based methods (Blasie & Palladino, 2005). However, these three teachers differed substantially in their extent of implementation. The remaining three teachers (50.0%) implemented the reform-based practices in the content area to a low degree, and their practices were more in alignment with the traditional lecture-type mode of knowledge transmission (Chang, 1998). Considerable differences within this group in the manner of implementation of content and related practices were present.

With respect to the implementation of practices in the area of classroom culture, the teachers were equally divided in to three groups (33.3% each). These groups represented high, low, and non-existent degrees of implementation of practices advocated by the MCE program. Since the contexts of practice of the teachers admitted of a wide variety, this spread in the outcome is expected.

RTOPTS Self-Reported Total Score and Domain Scores for the Teachers (N=6)

In order to ascertain the differences in the level of implementation of MCE program practices, individual teachers completed the RTOPTS. The reader is directed to the RTOPTS results section of research question 1, chapter 2, and Appendix I for information regarding RTOPTS.

Table 9 contains the individual teachers' self-reported RTOPTS total score and RTOPTS domain scores. To continue the analysis, this table is used in conjunction with Table 3 to categorize the RTOPTS scores in terms of the levels of implementation. The reader's attention is drawn to the notation used in Table 9, i.e., scores without superscripts denote MCE PROGRAM INTENTION level of implementation. The scores with a superscript represent a HIGH LEVEL implementation.

Table 9. *Self-reported RTOPTS Total and Domain Scores for the Teachers (N=6)*

RTOPTS	RTOP Domain	RTOPTS Teacher Self-reported Score					
		A	B	C	D	E	F
Total		84.0	81.0	79.0	75.0	79.0	79.0
	Lesson Design and Implementation	75.0	65.0[1]	60.0[1]	55.0[1]	80.0	70.0[1]
	Content	87.5	90.0	80.0	85.0	85.0	82.5
	Classroom Culture	85.0	80.0	87.5	75.0	72.5[1]	80.0

All the scores are expressed as percentages.
[1] Designate a HIGH LEVEL of implementation; all other scores represent MCE PROGRAM INTENTION.

RTOPTS Total Score

The results indicated that all the teachers (100%) self-reported their RTOPTS total score in the category MCE PROGRAM INTENTION. The range of self-reported RTOPTS total scores was 75.0 to 84.0.

RTOPTS Domain Scores

Lesson Design and Implementation Domain:

Results revealed that the self-reported RTOPTS lesson design and implementation domain scores for teacher A (75.0) and teacher E (80.0) were at the MCE PROGRAM INTENTION level of implementation. Further, the self-reported scores of teacher B (65.0), teacher C (60.0), teacher D (55.0), and teacher F (70.0) designated the HIGH LEVEL of implementation. The range of RTOPTS lesson design and implementation score was 55.0-80.0.

The RTOPTS lesson design and implementation scores of two teachers (33.3%) fell in the category MCE PROGRAM INTENTION, whereas the scores of four teachers (66.7%) represented the HIGH LEVEL of implementation.

Content Domain:

The results for content domain showed that the self-reported RTOPTS scores for all the teachers (100.0%) were designated by MCE PROGRAM INTENTION level of implementation. The range of RTOPTS content domain scores was 80.0-90.0.

Classroom Culture Domain:

The results for self-reported classroom culture domain yielded that the RTOPTS scores for teacher A (85.0), teacher B (80.0), teacher C (87.5), teacher D (75.0), and teacher F (80.0) were represented by MCE PROGRAM INTENTION level of implementation, whereas teacher E's score (72.5) indicated HIGH LEVEL of implementation. The range of RTOPTS scores for the classroom culture domain was 72.5-87.5.

The self-reported RTOPTS scores of five teachers (83.3%) in the classroom culture domain were at the MCE PROGRAM INTENTION level, and the score of one teacher (16.7%) was categorized as HIGH LEVEL.

Discussion

In their opinion, all the six teachers (100.0%) in this study implemented the practices of the MCE program similarly, i.e., to the fullest extent. Although all the teachers perceived their implementation to be of the highest order, there were differences in how the teachers perceived the application.

In the lesson design and implementation area, teachers' perceived level of implementation was split in to two categories, with two (33.3%) teachers reporting the implementation to the fullest possible extent and four teachers (66.7%) to a high degree. Again, teachers within each of the two categories differed from each other in how they carried out the self-reported implementation. As stated earlier, implementation at such high levels are indicative of highly accomplished practitioners of reform-based methods (Judson & Sawada, 2001).

In the content area, the teachers unanimously felt that they were implementing the MCE program practices in their classrooms to the fullest possible extent by exhibiting a deep knowledge of the subject and application of supportive instructional procedures.

With respect to the promotion of reform-based classroom culture, five teachers (83.3%) felt that their classroom practices in this area were in total alignment with the recommended practices, while one teacher (16.7%) felt his/her practices were highly aligned. The entire teacher reported results, both for the overall implementation of practices as well as implementation of practices in lesson design and implementation, content, and classroom culture, were indicative of the classroom implementation of MCE program practices to the fullest extent or to a high extent.

Semi-Structured Interview's Open-ended Questions on Lesson Planning and Content: Teachers' Levels of MCE Program Practices Implementation Response Results

In order to ascertain the level of implementation of MCE program practices, teachers' responses to three open-ended questions (see Appendix J) pertaining to lesson planning and content were categorized using the RTOP domain and statement codes that are described in research question. Again, the teachers responded to the following questions: (a) how do you plan your lesson, (b) what is important to you when you are planning your lesson and do you have a certain format for it, and (c) what do you do to make sure that students develop a depth of understanding of the content.

Using the teachers' responses that were parceled into one of three domains, the percentage scores in each domain (lesson design and implementation, content, and classroom culture) were computed. The weighted sum (previously described in chapter 3) of the percentage domain scores yielded the percentage total score for this data source. The percentage total score and the percentage domain scores for the teachers are summarized in Table 10. To convert the scores to levels of implementation, the continuum in Table 3 was utilized.

To support the quantitative data summarized in Table 10, teachers' quotes were sequestered and parceled into at least one of the three domains and a specific RTOP statements when the topic of the statement was mentioned by the teachers. Teachers' quotes were selected from an available pool of quotes derived from their responses, and sample responses are presented next. Responses were selected if they consisted of at least one complete sentence, and in some cases up to several complete sentences when available, that addressed specific RTOP statements in one of the three domains presented. The supporting quotes are organized in the same sequence as the domains appear in Table 10 (i.e., Lesson Design and Implementation, Content, Classroom Culture).

Lesson Design and Implementation:

The first RTOP statement #1 in this domain addressed students' preconceptions/prior knowledge. The specific statement is, "The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein." Teacher A described how the students' prior knowledge is assessed. Teacher A said, "I give them some prior knowledge. Usually I don't assume that my students already know it I just try to start from the basic level." This teacher's practice was consonant with the prior knowledge topic inherent to this RTOP statement.

Teachers described a variety of practices to engage the students as members of a learning community. The specific statement referred to is statement #2, "The lesson was designed to engage students as members of a learning community." On this same topic, Teacher D said

> I also try to have a lab each week that kind of ties in with what we're doing. I might do two or three labs on one topic if I have some that are engaging the kids like or I think they need to understand more about a topic or I'll even go back and do another lab that ties in with some things from earlier in the year

While sharing another method used to engage his/her students, Teacher B noted that "the kids have some hands on experience or some type of activity where they can practice their something that is kinesthetic. Usually that's a lab or an activity." Teacher F also elaborated on his/her different techniques used to promote student engagement. According to Teacher F,

> the heart of the lesson will be whatever activity, whatever worksheet or group work, possibly the web ?? or we use four types of questions, different things---- I also have the lessons that we will be using from the textbooks whatever the activity that we're doing for the day, the purpose and I also have the pre class work or some journal entries that would be relevant to the day before that. Sometimes it requires them to do writing.

Although methods described by these three teachers represent a diverse repertoire of engaging activities, all resonate with the second RTOP statement in this specific domain. Furthermore, all methods and activities discussed are hallmarks of research-based practices (Sawada et. al, 2002).

The third statement in this domain is focused on student exploration preceding formal presentation, which is characteristic of reform-based lessons. Specifically, the RTOP statement is, "In this lesson, student exploration preceded formal presentation." Elaborating on this topic, Teacher D expressed,

> I'll have a beginning activity and I'll try to have the new material I'm teaching and then they practice what I teach. So that's usually the way the lesson starts. Sometimes I have a demonstration after the preliminary activity. Students will do the preliminary activity, and then I'll have a demonstration and they they'll take notes about the demonstration and then I'll try to have a little summary after that

Teacher A supported the statement by acknowledging that "My preclass activity will be based on the prior knowledge they should have so that I can continue my lesson." In addition, elaborating upon the use of activities in the classroom Teacher A included his/her process for selecting activities. According to Teacher A, "First thing that I think about when planning my lesson is what should my students know, then where they are, use lower level activity and go to higher level." Teacher A's continuation of ideas was consonant with statement #5, "The focus and direction of the lesson was often determined by ideas originating with students." In this case, Teacher A described how student exploration preceded formal presentation and then proceeded with identifying how the focus and direction of lesson was often determined by ideas originating from students.

It is noteworthy that Teacher E's only comment pertaining to this topic deviated from the intended topic and focused upon a topic of his/her own choosing. Namely, this teacher centered his/her response on the topic of the school district's mandated core curriculum. Teacher E said,

> Our lesson plans are planned using the core curriculum that the school district is implementing and can say it's quite rigid and I like it. I like the core curriculum, the way lessons are planned and basically that's what I follow. You must follow the standards, the lesson plans to line up the standards and schedule. They give you the day and time line and all that so basically that's how I plan a lesson plan. It's following the core curriculum and the timeline that's provided.

The content of Teacher E's comment could not be related to any of the RTOP statements. Also, Teacher C did not respond to any of the three questions on this topic.

Content:

Teachers spoke about promoting coherent conceptual understanding of the subject matter, supporting the second statement in this RTOP domain. Teacher A offered the following description on conceptual understanding and its manifestation in his/her classroom:

> Most of the time when I teach balancing equations, my student have no idea what is an equation, what is a coefficient, what is a subscript. I just try to show them what a coefficient is, what a subscript is, how do you count the number of atoms. So I start at the bottom level and I slowly build it up

Teacher F described this topic in a different manner, claiming that "to ensure their understanding of it or sometimes I even have them to write it out in some type of 3 paragraph essay format, write out what they understand."

Teacher D shared ideas about reform-based lessons promote and value connections with other disciplines and/or real world phenomena. These ideas were related to RTOP statement #5, “Connections with other content disciplines and/or real world phenomena were explored and valued.” Specifically, Teacher D said,

> I think I try to make them see connections between what we’re learning now and what we started learning at the beginning of the year. I probably—I don’t know if they are achieving that in my class actually maybe they’re just getting a superficial understanding but I do try to bring in environmental issues, I try to tie it in with biology.

Teacher B described utilizing similar practices as evidenced by the statement “I just try to give them different ways in which they can look at it and actually utilize it in a everyday situation.”

Statement #6 of the content domain mentions that reform-based practices include students using a variety of representations for understanding concepts/phenomena. Specifically, it states “Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.” Teacher D’s statement, “when I taught them about the periodic table I tried to give them an in depth understanding by using charts and graphs and having them write an essay about it,” is an example of the essence of this RTOP statement.

Active engagement of students in thought provoking activity that involved the critical assessment of procedure is the topic inherent to statement #8. Specifically, the statement is, “Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.” This topic is a characteristic of reform-based practices exemplified by Teacher F’s reflection.

> I try to think of activities or a question or things that require them to use the information in an application process and also what is important to me is that they

> be able to critically think and apply the information and to use it in other situations. I'm not only trying to build chemistry skills but I'm also trying to build their thinking skills….. I try to make the students think higher at a higher level of thinking.

In a similar vein, Teacher A had this to say, "Each activity is to match the objective, to benefit whatever the objective is. I don't come up with the activity to pass time, but give them activity so they learn whatever I am teaching."

Statement #10 is, "Intellectual rigor, constructive criticism, and the challenging of ideas were valued." This topic is focused upon reform-based lessons value rigor and challenging of ideas. Teacher D shared how this was accomplished in the classroom:

> The tools I use but they have to go beyond that so that they can apply it. So I guess that's how I try to give them in depth understanding. I don't emphasize memorization; I emphasize using what you learned in some way.

Classroom Culture:

Statement #1's topic focuses on involving students in communicating their ideas to others using a variety of means and media. This statement reads, "Students were involved in the communication of their ideas to others using a variety of means and media." Teacher B had this to say about this topic,

> Basically I actually try to differentiate instruction. I did that before that was kind of a buzz word. I tried to do some things auditory, something with writing, something kinesthetic. I just try to give them different ways in which they can look at it and actually utilize it in an everyday situation.

Teacher F said, "I also have the pre class work or some journal entries that would be relevant. Sometimes it requires them to do writing."

Reform-based classroom is student centered with a high proportion of student talk with a significant amount of it occurring between and among students, and is the topic of statement # 3. Specifically, this statement is "There was a high proportion of student talk and a significant amount of it occurred between and among students." Teacher F shared this view and indicated that

> When I usually use the group assignment work compare where they have to do the Web DOK** that is one activity that I do to help make sure that they understand and we usually spend two to four days sometimes on a Web DOK because it's a process that requires time for them to think, for them to comprehend and for them to apply and I find that to be a group activity because they can help one another in a social aspect of bits and pieces of the information that they may not understand as individuals.

Teacher A had this comment regarding this practice, "most of the time, I make them work in pairs or make them work individually. During the activities I'm also available for them."

Statement #7's topic focused on whether the students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. This statement is presented as, "Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence." According to Teacher D,

> I think I was pretty successful with the trends in the periodic table and getting them to understand it I gave them a handout and had them explain the trends. They didn't have to memorize the trends they had a periodic table that had arrows that shows the trend but they had to explain why the trends were there. So I try to do that. They don't need to try to remember exactly like I have over there. I have electronegativity differences and how you can figure out if it's polar or non-polar.

Teacher D's response is best aligned with statement # 9, "The teacher acts as a resource person, working to support and enhance student investigations." Here, Teachers B and D described in different ways that they acted as resource persons. Teacher B mentioned that "Basically when I'm planning my lesson I do take a look at the guide in the text book what their suggestions are. Sometimes I look online for suggestions on how to be creative." Teacher A mentioned, "I know there's some disks I can use that are very helpful and have a lot of good graphics that will help the kids understand stuff more."

The selection of teacher quotes presented above represents those in alignment with the statements in each of the three domains. However, as evidenced by the percentages in Table 10, there exist teachers' statements that were absent or not aligned to any of the RTOP statements.

Table 10: *Teachers' Responses to 3 Interview Questions in Percentages (N=6)*

3 Interview Questions	RTOP Domain	Percentage of Teachers' Responses in Agreement with RTOP Statements					
		A	B	C	D	E	F
Total		52.0[1]	44.0	0.0	64.0[1]	0.0	56.0[1]
	Lesson Design and Implementation	80.0[2]	60.0[1]	0.0	80.0[2]	0.0	40.0
	Content	40.0	40.0	0.0	60.0[1]	0.0	50.0[1]
	Classroom Culture	50.0[1]	40.0	0.0	60.0[1]	0.0	70.0[1]

The maximum *possible* percent for each teacher in each domain was 100.
[1] Designate a HIGH LEVEL of response; [2] Represent MCE PROGRAM INTENTION; Zero score represents ABSENT level of response; all other scores represent LOW LEVEL of responses.

Interview Response Total Score

Specifically, results indicated that the Interview Response total scores of teacher A (52.0), teacher D (64.0), and teacher F (56.0) were at the HIGH LEVEL, whereas teacher B's score (44.0) was at the LOW LEVEL. Scores of teacher C (0.0) and teacher E

(0.0) indicated the ABSENT level of implementation. The range of Interview Response total scores was 0.0-64.0.

The Interview Response total score for three teachers (50.0%) were characterized as HIGH LEVEL, and the score for one teacher (16.7%) was at the LOW LEVEL. The scores of two teachers (33.3%) were designated as ABSENT level of implementation.

Interview Response Domain Scores

Lesson Design and Implementation Domain:

Results showed that for the lesson design and implementation domain, the Interview Response domain scores of teacher A (80.0) and teacher D (80.0) were in the category MCE PROGRAM INTENTION, and teacher B’s score (60.0) was HIGH LEVEL. Furthermore, teacher F’s score (40.0) indicated a LOW LEVEL, whereas teacher C (0.0) and teacher E’s (0.0) scores represented ABSENT level of implementation. The range of Interview Response scores for this domain was 0.0-80.0.

The Interview Response lesson design and implementation scores for two teachers (33.3%) were at MCE PROGRAM INTENTION level, and one teacher (16.7%) was at the HIGH LEVEL. Additionally, the score of one teacher (16.7%) indicated LOW LEVEL, whereas the scores of two teachers (33.3%) were at the ABSENT level of implementation.

Content Domain:

Results yielded that in the content domain, the Interview Response domain scores of teacher D (60.0) and teacher F (50.0) were at the HIGH LEVEL, whereas the scores of teacher A (40.0) and teacher B (40.0) were at the LOW LEVEL. Further, teacher C (0.0) and teacher E (0.0) scored at the ABSENT level of implementation. The range of Interview Response content domain scores was 0.0-60.0.

The Interview Response content domain scores for two teachers (33.3%) were categorized as HIGH LEVEL, and the scores for two teachers (33.3%) were denoted at LOW LEVEL. The scores of remaining two teachers (33.4%) represented ABSENT level of implementation.

Classroom Culture Domain:

Results revealed that in the classroom culture domain, the Interview Response domain scores of teacher A (50.0), teacher D (60.0), and teacher F (70.0) were at the HIGH LEVEL, whereas the score of teacher B (40.0) was designated as LOW LEVEL. Furthermore, the scores of teacher C (0.0) and teacher E (0.0) indicated ABSENT level of implementation. The range of scores for the Interview Response classroom culture domain was 0.0-70.0.

The Interview Response classroom culture domain scores for three teachers (50.0%) were at the HIGH LEVEL, and at the LOW LEVEL for one teacher (16.7%). The scores for two teachers (33.3%) were at the ABSENT level of implementation.

Discussion

On the whole, three teachers' (50.0%) responses (to three interview questions) were highly aligned with the RTOP statements, indicative of a high degree of implementation of MCE program practices. Of the remaining three teachers, one teacher's (16.7%) responses were aligned with reform-based practices to a small extent, whereas two teachers (33.3%) had no statements in alignment with the implementation of recommended practices.

The responses of the teachers in the context of lesson design and implementation had the greatest variety, representing a wide range of implementation of practices among the six teachers. Two teachers' (33.3%) responses overlapped with the RTOP statements in this domain, showing complete agreement with the reform-based practices. One teacher's (16.7%) responses were consistent with a high degree of alignment with the MCE program practices, whereas another teacher's (16.7%) responses showed limited agreement with the reform-based practices in the domain of lesson design and implementation. The remaining two teachers (33.3%) elicited no responses that could be interpreted as evidence of the implementation of reform-based practices pertaining to this domain. This expansive extent of responses in the lesson design and implementation area is consistent with the great variety of lesson plans submitted to the researcher.

Two teachers (33.3%) each had similar responses in the content domain consistent with high, low and non-existent degree of implementation of the MCE program practices respectively. Although the focus of the MCE program was to inculcate deep understanding of Chemistry content through inquiry-based methods (Blasie & Palladino, 2001), this was not uniformly reflected in the teachers' responses to the three interview questions.

The response pattern in the area of classroom culture was also varied. Three teachers (50.0%) had responses that were highly aligned with the promotion of reform-based classroom culture, whereas one teacher's (16.7%) responses did so to a small extent. The responses of two teachers (33.3%) gave no indication of the inculcation of a reform-based classroom culture.

To aid the reader, Appendix R summarizes the findings for research question 2 and its contributory questions from various data sources for all the teachers, as well as individual teachers.

Findings for Research Question 3

Research Question 3: What concerns do teachers express as factors that enable the implementation of the MCE program practices in their classrooms?

In order to ascertain the concerns of teachers regarding the factors that enabled them to implement the practices in their classrooms, data from two sources were reported, examined, and analyzed. These sources were the teachers' responses to the: (1) 2nd open-ended question amended to the self-reported Stages of Concerns Questionnaire (SoCQ); and (2) semi structured interview questions.

Response to 2nd Open-ended Question, Amended to Survey of Concerns Questionnaire (SoCQ), Results

The reader is reminded that a copy of the SoCQ and the amended open-ended questions appears in Appendix F. Also, the open-ended questions, as well as the scoring procedures for the responses, appear in Chapter 3.

Question 2 asked the teachers, "What is helping you to implement the MCE program practices?"

To analyze the teachers' responses to this question four categories (MCE program practices, student characteristics, administrative support, and other), each consisting of several enabling factors, were created. Then, the teachers' responses were examined independently by the researcher and a co-rater, and placed under the enabling factors they best fit as the evidence of an enabling factor. Differences in the placements of responses, between the researcher and the co-rater, were reconciled. All the enabling factors and a sample teacher response for each are listed in Appendix S.

Table 11 summarizes the frequency of the teachers' responses, to the 2nd open-ended question amended to the SoCQ, for each of the enabling factors.

Table 11: *Frequency of Enabling Factors Reported by Teachers (N=6) on the SoCQ*

Category	Enabling Factors	Frequency
MCE Program Practices	Depth of content knowledge	2
	Formal laboratory exercises and reports	3
	Hands-on problem-solving activities	3
	Group/Collaborative work	1
Student Characteristics	Good behavior	1
	Self-motivation	1
	Basic skills to follow instructions	1
Administrative Support	Supportive department head	1
	Laboratory assistant as Teacher Aide	1
	Adequate supplies	1
Other	Nothing	1
	Not using the MCE program practices	1

The results show that two groups of three teachers (50%) identified formal laboratory exercises and reports, and hands-on problem-solving activities, respectively as enabling factors in the implementation of the MCE program practices in their classrooms. Further, two teachers (33.3%) reported the depth of content knowledge as the enabling factor. Individual teachers (16.7%) identified each of the remaining enabling factors.

These were: Group/collaborative work; good behavior; self-motivation; basic skills to follow instruction; supportive department head; laboratory assistant as Teacher Aide; adequate supplies; nothing; and not using the MCE program practices.

Teachers' quotes supporting several of the factors in each category that enabled the implementation of MCE Program practices are described next. Teachers' quotes were selected from an available pool of quotes derived from their responses. Selected responses that consisted of at least one complete sentence or up to several complete sentences were reported when available. However, in some cases sentence fragments were selected because that was all that was available. The selected quotes cover the category codes (MCE Program Practices, Student Characteristics, Administrative Support, Other) and are presented in the same order as presented in Table 11. Since the teachers responded to the second open-ended question on the SoCQ and responded in different manners, only a limited number of quotes were available. These quotes are presented next.

MCE Program Practices:

As described in Chapter 2, the MCE Program has a unique structure and components. With respect to the strong conceptual content knowledge component associated with the MCE Program, Teacher F identified the depth of understanding of Chemistry acquired from his/her experience in the Program as an enabling factor in teaching his/her own students. Teacher F stated,

> The experience and practice that I acquired at the MCE program help me to better implement Inquiry Base Learning. Now that I have a deeper scientific knowledge base it allows me to only guide the students in the quest for the answer as well a teach fundamentals concepts to assist them along the way.

In addition to the content component, the MCE Program also had a laboratory component which was described by Teachers A and D. According to Teacher A,

> Laboratory experiences from MCE program were very helpful to teach students chemistry by doing science. It was very successful with average students. Students who had no interest in science actually participated in activities. Students learned science by discussing, solving and doing it.

Teacher D added, "I do labs every week and find this makes chemistry a great experience for my students."

Related to the students' laboratory exercises, Teacher F stressed the formal laboratory write-ups as enabling factors. Teacher F mentioned, "Another practice that I have implemented from the MCE program is the use of formal lab report write-ups. It gives students the experience for technical writing and the use of technology."

Another factor that was identified as an enabling factor was the Program's problem solving component. Teacher D asserted "I try to get students to actively work on problem solving in class. Students enjoy working out problems on the board." Similarly, Teacher E stated that he/she was equipped, and had "prepared knowledgeable students ready to solve problems scientifically."

Student Characteristics:

Key to implementing the Program Practices is getting the full participation of students who were prepared to participate. According to Teacher A, "it was easy to implement PIM because students were well behaved, motivated, and had basic skill to follow the instruction to carry out the activity." For this teacher, three student characteristics were required to enable the implementation of the Program Practices. This was the only teacher who commented on this topic during the interview.

Administrative Support:

As described in Chapter 2, support from the school administration is seen as essential to the Program implementation. Stressing the importance of administrative support, Teacher A stated that implementation is enabled, "when you have a lab department head and a lab assistant who will help you out to implement new practices… supplied materials in class as needed…. In other words, support from the administrators and lab assistant will really make a difference." This is the only teacher who focused her response on this topic.

Other:

Responses also centered on the teachers' lack of implementation of the MCE Program Practices. Two teachers admitted to not implementing the Program Practices in their respective classrooms. Specifically, Teachers B stated he/she was "not using the MCE Program practices." Similarly, Teacher D stated that "nothing" was helping him/her in the implementation of Program Practices, respectively.

Discussion

When asked the question 'What is helping you to implement the MCE program practices?,' the teachers responded in two ways. They interpreted the enabling factors to be those that 'currently' enabled or would 'potentially' enable them to implement specific aspects of the MCE program practices in their classrooms. Responses pertaining to both of the interpretations were included in the examples for enabling factors (see Appendix S), and the frequency counts for said factors given in Table 11. Three teachers (50%) in the study considered the students' ability to do formal laboratories and write laboratory reports, and the use of hands-on problem solving activities as important factors that enabled (or would enable) the implementation of the MCE program practices. Two teachers (33.3%) perceived the depth of knowledge acquired in the program as factors that assisted (or would assist) them in implementing the MCE program practices in their classrooms. The rest of the enabling factors (or potential enabling factors) were identified by one teacher (16.7%) each. It is important to note that the quantity of responses from the teachers varied from a single word or phrase to two paragraphs. One teacher responded to all the enabling (or potentially enabling) factors in the categories of student characteristics and administrative support, while the collective responses of this teacher as well as the rest were examples of the remaining categories (MCE program characteristics and other) and the enabling factors contained within these categories.

Response to Semi-structured Interview Questions Results

The reader is directed to Appendix J for a sample of semi-structured interview questions. To answer this research question, responses to all the semi-structured interview questions from all the teachers were looked at carefully for the presence of factors helpful in the implementation of the practices

All the responses to the semi-structured questions were examined and categories and enabling factors within the categories were developed, as explained in chapter 3. Some categories and enabling factors were new (compared to those in Table 11). These new categories, the enabling factors within the categories, and the teachers' responses that exemplify the enabling factors are presented in Appendix T. Both, the development of categories/enabling factors and alignment of teachers' responses with the factors, were carried out independently by this researcher and a co-rater, and any differences between the two were reconciled.

Table 12, on the following page, summarizes the categories, the enabling factors within the categories, and the frequency of the teachers' responses for each of the enabling factors, obtained from the semi-structured interview.

Results show that all the six teachers (100%) identified the depth of content knowledge acquired in the MCE program as an enabling factor in its implementation in their classrooms. Further, three teachers (50%) identified support from the administrators as an enabling factor. Groups of two teachers (33.3%) reported Group/Collaborative work, laboratory work, use of internet and technology, self-motivation, and adequate time and training for the students respectively as enabling factors. Additionally, individual teachers (16.7%) mentioned each of the remaining enabling factors. These factors were: formal laboratory exercises and reports; less preparations to allow more time for inquiry; use of POGIL and PIM; less lecturing/more of students taking ownership of learning; use of inquiry methods; students' focus on writing; higher level of students; students eager/willing to embrace inquiry methods; adequate supplies and resources; adjusting teaching strategies to student needs; teachers writing the curriculum aligned to MCE knowledge/practices; information on differentiating curriculum; teachers' personal motivation; and connecting with other MCE program participants.

Table 12: *Frequency of Enabling Factors Reported by Teachers (N=6) in the Interview*

Category	Enabling Factors	Frequency
MCE Program Practices	Depth of content knowledge	6
	Formal laboratory exercises and reports	1
	Group/Collaborative work	2
	Laboratory work	2
	Less Preparations (preps) to allow more time for inquiry	1
	Use of POGIL and PIM	1
	Less lecturing/More of students taking ownership of learning	1
	Use of internet and technology	2
	Use of inquiry methods	1
	Students' focus on writing	1
Student Characteristics	Self-motivation	2
	Higher level	1
	Eager/willing to embrace inquiry methods	1
Administrative Support	Adequate supplies/ Resources	1
	Support from administrators	3
Other	Adequate time & training for the students	2
	Adjusting teaching strategies to student needs	1
	Teachers writing the curriculum aligned to MCE knowledge/practices	1
		1
	Information on differentiating curriculum	
		1
	Teachers' personal motivation	1
MCE Program Design	Connecting with other MCE program participants	1

Teachers' quotes supporting the factors in each category that enabled the implementation of MCE Program practices are described next. Teachers' quotes were selected from an available pool of quotes derived from their responses. Selected responses that consisted of at least one complete sentence or in some cases up to several complete sentences were used when available. However, in some cases sentence fragments were used because that was all that was available. The selected quotes cover the category codes (MCE Program Practices, Student Characteristics, Administrative Support, Other, MCE Program Design) and presented in the same order as presented in Table 12.

MCE Program Practices:

In their responses, all teachers mentioned and identified that the depth of content knowledge acquired in the MCE Program as an enabling factor. As an example championing this depth of content knowledge component of the MCE Program Practices, Teacher B acknowledged that "We were getting deeper understanding of chemistry and that would help us to explain it to the students better." With respect to the topic of chemistry and related experiences learning the Program subject matter, Teacher C added: "The chemistry was great. They had the best teachers, the best professors in the world."

The MCE Program Practices also stressed the importance of incorporating technology in the classroom. On the topic of technology and its use in the classroom, Teacher E identified this practice as an enabling factor for him/her. Specifically, Teacher E noted that "a lot of things that I really do in my classroom that I got from Penn, for example like the use of internet and the use of technology." In a similar vein, Teacher F acknowledged the software application aspect of technology as an enabling factor.

Teacher F stated, “I also loved that they focused on technology. The way technology is moving. I use power point all the time, I’m teaching my student excel when they’re doing their lab reports.”

With respect to hands-on learning of chemistry content, the MCE Program Practices also had structured laboratory exercises for the students to experience first-hand. Describing how the use of labs in the MCE Program enabled their use in his/her own classes, Teacher A stated that “labs were great. Because of those labs I knew what to do. Usually I borrow equipments from Drexel Science in motion program. I do most of the labs with them and actually I wanted to do more labs after the MCE program.” On the same topic, Teacher D commented that “part of the program with MCE was as far as having students engaged I feel that doing labs is very engaging for students. So I do that.”

For several teachers, a benefit to his/her students was identified as an enabling factor. With respect to the MCE Program practice of allowing students to take ownership of their learning was also identified as an enabling factor, Teacher E’s quote succinctly states a benefit to students: “let them do it by themselves, kind of guided the instruction. It makes more sense and be able to learn much better than lecture, rather than me being the main speaker all the time.”

Student Characteristics:

Based on the teachers’ experiences with the MCE Program, they offered their ideas as to where the implementation of the Practices would be easier to accomplish. According to Teacher A, it would be easier to implement the Program practices in classes comprised of higher level students. Specifically, Teacher A stated that “as the students

move on to higher level classes it's very easy to implement Penn program and students will really get benefit from it." Not only did the teacher identify where the Program Practices could be implemented with greater ease, but also identified the type of student who would receive greater benefit from the related experiences. Similarly, Teacher F focused his/her discussion on the characteristics of students that would enable the implementation of the Practices. Specifically, Teacher F succinctly stated:
"The quality of students is a factor. It really works well- the inquiry methods, when you have students who don't mind to investigate and who are motivated to do so." Overall, the teachers remain cognizant of the students' contribution to the success of implementation of Program Practices.

Administrative Support:

The support from the administration was identified as an enabling factor. Resources, such as appropriate text books could be helpful in the implementation of the program as noted by Teacher F: "Some of the textbooks that I have are helpful. They give you some ideas to spark an inquiry and you may have to modify and change. So that type of resource is helpful." In addition, varying degress of administrative support were mentioned by Teachers A, B, and F. For instance, Teacher A mentioned the support of the administration in general and the department head in particular, saying "you have to get support from the administrators….. we need more support from the department head." Teacher B counted on the support of the principal as an enabling factor, adding "I think the administration, the principal that I currently have he would be supportive." Similarly, Teacher F mentioned the support of his/her principal as an enabling factor in the implementation as evidenced in the following excerpt.

> As far as administration, my principal loves to see, when she comes through, when the students are working in a group and they are really engaged in trying to find the answer to the question. She has walked in and observed that.

Other:

Although less often reported by the teachers, teachers also perceived enabling factors related to their unique situations. For instance, Teacher A offered the provision of adequate time and training of the students in MCE program methods as enabling factors. With respect to the topics of time and training, he/she mentioned "It takes time, you cannot implement PIM right away. It takes time. You have to train them."

With respect to the ability to change and adapt teaching strategies to suit the needs and strengths of students was an asset in the implementation of the Program Practices as expressed by the statement, Teacher C stated, "so even in mid stream you may have to change horses because if you look out and it's not getting across that night you better come up with a way to get it across." With respect to the success of implementing the Program Practices, Teacher E spoke of his/her self-motivation as an enabling factor: "One of the things that is helping me is my personal motivation actually, so I will be able to give proper instruction to the kids."

MCE Program Design:

Reflecting on factors that would have enabled him/her to implement the MCE Program Practices, Teacher D acknowledged,

> I think that one thing that would help me is if I communicated more with the people who were involved in the MCE once I finished the program either by e-mail or by participating more in activities with the program. I think that would have helped me to implement it if I was checking back with my colleagues at MCE to discuss my classroom practice with them. I think that would have helped.

This was the only teacher to address this topic during the interview.

Discussion

If the teachers were implementing the MCE program practices to any extent, they described the enabling factors present in their situations. If the teachers were not implementing the practices, they interpreted the enabling factors to be the ones that they perceived as being essential for implementation. Both, the existing and perceived (as potentially) enabling factors, are included in the frequency count shown above. The teachers were unanimous (100%) in asserting that the MCE program emphasized conceptual understanding of Chemistry that enabled (or would enable) them to implement the program in their classrooms. Only three teachers (50%) reported administrative support as an enabling (or would be enabling) factor. Five different pairs of teachers (33.3%) expressed group/collaborative work, laboratory work, use of internet and technology, self-motivation, adequate time and training for the students respectively as enabling (or potentially enabling) factors. The rest of the factors in the table above were regarded as enabling (or would be enabling) factors by individual (16.7%) teachers. The enabling (or potentially enabling) factors within each category were supported by statements from several teachers, except for the MCE program design category. Only one teacher, teacher D, responded that networking with other teachers who had participated in the MCE program would have helped him/her to implement its practices in his/her classroom.

Findings for Research Question 4

Research Question 4: What concerns do teachers express as the factors that hinder the implementation of the MCE program practices in their classrooms?

In order to ascertain the factors that hindered the teachers in this study from implementing the practices in their classrooms, data from three sources were reported, examined, and analyzed. These data sources were the teachers': (1) self-reported Stages of Concern Questionnaire (SoCQ); (2) responses to 3rd open-ended question amended to the SoCQ; and (3) responses recorded in the semi-structured interview.

Stages of Concern Questionnaire (SoCQ): Frequency of Teachers' Responses and Individual Teacher Profile Results

The SoCQ consists of 35 statements requiring responses on a 7 point Likert-type scale (see Appendix F). The teachers' raw scores were converted to percentile scores for the seven stages of concern using the Quick Scoring Device (George, Hall, & Stiegelbauer, 2006). The reader is referred to Chapter 3 for a description of the instrument and scoring procedure. The percentile scores for the stages were tallied and the frequencies of the two stages of concern receiving the highest scores, and the frequencies of the stages of concern receiving the lowest scores were reported and further analyzed.

Stages of Concern Questionnaire (SoCQ): Frequency of Teachers' Responses Results

Table 13, on the following page, summarizes the frequency of the two highest stages and the lowest stages of concern among the six teachers in this study.

Table 13. *Frequency of the Two Highest and the Lowest Stages of Concern for Teachers (N=6)*

	Stages of Concern							
Rank	0	1	2	3	4	5	6	Total
Highest	6	0	0	0	0	0		6
2nd Highest				2		2	2	6
Lowest					5	1		6

Table 14 contains the three dimensions of concerns, the seven stages of concerns categories, as well as a description of the teacher's behavior for each concern category.

Table 14. *Stages of Concern by Dimension, Number and Category name, and Teacher's Behavior*

Dimension	Stages of Concern Number and Category	Teacher's Behavior
Impact	6 REFOCUSING	The focus on exploration of more universal benefits from the innovation. Individual has definite ideas about alternatives to innovation.
	5 COLLABORATION	The focus is on coordination and cooperation with others regarding use of innovation.
	4 CONSEQUENCE	Attention focuses on impact of the innovation on students in his/her immediate sphere of influence.
Task	3 MANAGEMENT	Attention is focused on the processes and tasks of using the innovation and best use of resources.
Self	2 PERSONAL	Individual is uncertain about the demands of the innovation, his/her inadequacy to meet those demands, and the role of the innovation.
	1 INFORMATIONAL	A general awareness of the innovation and interest in learning more about it.
	0 UNCONCERNED	Little concern about or involvement with the innovation is indicated.

Adapted from George, Hall & Stiegelbauer (2006)

Table 13 was used in conjunction with Table 14 for continued analysis of the teachers' concerns. Results show that, based on the self-reported SoCQ, all the teachers (100%) received the highest percentile score for the '0' (UNCONCERNED) stage of concern. The stages of concern numbered 3 (MANAGEMENT), 5 (COLLABORATION), and 6 (REFOCUSING) received the second highest percentile score from two teachers (33.3%) each. The stage of lowest concern for five teachers (83.3%) was 4 (CONSEQUENCES), whereas one teacher (16.7%) reported the lowest stage of concern as 5 (COLLABORATION).

Stages of Concern Questionnaire (SoCQ): Individual Teachers' Profile Results

The distribution of percentile scores across the seven stages of concern for the teachers is shown below in Table 15.

Table 15. *Stages of Concern Profile for Teachers (N=6) in Percentiles*

	Stages of Concern						
Teacher	0	1	2	3	4	5	6
A	97	43	57	88	16	36	52
B	99	60	35	83	13	19	26
C	98	30	5	39	1	12	42
D	87	75	52	39	63	31	77
E	96	84	41	65	19	91	20
F	98	60	63	43	21	64	34

Further, to assist the reader in visualizing the trends across all the stages of concern, graphs of stages of concern vs. percentile scores for all the teachers can be found in the Appendix L.

Highest SoCQ Score

Results reveal that all the teachers received the highest score for the UNCONCERNED stage of concern. The percentile scores for this stage ranged from 87 to 99.

Second Highest SoCQ Scores

Results show that for teacher A the second highest stage of concern was MANAGEMENT.

Teacher B had the second highest score in the MANAGEMENT stage.

Teacher C's second highest score was in the REFOCUSING stage of concern.

The second highest percentile score for teacher D pertained to the REFOCUSING stage of concern.

The second highest score for teacher E was for the COLLABORATION stage of concern.

Teacher F's second highest stage of concern was COLLABORATION.

The Lowest SoCQ Scores

Teachers A, B, C, E, and F received the lowest scores for the CONSEQUENCE stage of concern, whereas teacher D received the lowest score for the COLLABORATION stage of concern.

Discussion

Group Characteristics of Stages of Concern

At the time the teachers completed the questionnaire, all of them were not concerned about implementing the MCE Program practices in their respective classrooms. This is generally due to other priorities, topics, initiatives, programs, activities, or tasks being more important to the teachers at this juncture, therefore taking precedence over the implementation of MCE program practices and related concerns (Hall & Loucks, 1979).

Although all the teachers were not concerned about the implementation of the MCE Program practices, they were equally divided among their second highest concerns about management (33.3%), collaboration (33.3%), and refocusing (33.3%) issues that may have hindered the implementation of MCE program practices in their classrooms. For the two teachers who had management concerns, their concerns were related to time, logistics, and other classroom management issues pertaining to the implementation of MCE program practices (George, Hall, & Stiegelbauer, 2006). Two teachers, who reported concerns about collaboration, were concerned about working with others in relation to the implementation of MCE program practices. Teachers scoring high in this stage were, generally, team leaders who had concerns about coordinating with others (George, Hall, & Stiegelbauer, 2006). Two teachers expressed refocusing as their second highest stage of concern. This meant that these teachers had strong ideas about how to make changes or improve the MCE program practices to suit their needs (George, Hall, & Stiegelbauer, 2006).

Five teachers (83.3%) gave the lowest value to the consequence stage of concern. This indicated that these teachers were least concerned about the effects of MCE Program practices on their students.

The lowest value for one teacher (16.7%) was at the collaboration stage of concern which meant that this teacher was least concerned about working with other teachers in the implementation of MCE program practices.

Individual Characteristics of Stages of Concern

Based on the individual responses to the SoCQ, a percentile score for each stage for each teacher was determined. From these percentile scores, a profile graph was generated for each teacher (see Appendix L).

Teacher A's profile was indicative of a non-user of the innovation (MCE program practices) due to concerns about his/her ability to manage the practices in his/her classroom, coordination of tasks and students, not having enough time, and conflicts between his/her interests and responsibilities towards implementing the MCE program practices. Additionally, teacher A has personal concerns such as his/her role if he/she used the practices in the classroom, time and energy commitment, and how his/her teaching was supposed to change if he/she decided to use the innovation. These concerns hindered him/her from using the practices in his/her classroom. Teacher A was not at all concerned about his/her students' attitude towards the MCE program practices and how it would affect the students.

Teacher B was also a non-user of MCE program practices in his/her classroom and had many of the same concerns as teacher A, hindering the implementation of the practices. However, instead of personal concerns, he/she had informational concerns, i.e., he/she would like to know how the MCE program practices were better than the classroom practices he/she was using currently and what resources would be available if he/she adopted the practices.

Teacher C also did not use the MCE program practices in his/her classroom. However, this was supported by teacher C's belief that he/she knew and used better approaches that worked with his/her students. Additionally, this teacher had management concerns such as conflicts between his/her interests and responsibilities, not having enough time to organize the tasks etc. Similar to teachers A and B, teacher C was not at all concerned as to how the implementation of MCE practices would affect his/her students and their attitude towards it.

Similar to other teachers in the group, teacher D did not implement the MCE program practices. However, this was due to his/her belief that he/she knew about better approaches that worked and the need to modify certain MCE program practices to be applicable with his/her students. Also, he/she had informational concerns such as what resources would be available if he/she used the innovation, and how were MCE program practices better than what he/she was currently using in his/her classroom. Teacher D was not concerned about collaborating/helping his/her colleagues with the use of MCE program practices.

Teacher E was also a non-user of the MCE program practices. This was due to concerns about collaboration and his/her realization that he/she had limited knowledge about it and the resources that would be available if he/she decided to use it. Teacher E was concerned about his/her ability to collaborate with colleagues to use the MCE program practices. Teacher E was not concerned about how the students would react or how it would affect them, if he/she used the practices.

Teacher F had the same concerns as teacher E, except instead of informational his/her concerns were personal, which meant that he/she would like to know how the use of MCE program practices would affect or change his/her teaching, what would be his/her new role, and the time /energy commitment required. These concerns hindered his/her ability to implement MCE program practices in his/her classroom.

Response to 3rd Open-ended Question, Amended to Survey of Concerns Questionnaire (SoCQ), Results

The reader is directed to Appendix F for a copy of the SoCQ with its amended questions. Specifically, the 3rd open-ended question asked the teachers, 'What is inhibiting you from implementing the MCE program practices?

The analysis procedure for the responses is described in chapter 3. Similar to research questions 3, the analysis of responses here consisted of developing three categories (School district policy, student characteristics, and administrative support) and several hindering factors within these categories. Then, the statements reported by the teachers were placed under the corresponding inhibiting factors till all the statements were exhausted. The researcher collaborated with a co-rater in creating the categories for the hindering factors. All the categories, hindering factors, and an example of a response pertaining to each hindering factor are reported in Appendix U. Additionally, a frequency count of responses that fell into each hindering factor was made and reported.

Table 16 summarizes the frequency of the teachers' responses to the 3rd open-ended question amended to the SoCQ with respect to factors that hindered them from implementing the MCE program practices in their classrooms.

Table 16: *Frequency of Hindering Factors Reported by Teachers (N=6) on the SoCQ*

Category	Hindering Factors	Frequency
School District Mandates	Core Curriculum and Pacing Schedule	4
	Test Preparation (Standardized, Benchmark, AP and IB)	2
	Policies	1
	Administrative Paper-work	1
	Large Class-size	1
Student Characteristics	Unprepared for Student-centered Work	1
	Poor Math and Reading Skills	1
	Lack of Motivation	1
	Lack of Basic Skills to follow Instructions	1
Administrative Support	Unsupportive Department Head	1
	Unresponsive Administration	1
	Lack of Resources	1

Results show that four teachers (66.8%) reported the core curriculum and pacing schedule as a factor hindering the implementation of MCE program practices in their classrooms. Further, two teachers (33.3%) reported test preparation as a hindering factor. Individual teachers (16.7% each) identified ten factors, spread over the three categories of schools district mandates, student characteristics, and administrative support, as hindrances in implementing the practices. These factors were: policies, administrative paper-work, large class size, students unprepared for student centered work, poor math and reading skills of students, lack of motivation, lack of basic skills to follow instructions, unsupportive department head, unsupportive administration, and lack of resources.

Teachers' quotes supporting several of the factors in each category that hindered the implementation of MCE Program practices are described next. Teachers' quotes were selected from an available pool of quotes derived from their responses to the third open-ended question on the SoCQ. Since the teachers did not respond in the same manner, only a limited number of quotes were available and are presented next. Selected responses that consisted of at least one complete sentence or up to several complete sentences were used when available. However, in some cases sentence fragments were selected because that was all that was available. The selected quotes cover the category codes (School District mandates, Student Characteristics, and Administrative Support) and are presented in the same order as presented in Table 16.

School District Mandates:

The School District of Philadelphia has a core curriculum and an associated planning and scheduling timeline (PST) that prescribes what needs to be taught in classrooms on a weekly basis in all the subjects, including chemistry. Teachers throughout the district are required to follow the core curriculum and the PST and are evaluated on the fidelity with which they do so. Teacher F cited the mandated core curriculum as a hindrance in implementing the practices of the MCE Program in his/her classroom. He/she stated that

> The thing that inhibits me from implementing the scientific knowledge on a deeper level is the timeline issued by the school district. It does not allow the teacher to spend sufficient amount of time to cover some topics thoroughly and it limits the development of skills for students to become independent and critical thinkers.

Teacher D echoed, “The dictates of the core curriculum reduce opportunities for teacher made lessons.” Teachers B and E supported these statements by stating that “The restraints of the core curriculum and the pacing schedule” and “Rigid core curriculum,” respectively, were hindering factors in the implementation of MCE program practices.

Related to the core curriculum and PST are the school district’s mandated Benchmark tests in the subject, given at the end of every five-week cycle of instruction, and the federally mandated annual high stakes PSSA (Pennsylvania State System of Assessment). Additionally, for students enrolled in accelerated programs such as Advanced Placement (AP) or International Baccalaureate (IB) test preparation takes up a considerable amount of instructional time. Therefore, time spent in preparing the students for various tests was quoted as one of the inhibitory factors in the implementation of MCE Program practices by Teachers A and D. Teacher A stated, “with an AP or IB class where your main priority becomes teaching and reviewing the required topics before the exam,” other priorities take a back seat. In Teacher D’s words, “the need to cover a lot of material and prepare students for tests takes precedence” over other priorities. Teacher C claimed the “school district policy” as the factor inhibiting his/her implementation of the practices in his/her classroom.

The school district also requires the teachers to maintain a detailed documentation of paper work associated with disciplinary and other referrals. Teacher B admitted that “there is a lot of paper work and obligations during prep time (i.e., CSAP meetings, performance reviews…" that use up his/her time and hinder him/her from implementing MCE Program Practices in the classroom.

According to the School District's policy, maximum class size is 33 students. Teachers find this large number of students difficult to manage, especially during activities and lab. This led to the Teacher E's claim that "Large class sizes" were his/her reason for lack of implementation of the reform- based practices in the classroom.

Student Characteristics:

Prevalence of certain student characteristics was identified by Teachers A, D, and E as factors non-conducive to the implementation of research-based practices in their urban classrooms. As a hindering factor, Teacher A mentioned, "Having lower level classes where students don't follow the instruction and your top priorities becomes classroom management" instead of the promotion of inquiry-based practices.

According to Teacher D, "lack of student preparation makes student centered work unproductive" and Teacher E blamed "demotivated students and poor math and reading skills of our students" for his/her inability to implement the reform-based practices.

Administrative Support:

Emphasizing the need for administrative support, Teacher A noted that "No support from the department head and the lab assistant" as reasons for the absence or inadequate implementation of the MCE Program practices, while Teacher E said "Poor or lack of resources" were preventing him/her from using the practices in his/her classroom.

Discussion

Five (of the six) teachers (66.8%) targeted the School District of Philadelphia's core curriculum and pacing schedule (mandated by the district) as the biggest hindrance to the implementation of the MCE program practices. This was followed by two teachers (33.3%) pointing to the large amount of instructional time spent in preparing the students to succeed in a variety of assessments mandated by the school district, and federal laws. Individual teachers (16.7% each) cited factors such as school district policies, administrative paper work, large class sizes, students not being prepared for student-centered work, poor math and reading skills of students, students' lack of motivation, lack of basic skills to follow instructions, unsupportive department head, unresponsive administration, and lack of resources as the inhibitory causes. It is important to note that many teachers' responses were represented in the hindering factors pertaining to each category.

Response to Semi-structured Interview Questions Results

As mentioned earlier, a copy of sample questions in the semi-structured interview can be found in Appendix J.

To analyze the teachers' responses to all the questions, categories were generated, in collaboration with a co-rater, and hindering factors within the categories were developed. Then, teachers' statements were placed under the corresponding hindering factors. Some categories and hindering factors were the same as for the analysis of SoCQ's 3rd open-ended question.

However, some categories and hindering factors were new to this data source. Examples of new hindering factors and the teachers' responses aligned to these are reported in Appendix V. This data was then summarized in a table of frequency count for each hindering factor.

Table 17, on the following page, summarizes the frequency of the teachers' responses (to the semi-structured interview questions), for each of the hindering factors. Results show that three groups of five teachers (83.3%) reported school district's mandated core curriculum and pacing schedule, many classes/preps/duties/lack of time, and students unprepared/unwilling for student-centered/inquiry work respectively as hindering factors.

Further, five groups of three teachers (50%) identified single laboratory period, students' lack of motivation, lack of resources, no/restricted access to computer lab/technology, and lack of collaboration with other teachers in the school respectively as hindering factors.

Also, nine different pairs of teachers (33.3%) reported these as hindering factors: test preparation; large class size; students' poor math and reading skills; students who cannot focus; need to train students how to work in a group; students who need more time to learn the basics; MCE program practices not being realistic for a high school classroom; MCE program's education course not being helpful; and class management/control problems.

Table 17: *Frequency of Hindering Factors Reported by Teachers (N=6) in the Interview*

Category	Hindering Factors	Frequency
School District Mandates	Core Curriculum and Pacing Schedule	5
	Test Preparation (Standardized, Benchmark, AP and IB)	2
	Policies	1
	Administrative Paper-work	1
	Parental calls	1
	Large Class-size	2
	Many classes/Preps/Duties/Lack of time	5
	Single Laboratory period	3
Student Characteristics	Unprepared/unwilling for Student-centered/Inquiry Work	5
	Poor Math and Reading/Writing Skills	2
	Lack of Motivation	3
	Students who cannot focus	2
	Low Level	1
	Need to train how to work in a group	2
	Do not reflect on previous knowledge	1
	Often require reteaching	1
	Need more time to learn the basics	2
	Work only for credit	1
	Resistance to learn/explain	1
Administrative Support	Unsupportive Department Head	1
	Unresponsive Administration	1
	Lack of Resources	3
	Unconcerned Administrators	1
	Unsupportive NTA	1
	Unsupportive lab assistant	1
	No/restricted teacher acceess to computer lab/Technology	3
MCE Program Design	Lack of networking with MCE staff/students	1
	Not realistic for High School classroom	2
	Professors out of touch with HS environ.	1
	2 Pedagogy courses not helpful	2
	Teachers in Ed. courses substandard	1
Teachers' Characteristics/ limitations	Other priorities took precedence	1
	Class management/control problems	2
	Inability to engage the students	1
	Lack of collaboration with other teachers	3
	Not enough time to develop understanding/thinking skills	1

Additionally, one teacher (16.7%) each identified the school district policies, administrative paper work, parental calls, low level of students, students who do not reflect on previous knowledge, students who do not retain the material taught, students who only work for credit, students who resist learning, unsupportive department head, unsupportive administration, unconcerned administrator, unsupportive lab assistance, unsupportive NTA, lack of networking with MCE staff /students, MCE program professors being out of touch with high school environment, teachers in MCE program's education courses being substandard, other priorities taking precedence, inability to engage the students, and not having enough time to develop students' understanding/thinking skills as the hindering factor in the implementation of MCE program practices in their classrooms.

Teachers' quotes supporting several of the factors in each category that hindered the implementation of MCE Program practices are described next. Teachers' quotes were selected from an available pool of quotes derived from their responses to the interview questions. Selected responses that consisted of at least one complete sentence or up to several complete sentences were used when available. However, in some cases sentence fragments were selected because that was all that was available. Since the teachers did not respond in the same manner, only a limited number of quotes were available and are presented next. The selected quotes cover the category codes (School District Mandates, Student Characteristics, Administrative Support, MCE Program Design, and Teachers' Characteristics/Limitations) and are presented in the same order as presented in Table 17.

School District Mandates:

In their responses, five of the six teachers in the study pointed at the School District's mandated core curriculum and pacing schedule and its perceived shortcomings as a factor inhibiting the implementation of the practices. Teacher A stated, "with all the core curriculum and the benchmarks I hardly get time to touch all the topics and when it's not easy like the school district says you have to start on day one, and it is not possible to do so." According to Teacher B,

> There are a lot of subjects that we have to teach in a very short amount of time. For example, I think density I think we get one day and that's it so there really isn't time to do a lab and to do the inquiry and to do review and so on and so forth. So that would be a restraint, the core curriculum and the pacing schedule.

In addition to the core curriculum and the pacing schedule, many classes and preparations and lack of time were cited as hindering factors. As evidenced by Teacher D,

> I think what's holding me back is just how busy I've been…I had to teach physical science as well as chemistry so that's preparing two sets of classes a day and coming up with something that is more student directed is I think more challenging than just presenting material… I don't think I really had time to organize lessons with as much engagement for my students on a daily basis…. I had to teach two subjects that had the core curriculum and I had to implement them with totally new books.

For Teacher E, the lack of consideration in the core curriculum of the students' level of knowledge and skills was an inhibiting factor. According to Teacher E,

> One of the big things is the core curriculum that we have to follow with the school district. The other thing is the curriculum doesn't take care of different levels of student that we have in our schools. For example there is no way you can give us the same time line for the student in a neighborhood high school like at xxxx High school and a student in Girls High. It doesn't make sense at all.

Teacher F wove together a confluence of factors, such as the core curriculum, lack of time for practicing inquiry methods, and single lab period, as the reasons for inadequate implementation of MCE program practices. Specifically, Teacher F stated,

> It (the core curriculum) does not lend as much time to get in depth with some of the topics and if you can't get too deep then students won't be able to elaborate or expand on some needed skills research skills, presentation skills, use of technology skills, critical thinking skills, logical and analytical way of breaking things down. In the field of science research, time is of the essence. Scientist who conduct research need time to find the answer or the solution. So as our children need time to understand these concepts work on their own through the inquiry base method and things of that nature. So between time itself and because I don't have double lab periods we really can't expand too much. It has to be done within a 50 minute time period and it's really haste paste and clean up and try to push the topic within that time. But between time itself and the timeline by the school district; those are the two main factors that inhibit me.

Teacher B, also concurred with the inadequacy of single lab period as an inhibitory factor, said, "we actually don't have double lab periods we only have 50 minute periods, so I don't have the time." In support of the lack of time as a hindering factor, Teacher C added, "we don't have the time to analyze and reflect on things, the way they want to do it."

The time taken up for preparing the students to succeed in various tests took precedence over other considerations. As stated by Teacher A, "my main concern was to prepare them for xx exam and I am not concern about PIM. I just want to give them as many information as I can and prepare them for the test." On the same topic, Teacher D said, "I would have to do testing. They wanted to know if we were succeeding in the benchmark test."

Teacher C added, "we have constant testing that the city grades you on… testing, the constant testing. That's a school district policy."

In elaborating on how some of the School District's other mandated work and large class sizes impact adversely on the implementation of the MCE Program practices, Teacher B stated,

> there's also a lot of things that I have to do as far as like paperwork and CSAPs and a lot of parental calls for a large amount of students. So if I had a lower amount of students in the classroom, right now I have 165 so sometimes I have to make phone calls for a lot of those kids so that's what hinders me from doing that.

The many roles and responsibilities teachers have to assume in their situations leaves little time for implementation of the practices. As poignantly stated by Teacher F,

> Well being in a small high school…causes many teachers to wear many hats so time management is really, time is not a friend of ours, not a friend of mine so I like other responsibilities that I have in the school but it prohibits me to really get into the practices of the MCE.

Student Characteristics:

Students' lack of preparedness, enthusiasm, and willingness to take part in inquiry activities were mentioned as inhibitory factors in the implementation of the practices by five of the six teachers. Teacher E said, "most of the kids want you to teach them and give them the answer at the same time and give them the grade… they still want the teacher to do it for them". Similarly, for Teacher D, "student-centered approach doesn't always work when my students aren't that willing to work".

Referring to the lack of motivation among students, Teacher C had this reaction

> I really believe there's something missing in today's child. I don't think there's that desire or that burning quest to be an A student. I'm locked in with the best in the city who says, "Oh just give me a D and I'm happy," and this has to change.

Teacher A also supported lack of motivation among students as an inhibitory factor, stating, "It depends on how motivated the students are and also what their goals are. If you get a very low level class where the students are not motivated, it is difficult to implement the research-based practices."

Teacher E found that students had resistance to learn and explain concepts, an important skill in the research-based methods, by noting that

> Kids don't like it especially when you ask them why you had to link this concept with this. They don't want to go into the actual explaining why for example an atom should be linked to a molecule which links with the other one.

Student characteristic of not reflecting and connecting to previously acquired knowledge was described as a hindering factor by Teacher A in these words "students they do not want to go back and look what they already learned. They will raise their hands and say, what is this, what is that, can you explain it again? Or maybe they just forgot everything."

Administrative Support:

Complaining about the lack of resources and its adverse impact on the ability to implement the MCE Program practices, Teacher E said,

> they don't provide the materials to go with it. They tell us this is what you're supposed to do. On the other hand there are no materials to go with the core curriculum. They don't give us the lab materials that we need. We get only $100 for supplies and the rest is for me to figure out and it becomes very frustrating.

In the same vein, Teacher C felt that lack of money was a hindering factor in urban schools. He added, "Chemistry is becoming more and more technology. Basic wet bench chemistry isn't practical, doesn't exist. To outfit just one class in a Vernier computerized system, we're talking, this is not counting computers, we're talking $5,000."

Teacher E felt unsupported by the school's administration when students misbehaved and expressed her frustration in the statements, "There are no clear consequences for misbehaving in the classroom. And that really becomes a big issue of concern for me as a teacher. This impacted negatively the ability to implement inquiry-based methods."

In Teacher D's opinion, not being asked by the administrator to implement the practices in his/her classrooms hindered its implementation. He/she expressed, "It wasn't a push from the administration, [such as] "Oh, are you implementing the MCE program?" The administration didn't care about that."

MCE Program Design:

Some teachers were critical of certain aspects of the MCE Program itself and felt that improvement in these areas would translate into better implementation in high school classrooms. Teachers B and D felt that the program was not realistic for implementation in a high school classroom. For instance, Teacher B said,

> I think that they could focus maybe more on the things that they could actually implement into the classroom that would be much better…. I think it would have been a lot helpful if they just implemented some things that are more high school related.

Adding to this same idea, Teacher D said, "I'm interested in ways that I can implement the program and figuring out ways to make it work in a classroom setting with teenagers not with teachers who are science teachers who are very interested in the materials."

Although full of praise for MCE Program's content courses, Teachers C and F were critical of its two education courses and thought that these did not help in the implementation of the practices in urban classrooms . Teacher F said,

"I wish there was more focus on the educational base than the two years just two educational courses that because it's implementation of the content with the education I think that it could probably focus more on the educational courses." According to Teacher C, "I think their education end of the course for lack of many things is lacking a whole lot."

The inability to use MCE Program as a continued resource after graduation was a hindering factor for Teacher B, who noted, "I don't think there's anything that they have in the program that allows you to maybe call them up like a hotline or something or ask questions its nothing like a forum or anything post."

Teacher's Characteristics/Limitations:

With respect to collaboration with other teachers in the school and/or other graduates of MCE Program, three of the six teachers in the study stated that lack of such opportunities hindered their ability to implement the program in their classrooms. Teacher F said, "I would like to collaborate more and show him (the other science teacher in school), you know be a front-runner, how to use those practices but people have to be willing to accept change, and to implement change." Regarding the same topic, Teacher E mentioned,

> I see there is no time for inviting teachers to collaborate with each other. Teachers in the same academy for example they don't have the same prep, they don't have the same lunch and still are in the same academy. When you come to the science department again it's the same thing you're not having the same

> common period or time that can bring you together and work together. People are not given time to lesson plan together. Time for collaboration is not there.

Teacher D simply stated that he/she "just became preoccupied with other things that needed to be done," and this left little time for collaboration.

Discussion

When asked to elaborate upon and prompted in their individual interviews, the teachers came up with a wide-ranging array of obstacles that stood in the way of implementing the practices of the MCE program in their classrooms. Two of the three obstacles cited by five teachers (83.3%) in the study belonged in the category of school district's mandates, and the third onewas in the category of student characteristics. One of the obstacles in the school district's mandates category was, the Core curriculum and the pacing schedule. In the School District of Philadelphia all the teachers are required to follow the same curriculum in the regular chemistry course and are provided the same primary resource (textbook). An essential component of this system is the pacing schedule, a day-by-day account of the coverage of the curricular material, which is the same for all the classes, irrespective of the population of students the school caters to.

The second obstacle in the school district's mandate category cited by five teachers (83.3%) was, the calss limit of 33 students and the fact that a teacher could be given up to 3 different subjects (preparations) to teach everyday, with students at various levels of preparedness, language proficiency, and abilities (from specila needs to gifted) in each class. The student characteristic cited by five teachers (83.3%) as a hindering factor was the prevalent teaching practices in a school setting, with a vast majority of students being used to teacher-centered, teacher-driven lessons, and being prepared to take ownership of their learning necessary for inquiry-based lessons.

The causes described by half the teachers were also beyond their control, such as single laboratory periods, unmotivated students, lack of resources, lack of teacher access to technology, and no opportunity to collaborate with peers in the school.

To exacerbate the situation, two teachers (33.3%) in this study felt that they faced conditions such as large class sizes, preparing the students for many tests, class management problems, and students who were unprepared academically and behaviorally to act as responsible learners.

Some teachers (16.7-33.3%) felt that the design of the MCE program itself did not prepare them adequately in certain respects, such as how to transfer the methods of teaching to an urban high school setting with the challenges described above. Others (16.7-33.3%) admitted to their own inability to engage the students and letting other initiatives take precedence over the implementation of the MCE program practices.

CHAPTER 5

CONCLUSIONS, DISCUSSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Introduction

This chapter provides: a summary of the research study; summaries of findings; discussions and emergent conclusions; implications; and recommendations for future research in the professional development area of science education.

Summary of the Research Study

The purpose of the study was to investigate the extent to which a group of six teachers, who had graduated from an exemplary professional development program in chemistry education, were implementing the recommended program practices in their urban high school classrooms. In addition, this research examined how did the implementation of program practices differ among the teachers, and also attempted to determine the factors that enabled and inhibited the implementation of said practices.

In the year 2000, Master of Chemistry Education (MCE) Program admitted its first cohort of science teachers in the Philadelphia area. The intent of the Program was aimed at developing a deep knowledge of chemistry within the teachers, while the teachers concomitantly learned and experienced first hand recommended research-based inquiry methods integral to 10 courses spread over 26 months. This study looked only at the practices of the program graduates who were teaching chemistry in the School District of Philadelphia at the time of this study. Six of only seven such teachers, who graduated from the program between 2002 and 2006, agreed to participate in the study.

In this 15-week long research, the teachers' degree of implementation of the MCE Program practices in their classrooms was probed through various perspectives using multiple data sources. At the commencement of the study, the teachers completed a self-reported Stages of Concern Questionnaire (SoCQ, see Appendix F) that probed their concerns regarding the implementation of Program practices through thirty five statements. Amended to this questionnaire were three open-ended questions. The first question asked them to identify and rate their overall level of implementation of research-based practices by choosing from a set of five descriptors provided and by ranking their practices. The second and third questions asked them to shed light on factors that enabled and hindered the implementation of the practices, respectively.

Each teacher was also observed teaching three times by the researcher, in the 15-week duration of the study. The instrument, Reformed Teaching Observation Protocol (RTOP, see Appendix G), was used for documenting and scoring this researcher's observations of the teachers in action in their respective classrooms. Twenty-five different aspects of research-based practices spread over three domains (lesson design and implementation, content, classroom culture) were evaluated using 25 statements exemplifying the research-based practices inherent to the instrument. The teachers' overall score, as well as the scores for each of the three domains, were further parceled into one of four different levels of implementation of Program practices (Absent, Low, High, or MCE Program Intention). Copies of the teachers' lesson plans were also requested by this researcher on the days that each teacher was observed.

Towards the end of this study, the teachers provided a detailed perspective of their own practices by completing a survey. This survey, called the Reform Teaching

Observation Protocol Teacher Survey (RTOPTS, see Appendix I), was created by this researcher. This survey was a modification of the RTOP instrument, whereby the same 25 research-based practices embodied in the RTOP were reflected in the survey's 25 statements. The teachers' self-reported scores (overall, as well as in the domains of lesson design and implementation, content, and classroom culture) on the RTOPTS determined their levels of implementation (Absent, Low, High, or MCE Program Intention).

At the end of the study, the researcher interviewed the teachers with three common broad questions (Appendix I) regarding their practice and the remaining specific questions regarding their concerns about the implementation of Program practices in their classrooms. The teachers' responses to the three interview questions were also examined by comparing the classroom practices described, to the classroom practices embodied in the 25 statements of the RTOP instrument. The teachers' level of implementation of Program practices was identified (Absent, Low, High, or MCE Program Intention) for the domains of lesson design and implementation, content, and classroom culture. The remaining interview questions probed the teachers' beliefs about the enabling and hindering factors regarding the implementation of Program practices in their respective classrooms. The findings and emergent conclusions are summarized below.

Summary of Findings, Discussions, and Emergent Conclusions

In this section the summaries of findings and related discussions are revisited, and emergent conclusions are presented for each of the research questions. As an aid to the reader, the contributory questions, if any, are also presented here for completeness.

Research Question 1:

How does graduation from a twenty-six month content intensive professional development program for high school teachers, whose goal is to improve the teachers' knowledge of research-based instructional practices (in the domains of lesson design and implementation, content, and classroom culture), affect the classroom practices of the group of teachers in an urban environment?

Three contributory questions assisted in answering this research question.

(1) To what extent does the group's lesson design and implementation reflect the research-based instructional practices?

(2) To what extent are the group's content knowledge and application of supportive procedures exhibited during their classroom instruction?

(3) To what extent does the group of teachers promote a student-centered classroom culture, consistent with the research-based practices?

Summary of Findings and Discussion

When asked to select one of five descriptors (Non-user, Novice, Intermediate, Old-hand, Past-user), in the open-ended question in the questionnaire that best revealed their levels of implementation of Program practices, the research findings indicated that the group overwhelmingly chose the Intermediate descriptor. When asked to use a numerical scale to rate their levels of implementation of Program practices in their classrooms, the findings suggested that the level of implementation of research-based practices was at a low level. While the group described their level of implementation of MCE Program practices in their classrooms as intermediate users, they also perceived themselves as minimally implementing the research-based practices. This difference in perspective could possibly be due to the fact that no explanation accompanied the descriptors of the implementation, and none of the teachers asked for further clarification of the meanings of these terms. As such, the teachers interpreted these descriptors in their own ways. The questions amended to the questionnaire were intentionally open-ended to elicit the teachers' spontaneous interpretations and responses regarding the extent of implementation of MCE Program practices in their classrooms.

The findings above are now discussed further with respect to each of the three domains (lesson design and implementation, content, and classroom culture). With respect to the lesson design and implementation domain, the average scores for the levels of implementation of the Program practices in their classrooms for the group when observed and interviewed by this researcher were indicative of a low level of implementation. A different result was obtained when the teachers were surveyed. The average self-reported score for group's level of implementation of Program practices suggested a higher level than from classroom observations.

With respect to the content and the classroom culture domains, the group's average scores for the implementation of Program practices in their classrooms when observed and interviewed by this researcher represented low levels. However, the survey scores suggested that the group's average levels of implementation of Program practices for both of these domains were indicative of the highest level (MCE Program Intention).

The group of teachers exhibited research-based practices in the domains of lesson design and implementation, content, and classroom culture to a low extent when observed by this researcher. Similarly, a low extent of implementation of research-based practices was also admitted by the group of teachers when prompted to describe their classroom practices in the three domains via very broad open-ended questions during the interview. However, a high level of implementation of Program practices was self-reported by the group on the survey. It is worthwhile to note that the survey included highly focused and directed statements characteristic of research-based practices. In the case of the survey, the teachers' responses were representative of the ideal teacher behaviors, the intent of the reform movement in science education.

These survey responses, although not corroborated by observation and interview, were possibly due to social desirability factors (Edwards, 1957, 1990). In brief, social desirability is defined as "the pervasive tendency of individuals to present themselves in the most favorable manner relative to prevailing social norms and mores" (King & Bruner, 2000, p. 80). This phenomenon occurs because individuals are prone to over report activities that are deemed to be socially and culturally desirable (Groves, 1989; Nunnally, 1978; Zerbe & Paulhus, 1987). In other words, the teachers reported the best practices recommended by research and espoused by the MCE Program, but not necessarily practiced by them in their classrooms.

Also, in literature, some researchers attribute the mismatch between reform intent and actual classroom practice to three factors: 1) the researchers' use of different frames to measure progress towards the attainment of reform practices (Knapp, 1995; Spillane & Jennings, 1997); 2) the teachers' diverse interpretations of reform methods in terms of their existing beliefs about subject matter, teaching and learning (Cohen & Ball, 1990); and, 3) the teachers' propensities to change some aspects of their practice to be more aligned with the reform methods, while leaving others unaltered (Ball, 1990). Generally, teachers change the practices such as grouping arrangements and materials, the behavioral regularities, relatively readily (as evidenced in this study). However, discourse norms and academic tasks, the epistemological regularities, are more resistant to change (Spillane & Jennings, 1997). Therefore, a careful examination of teachers' classroom practices, as they implement reform methods, will be helpful in understanding the course of reform implementation and may help explain the difference (Spillane & Zeuli, 1999).

Conclusion

On the basis of these findings, the researcher concluded that graduation from a twenty-six month content intensive professional development program for high school teachers, whose goal is to improve the teachers' knowledge of research-based instructional practices (in the domains of lesson design and implementation, content, and classroom culture), has affected the classroom practices of the group of teachers in an urban environment to a low extent compared to recommended practices inherent to the MCE Program.

Research Question 2:

How are the teachers' classroom practices (in the domains of lesson design and implementation, content, and classroom culture) different from each other when implementing the research-based MCE Program practices?

Three contributory questions assisted in answering this research question.

(1) To what extent are the teachers' designed and implemented lesson plans different from each other when implementing the practices?

(2) To what extent are the teachers' content knowledge and application of supportive procedures exhibited during their classroom instruction different from each other?

(3) To what extent is the teachers' promotion of a student-centered classroom culture different from each other, but consistent with the research-based practices?

Summary of Findings and Discussion

The findings suggested that when asked to self-report their overall level of implementation of the MCE Program practices in their classrooms, on the open-ended question in the questionnaire, five of the six teachers chose the descriptor Intermediate for this activity. Only one teacher chose Non-user to describe his/her level of implementation of the research-based practices. On a numerical scale, however, their self-reported scores were more spread out with more scores at the extreme (Absent and High) levels of implementations of the practices than in the middle (Low) level.

Most teachers chose the Intermediate descriptor for their implementation of the practices. One teacher chose the descriptor non-user for this purpose. This one teacher also chose, along with his/her cohort-mate, the absent level to rate themselves on the numerical scale of implementation of MCE Program practices. Coincidentally, both were in the first cohort, and had graduated from MCE program the earliest among the group of teachers in the study. In the same vein, the teacher who provided his/her implementation of practices the highest numerical value was the most recent graduate of the program. The remaining teachers, who graduated with the second and the third cohorts, self-reported their implementation of practices as high or low. Further, there was a lack of correspondence between the descriptors and the numerical scores of teachers’ self-reported levels of overall implementation of the practices. This may have been due to the fact that the two ratings were meant to be independent of each other by design, therefore, the researcher did not provide a correspondence between the two, and the teachers never asked for clarification, choosing to interpret the descriptors and the numerical ratings in their own ways.

The findings above are now discussed further with respect to each of the three domains (lesson design and implementation, content, and classroom culture). With respect to lesson design and implementation domain, the average observation scores for the teachers were distributed across the Absent, Low, and High levels of implementation of Program practices. However, the level of implementation of Program practices for the majority of teachers was at the low level. The teachers' responses in the interview pertaining to this same domain were distributed more widely, i.e., among all the four possible levels (Absent, Low, High, and MCE Program Intention). This distribution was more heavily and equally weighted at the two extremes (Absent and MCE Program Intention). In the case of the survey, the self-reported levels of implementation of Program practices were narrowly clustered at the two highest levels, i.e. High and MCE Program Intention. Here, twice as many teachers reported implementing the Program practices at the high level.

With respect to the content domain, the average observation scores for the teachers' level of implementation of the Program practices were equally distributed between two levels (Low, High). When interviewed, the levels of implementation of the practices were distributed equally across three levels (Absent, Low, High). However, the teachers' survey scores indicated only the highest level of implementation of Program practices, i.e., the MCE Program Intention.

With respect to the classroom culture domain, the observation scores of the teachers were equally distributed across the Absent, Low, and High levels of implementation of MCE Program practices. When interviewed, half the teachers believed that they implemented the MCE Program practices at the High level; the remaining teachers' perceived levels of implementation of Program practices were distributed between two levels (Absent, Low), with a higher concentration at the Absent level. For the self-reported survey, the levels of implementation of the Program practices were narrowly clustered at the top two levels (High, MCE Program Intention). Here, five teachers reported the MCE Program Intention level, whereas only one teacher indicated the High level.

The teachers' levels of implementation of the Program practices, in the three domains, derived from the observation and interview revealed scores that were spread out over a broader spectrum of three or four levels (Absent, Low, High, MCE Program intention), indicative of a much greater variation in the implementation of Program practices among the teachers and among the domains. The levels of Program practices leaned more heavily towards the Low, suggesting that more teachers were not utilizing research-based practices to a significant extent. However, the results from the survey were narrowly clustered at the two highest levels of implementation (High, MCE Program Intention) indicative of the similar nature of the teachers' perceived practices. The clustering of the self-reported survey responses in a narrow band, compared to the broad sweep of results from the observation and the interview may have been due to social desirability effects (Nunnally, 1978). As described earlier in this section, these arise due to respondents' tendencies to present themselves in a favorable position with regard to social norms (Nunnally, 1978). In this study, the norms were the exemplary practices promoted by the MCE Program and expressed through 25 statements in the

RTOPTS. The social desirability effects were possibly not due to a deliberate attempt by the teachers to misrepresent their practices, but due to self-deceptive positivity, an honest but overly positive self-presentation, the conscious tendency to see oneself in a favorable light (King & Bruner, 2000; Paulhus, 1991). Whatever be the origin, social desirability has the potential to distort the information gained from self-reports (Sudman & Bradburn, 1974), typically resulting in the compression of the range of responses around an end of the scale (Cote & Buckley, 1987; Hattie, Fletcher, & Watkins, 2006), similar to the RTOPTS responses in this study.

As mentioned earlier, another view of this lack of correspondence between the perceived reform methods and actual classroom practices points to three possible factors influenced by the teachers' beliefs, ambient cultural norms, and resources (Spillane & Zeuli, 1999).

The results from the classroom observations of the teachers and their interview responses were similar in that both showed a greater variation in the levels of implementation of the practices among the teachers. However, the levels of implementation of Program practices, in the three domains, were not corroborated by the observation and interview results for the majority of teachers. This may have been due to the presence of the interviewer affecting the rate and quality of responses (Singer & Kohnke-Aguirre, 1979; Singer, Frankel, & Glassman, 1983). Further, when the topic of interview is sensitive in nature, the mere presence of the interviewer may lead to distorted reporting of sensitive behavior and beliefs (Schaeffer, 2000; Tourangeau, Rips, & Rasinski, 2001). All of these factors were evident in this study, with a teacher producing no response in the interview, to some speaking several paragraphs, and one teacher talking about what was of immediate concern to him/her, e.g. the core curriculum and class management.

It is worth noting that the teacher in the study who graduated from the program most recently was the only one implementing the practices at a high level in his/her classroom in all the three domains (lesson design and implementation, content, and classroom culture) during classroom observations. Also, half the teachers were observed to be implementing the practices in the content domain at a high level (i.e., this number was greater than the numbers for the other two domains). This may have been due to an emphasis on developing the depth of understanding of chemistry in the MCE Program as evidenced by the statement “The courses in chemistry are designed for depth of understanding of fundamental concepts and the interconnectedness of these concepts” (Blasie & Palladino, 2005, p. 567).

Conclusion

On the basis of these findings, the researcher concluded that the teachers' levels of implementation of MCE Program practices differed in terms of being absent, low level, high level, or MCE Program Intent level with inconsistencies in the extent of the teachers' levels of Program practices contingent upon the teacher, and the type and nature of data source used to ascertain them.

Research Question 3:

What concerns do teachers express as factors that enable the implementation of the MCE program practices in their classrooms?

The reader is reminded that the teachers' self-reported responses to the questionnaire's second open-ended question and an interview question were utilized to arrive at the findings.

Summary of Findings and Discussion

When asked to self-report the enabling factors in the questionnaire for implementing the MCE Program practices in their respective classrooms, the findings indicated that the teachers suggested twelve factors (described below) distributed among four categories: MCE Program practices; Student Characteristics; Administrative Support; and Other. Majority of teachers suggested four factors (depth of content knowledge, formal laboratory exercises and reports, hands-on problem-solving activities, and group/collaborative work) related to the MCE Program practices as either currently enabling or potentially enabling. Furthermore,

1. Three of the six teachers reported formal laboratory exercises and reports and hands-on problem-solving activities as factors that currently enabled or would potentially enable the implementation of the practices;
2. Two of the six teachers reported the depth of content knowledge gained in the MCE Program as an enabling factor, while one teacher out of six reported group/collaborative work;
3. In addition to the factors just described, one teacher out of six expressed student characteristic-related enabling factors (good behavior, self-motivation, and basic skills to follow instruction) and administrative support-related factors (supportive department head, laboratory assistant as teacher aide, adequate supplies) as enabling or potentially enabling; and

4. Two of the six teachers did not report any enabling factors, but for different reasons (Nothing, Not using the MCE Program practices).

Fifteen weeks later when asked to identify in the interview, factors enabling the implementation of the MCE Program practices, the findings suggested that the teachers mentioned twenty one factors distributed among four of the above categories and an additional category (MCE Program design). Furthermore,

1. The teachers were unanimous in identifying the depth of knowledge of chemistry gained in the MCE Program as an enabling factor in implementing the practices in their classrooms;
2. Three of the six teachers highlighted the support from the administrators as an enabling (or potentially enabling) factor;
3. Two of the six teachers reported group/collaborative work, laboratory work, use of internet and technology, student self-motivation, and adequate time and training for the students as enabling (or potentially enabling) factors; and
4. Individually, different teachers expressed single instances, totaling fourteen enabling (or potentially enabling) factors spread over the five categories.

Both the data sources, the questionnaire and the interview, were similar in some key respects, i.e. both sought the teachers' views regarding the factors that enabled the implementation of the practices in their classrooms. It is important to note that the teachers interpreted the question in two different ways. The teachers interpreted the question to simultaneously mean the factors that currently enabled or potentially would enable them to implement the Program practices in their respective classrooms.

There were important differences in the responses provided by the teachers to the questionnaire and the interview. At one extreme were two teachers who responded, but did not contribute any enabling factors in the questionnaire. At the other extreme was a teacher who solely contributed six factors in two categories that enabled or would potentially enable him/her to implement the Program practices. In between these two extremes, four teachers expressed a total of four enabling (or potentially enabling) factors covering one category.

The interview resulted in almost double the number of enabling factors or potentially enabling factors contributed by all of the teachers in five categories. This may have been due to the probing and encouragement of the researcher during the interview, to elicit responses from all the teachers.

The five factors that more than one teacher identified at the commencement of the study (via the questionnaire) and also at the conclusion of the study (via the interview) were: depth of knowledge, formal laboratory exercises and reports, administrative support, self-motivated students, group/collaborative work in the classroom. The most reported enabling factor was the depth of knowledge obtained in the MCE Program. To a lesser degree, equal mention was given to the formal laboratory exercises and reports and administrative support. Self-motivated students and group/collaborative work were reported least often by more than one teacher.

Three of the five factors (depth of knowledge, formal lab exercises and reports, group/collaborative work) were essential components of the MCE Program (Blasie & Palladino, 2005). Therefore, it is not surprising that many teachers mentioned these consistently as enabling (or potentially enabling) factors for implementing the MCE

Program practices in their classrooms. To buttress this point, five out of six teachers did not have double-laboratory periods in their teaching rosters.

The remaining two factors (administrative support, self-motivated students) were contingent on each teacher's context of practice. With respect to the administrative support factor, continued support in implementing inquiry-based approaches to teaching and learning, an integral method of the MCE Program, has been discussed in the literature (Lombardo, 2000). Teachers' quotes corroborating the teachers' needs for administrative support have already been presented earlier in this chapter. Without continued support from the administration during the implementation of MCE Program Practices, the goals established for teachers and students cannot be reached.

With respect to the self-motivated students factor, the specific student characteristic of student's self-motivation has been reported to aid in inquiry-based approaches (King, 1995). However, students' behavior in an urban environment can be resistant towards participation in classroom activities (Barton, 2001; Bouillion & Gomez, 2001). During the interview, teachers offered brief perspectives on students' behavior, in general, and students' resistance towards participation in scheduled activities, in specific. The teachers' views are presented next.

A major premise of the MCE Program Practices (see Chapter 2) is that students revisit previous experiences and incorporate them into new experiences. On this topic, Teacher A said, "students do not want to go back and look at what they already learned." Extending experiences via homework assignments is another premise of the MCE Program Practices. On the topic of homework and the students' willingness to complete assignments, Teacher D expressed, "If I am not going to collect it (i.e. assignment) in some way shape or form, frequently they won't even attempt the problem." Furthermore, Teacher D expressed that "my students are not that willing to work."

The instructional strategies and structured activities require that students assume a different role in the learning process when compared to traditional strategies and related activities. With respect to this new role for students, Teacher E exclaimed, "you know sometimes kids refuse change." Teacher B said that his/her "students don't follow the instruction." With respect to the topics of instructional strategies, structured activities, and the new role for students, Teacher E's students simply "resist some of the things I was doing." Without the students' complete support in the learning process and related activities during the implementation of the MCE Program Practices, the goals established by the MCE Program for students cannot be achieved as intended.

Conclusion

On the basis of these findings, the researcher concluded that the teachers' concerns expressed as factors that enabled, or would have enabled, the implementation of the MCE Program practices in their classrooms were depth of knowledge, formal laboratory exercises and reports, administrative support, self-motivated students, and group/collaborative work.

Research Question 4:

What concerns do teachers express as factors that hinder the implementation of the MCE program practices in their classrooms?

The reader is reminded that the teachers' self-reported responses to thirty-five statements and the third open-ended question in the questionnaire, and some interview questions were utilized to arrive at the findings.

Summary of Findings and Discussion

On the questionnaire, when the teachers were asked to rate their concerns regarding the implementation of MCE Program practices in their respective classrooms, the findings indicated that the teachers unanimously provided the 'Unconcerned' stage of concern the highest score, implying that the teachers were not concerned about the implementation of the Program practices. The second highest concern scores given by the teachers were equally distributed among the 'Management', 'Collaboration', and 'Refocusing' stages of concern. This meant that the teachers were concerned about issues of organizing, managing and scheduling information and resources germane to the implementation of the Program practices, coordinating and cooperating with other teachers regarding the use of Program practices, and the possibility of making major changes in and replacing the Program practices with alternatives. Additionally, the findings revealed that five of the six teachers were least concerned with the impact of the implementation of the Program practices on students' performance and competencies, while collaboration with others regarding the implementation of Program practices was of least concern to one teacher.

1. When asked to self-report the hindering factors, in the questionnaire, for implementing the MCE Program practices in their respective classrooms, the findings indicated that the teachers suggested twelve factors (described below) distributed among three categories: School District Mandates; Student Characteristics; and Administrative Support. All the teachers contributed to the category School district mandate and expressed the five factors associated with this category (Core curriculum and pacing schedule, test preparation,

policies, administrative paper work, and large class size) as the most frequent hindering factors in the implementation of the Program practices. Furthermore, four of the six teachers reported the Core curriculum and pacing schedule as a hindering factor in the implementation of the practices.

2. Two of the six teachers reported the time and effort expended in preparing their students for various tests as a hindrance to the implementation of the MCE Program practices.
3. In addition, one teacher out of six expressed other school district mandate-related factors (policies, administrative paper work, large class-size), student characteristic-related factors (unprepared for student-centered work, poor math and reading skills, lack of motivation, lack of basic skills to follow instruction), and administrative support-related factors (unsupportive department head, unsupportive administration, lack of resources) as hindering the implementation of MCE Program practices in their urban classrooms.

Fifteen weeks later when asked to identify in the interview, factors that hindered the implementation of the MCE Program practices in their classrooms, the findings revealed that the teachers mentioned thirty-six factors distributed among three of the above categories and two additional categories (MCE Program Design and Teachers' Characteristics/Limitations). Furthermore,

1. Five out of six teachers expressed that three factors, i.e., core curriculum and pacing schedule, many classes/preps/duties/lack of time, and students unprepared/unwilling for student-centered /inquiry work were hindering them from implementing the MCE Program practices in their classrooms.

2. Three of the six teachers mentioned single laboratory period, lack of motivation on the part of students, lack of resources, no/restricted teacher access to computer lab/technology, and lack of collaboration with other teachers as the factors hindering the implementation of MCE Program practices in their classrooms.
3. Two of the six teachers described the following factors as hindering the implementation of Program practices in their classrooms: (time and resources spent on) test preparation, large class size, poor math and reading/writing skills of students, students who cannot focus, students who need to be trained to work in a group, students who need more time to learn the basics, MCE Program practices not being realistic for high school classrooms, unhelpful pedagogy courses in the MCE program, and the teachers' class management/ control problems.
4. Individually, different teachers expressed single instances, totaling nineteen hindering factors spread over the five categories.

The interview resulted in almost three times the number of hindering factors contributed by all of the teachers in five categories than elicited from the questionnaire. This may have been due to the probing and encouragement of the researcher during the interview, in an attempt to elicit the most responses from the teachers.

The ten factors that one or more teachers identified as hindering factors both at the commencement of the study (via the questionnaire) and at the end of the study (via the interview) were: core curriculum and pacing schedule, test preparation, administrative paper-work, large class-size, students not prepared for student-centered work, poor math and reading skills of students, students' lack of motivation, unsupportive department head, unresponsive administration, and lack of resources.

Teachers were nearly unanimous (prior to and after the study) in singling out the school district's mandated core curriculum and pacing schedule as the hindering factor. This was followed by two of the teachers reporting (prior to and after the study) the time and resources spent in preparing the students to take various mandated tests as the hindering factor.

The supremacy of core curriculum in the district that the teachers were required to follow with fidelity, keep pace with, and were continually evaluated on adherence to, was very likely the reason for the unanimously high score they gave to the 'Unconcerned' stage of concern when asked to rate the implementation of the MCE Program practices. This preoccupation with the core curriculum may also explain 'Refocusing' (having definite ideas about alternatives to MCE Program practices) being the second highest stage of concern for two of the teachers. Two of the hindering factors, unsupportive department head and unresponsive administration, corroborate 'Collaboration' being the second highest stage of concern for two teachers. The remaining seven hindering factors could be the possible explanations for 'Management' being the second highest stage of concern for the remaining two teachers, with regard to the implementation of MCE Program practices in their classrooms. Furthermore, the teachers were preoccupied with hindering factors such as students' lack of motivation and preparedness to be concerned with how the implementation of MCE Program practices affected the students, resulting in five of them rating 'Consequence' as the lowest stage of concern.

Conclusion

Based on these findings, the researcher concluded that the teachers' concerns expressed as factors that hindered the implementation of the MCE Program practices in their classrooms were, first and foremost, the core curriculum and pacing schedule, followed by test preparation, administrative paper-work, large class-size, students not prepared for student-centered work, poor math and reading skills of students, students' lack of motivation, unsupportive department head, unresponsive administration, and lack of resources.

Implications

In this section, first the conclusions of the study will be elaborated upon to frame the context for the implications. Then, the implications derived from these conclusions will be described.

Generally, the teachers in the study implemented the reform-recommended MCE Program practices in their urban classrooms at a low level. A mixture of drops of reform-based practices in a pool of traditional methods permeated the classroom instruction of the teachers in the study. Thus, bits and pieces of reform were present in their classroom practices, but the core intent was not realized, leading to the perpetuation of largely traditional practices, similar to many studies reported in the literature (Cohen, 1990; Putnam, 1992). Further, the mixture of the two methods changed depending on the topic, goals of the lesson, and the given time as evidenced by the fluctuating levels of implementation of the Practices in the three observations of the teachers. As described very succinctly by Cohen (1990), the characteristics of the implementation showed that, "New threads were introduced, but old threads were not pulled out. The old and the new lay side by side, and so the fabric of instruction was different. However, there seemed to be little mutual adjustment among new and old threads" (Cohen, 1990, p. 314).

As Wilson (1990) has stated, implementing the reform-based methods is not adopting "a few new activities and instructional strategies" (p.308), for at its heart reform-based practices "assume fundamentally different things about the nature of learning and knowing" (p. 308). In describing one of the methods practiced in the MCE Program, one teacher mentioned acquiring the 'tricks to engage the students by working in groups', clearly implying the reform as an "add-on, not a fundamental reorganization" (Wiemers, 1990, p. 291). Larry Cuban called this phenomenon 'conservative Progressivism' and expressed it concisely as, "many teachers constructed hybrids of particular Progressive practices grafted onto what they ordinarily did in classrooms" (Cuban, 1984, p. 323).

In the three domains of lesson design and implementation, content, and classroom culture, some of the implications of low level of implementation of reform-practices and continuation of traditional practices were as follows.

Lesson design and implementation: There was little effort to explore the students' prior conceptions and understandings (8), teachers "maintained control of direction, content, and pace" (Cohen, 1990, p. 322), there was no exploration of scientific problems, students generally did not generate multiple solutions to problems, and alternative interpretations and answers (Wilson, 1990).

Content: Teachers conveyed the knowledge of chemistry as a fixed body of facts, rather than as a particular way of framing and solving problems, or as a subject in which "questioning and explanation were essential to learning and knowing" (Cohen, 1990, p.

322). Often the teachers worked near the “surface of the subject, many elements of understanding and many pedagogical possibilities remained invisible” (Cohen, 1990, p.323). Teachers’ use of hands-on/student centered activities were filtered through the established practice, with students being given little opportunity to figure out and make sense by themselves (Cohen & Ball, 1990a). Generally, the teachers did not use a wide variety of teaching strategies to develop conceptual understandings, and did not allow students sufficient time for reflection, designing investigations and critical assessment of procedures (Wallace & Kang, 2004). Teachers continued to dominate, and “the aims of instruction remained focused on supplying students with correct procedures for obtaining right answers” (Sykes, 1990, p. 349). Some teachers used activities designed to help students make sense of chemistry, but used them as a vehicle to provide the right/wrong answer (Cohen, 1990).

Classroom Culture: A majority of the activities were highly structured that “restricted the questions and ideas that could occur to students, for thought is created, not merely expressed, in social interactions” (Cohen, 1990, p. 322). The classroom discourse was generally constrained rather than open, with few opportunities for students to initiate discussion, explore ideas, or even ask questions. While students were invited to ask questions, only certain types of questions received attention and were answered (Wiemers, N.J., 1990) limiting teachers’ knowledge of students’ understanding. The teachers acted as dispensers of knowledge rather than as facilitators of students’ construction of understanding. Group work was often a venue for socialization, and did not promote mutual student engagement with complex problem-solving tasks (Sykes, 1990).

The amount by which the new practices were molded and incorporated into the traditional practices varied to different extents among the teachers in the study. Again, this is consistent with earlier studies, such as Cohen and Ball's (1990) landmark study of the implementation of mathematics reform efforts in California.

Further, in the present study of implementation of reform practices in urban chemistry classrooms, the teacher who graduated most recently from the MCE Program exhibited consistently high levels of implementation of the reform-methods during classroom observations, while the practices of one of the graduates of the first cohort were most traditional, with the reform alignment of the practices of the rest of the teachers in between these two extremes. This finding is consistent with Cohen's (1990) observation that lack of guidance regarding implementation once teachers are out of the program and on their own, results in a variety of interpretations, resulting in a "melange" of practices (Cohen, 1990, p. 311). This points to the continued need to support and nurture the teachers, as they learn to implement the practices, after they have graduated from the intensive MCE Program (Wilson, 1990, 13).

A puzzling finding of this research was the discrepancy between the teachers' perceived implementation (high) of the reform-based MCE Program practices and the implementation observed by this researcher (low). However, this discrepancy is quite pervasive in literature, e.g., in a sample of twenty-five math teachers who reported familiarity with reform efforts and said were implementing these in their classrooms, "only four taught mathematics in ways that resonated with reformers' proposals" (Spillane & Zeuli, 1999, p. 19). According to Yerrick et al. (1997) teachers' intricate cognitive system of resolving and rationalizing mechanisms allowed them to sincerely believe that their practice had changed without changing the core beliefs. According to Ball (1990) “This highlights the conceptual difficulty of communicating an alternative vision of teaching to those who would enact it: how to communicate and provide guidance for change in a way that is comprehensible and yet challenges current practice?” (p. 259).

Additionally, the broad definitions of inquiry described in the National Science Education Standards (NRC, 1996) provide little guidance to teachers for the actual planning, teaching, and evaluation of research-based methods such as inquiry in the naturalistic setting of the high school science classroom. This leaves the door ajar for a multitude of interpretations of reform-based methods, with inquiry at their core, consistent with the maintenance of teachers’ existing techniques, goals, and expectations (Cronin-Jones, 1991; Olson, 1981). The variance between the intent of reform-based practices and the teachers’ interpretations, may explain the discrepancy between the teachers’ self-reported scores of their practices and those of the observer’s. Perhaps due to their strong emphasis on conceptual knowledge and understanding, teachers were likely to interpret inquiry as asking questions or interpreting data only, whereas one of the definitions of inquiry in the reform-based practices is given as “ a multifaceted activity that involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, using tools to gather, analyze, and interpret data, proposing answers, explanations, and predictions, and communicating the results” (NRC, 1996, p.23; Keys & Kennedy, 1999).

Some hallmarks of reform-based instructional practices are, probing students' preconceptions, active engagement of students, and significant communication between and among students. The teachers in this study interpreted reform-based practices in different ways. For instance, instead of probing students' preconceptions and altering their instructional strategies to address these, the teachers addressed their ideas of student preconceptions in the existing instructional framework. With respect to the active engagement of students, this was perceived by the teachers as providing hands-on activities and conducting lab investigations following a cook-book type recipe provided by the instructor, instead of students designing and conducting investigations into authentic questions generated from their experiences.

Also, to implement the reform practice promoting significant communication between and among students, students were placed in groups or worked in pairs. However, this was done without any further explication of their roles, i.e., the form was created without the accompanying function. As Keys and Kennedy (1999) pointed out, based on a study by Bird and Weller (1997), "dilemmas about teacher and student roles continued to present obstacles to inquiry-oriented science teaching" (p. 317). During the inquiry process, the teachers and students have specific roles. With respect to teacher-centered traditional activities versus student-centered inquiry activities, the teachers in the study did not consistently exhibit practicing inquiry-based student-centered activities. They did, however, resort to predominantly teacher-centered, tradititional practices. Thus, the practices that these teachers implemented were not far removed from traditional practices or were an add-on to their traditional practices.

These misinterpretations and difficulties lend credence to the point that planning and teaching via inquiry-based methods, called for by the reform movement, is a highly complex and skilled enterprise (Bird & Weller, 1997; Flick, 1997), and the "task of translating reform ideas into useable forms" (Keys & Kennedy, 1999, p. 331) in the classroom cannot be circumvented. As Flick (1997) argues, "If inquiry is to become a viable, mainline approach to teaching science, researchers and teachers must become more explicit about the behaviors and thoughts of teachers engaged in inquiry teaching (p. 2)." Since the context of classroom practice such as the characteristics of learners, the school culture, and the science topic etc. has such a strong influence on the nature of implementation, "the details of inquiry-based teaching will need to be worked out in context" (Lijnse, 1995, p. 192). This leads to the recommendation for bridging the theory-practice gap, i.e. developmental research (Lijnse, 1995) mentioned in the recommendations section of this chapter.

When the teachers were asked to identify the factors that enabled and hindered the implementation of reform-based MCE Program practices in their urban classrooms, they named depth of knowledge, formal lab exercises and reports, administrative support, self-motivated students, and group/collaborative work most frequently as the enabling factors, and core curriculum and pacing schedule, test preparation, administrative paper work, large classes, unprepared/unmotivated students with low skills, lack of administrative support and resources most frequently as the hindering factors. Given the low level of implementation, it is not surprising that the teachers named twice as many hindering factors as enabling or potentially enabling factors. In the literature, the discussion of the implications of these factors on the implementation of reform practices diverges into two broad strands; one strand primarily emphasizes factors internal to the teachers, i.e., teachers' knowledge base, goals, beliefs, the need for examination/shift in beliefs, resolution of conflicting beliefs, and the interaction between the internal factors and the cultural factors in the context of practice as facilitators/impediments to the implementation (Ball, 1990; Ben-Peretz,1990; Collopy, 2003; Cory & Gamoran, 2006; Darling-Hammond, 1990; Feiman-Nemser & Buchmann, 1986; Olmedo, 1997). The second strand lays the blame on factors external to the teachers, such as the contextual situation of schooling and the ideal unattainable goals of the reform in the context of schooling (Doyle, 1988; Henningsen & Stein, 1997; Kennedy, 2005; Stylianides & Stylianides, 2008). Both of these strands of implications are applicable to the conclusions of this study and are discussed subsequently.

Teachers in this study unanimously stated the depth of content knowledge acquired in the MCE Program as an enabling or potentially enabling factor in implementing its practices in their classrooms, consistent with literature (Anderson & Helms, 2001; Richardson, 1996; van Driel, Beijaard, & verloop, 2001). However, similar to the teachers in this study, well-prepared teachers are not able to implement meaningful reform in the context of their practice (Duffee & Aikenhead, 1992; Huberman & Middlebrooks, 2000; Tobin & McRobbie, 1996). This failure has been attributed to the teachers' perceptions and beliefs about students, teaching, learning, need for test preparation and curriculum coverage, and lack of time etc. that drive their decisions regarding instructional practice (Brickhouse, 1990; Munby, Cunningham, & Locke, 2000; Pajares, 1992; Tobin & McRobbie, 1996). According to Nespore (1987), teachers rely on their core belief systems rather than academic knowledge as determinants of classroom actions. Five out of six teachers in the study held the belief that their students were unprepared/unwilling for student-centered/Inquiry work, and the coverage of core curriculum and lack of time were among the top hindering factors. Therefore, their classroom practices were largely traditional emphasizing drill and acquisition of facts, molded to align with their perceptions and beliefs (Meijer & Verloop, 1998). Cronin-Jones concluded, "In order to ensure more congruence between intended and implemented curricula, developers should put more effort into determining and considering existing teacher belief structures before developing new curricula" (1991, p.248). Haney, Czerniak, and Lumpe (1996) determined that most powerful component of reform may be the opportunity to experience success with inquiry-based teaching.

However, although the teachers in this study believed in the inquiry-based practices learned in the MCE Program and were willing to implement it, they felt constrained by the mandate to follow the school district's core curriculum and pacing schedule. This resulted in a struggle to balance their own beliefs with the culturally sanctioned beliefs of the educational system.

The interaction with cultural factors strongly influences the nature of classroom practice and moves it in the direction unintended by the reform-practices. It is reported that teachers with a strong knowledge base and equally strong belief in reform-based practices, similar to some teachers in this study, when confronted with the conditions present in their urban classrooms ended up compromising their beliefs and taught in traditional ways (Powell, 1997). Therefore, reform efforts must be redesigned so that they are amenable to being transformed into learner centered (andragogical) practices, 'in the context of classroom practice'.

Additionally, good quality professional development, such as the MCE Program, is sustained and develops deep knowledge of content and inquiry-based practices, a far cry from the one-shot deals of former years. However, this progress in the professional development design has only resulted in 'activating' teacher learning and raising it to high levels, as has happened with the teachers in the present study who feel they have the depth of knowledge as a result of participating in the MCE Program, and are empowered to implement the reform-based methods. What has not occurred, causing a lack of implementation of the practices in the urban high school classrooms, is how to enable the teachers with the requisite knowledge and skills to 'deliver' these practices in the context of their practice on a daily basis, i.e. how to promote a culture of reform-based practices in their diverse classrooms. This should be the next challenge effective professional development programs have to tackle, to make the recommendations of reform a reality in urban classrooms. It is also one of the recommendations stemming from this study. Again, a growing body of literature exists in this area (Engestrom, 1998; Horn, 2005).

As some teachers in the study suggest, even the best prepared teachers will not be able to deliver if the local administration is not supportive, class sizes are large, the resources are lacking, there are classroom management issues, and other competing priorities, such as the core curriculum and the pacing schedule in the school district under consideration (Henningsen & Stein, 1997; McLaughlin & Talbert, 1993; Olmedo, 1997; Peterson, 1990; Sarason, 1982; Stylianides & Stylianides, 2008; Sykes, 1990). As Darling-Hammond points out, "teachers will gear their teaching methods and strategies to the type of performance elicited by standardized tests, particularly when the tests are the basis for important decisions about students or schools (Bussis, 1982; Darling-Hammond

& Wise, 1985; Goodlad, 1984; Haney & Madus, 1986). The more immediate pressure will necessarily win out. The framework will have to fit in around the edges" (p. 343).

The above discussions raise the broader question, if the goals of reform can ever be realized in the context of classrooms, an occurrence that has eluded the practitioners of science education for several decades. Here it is fitting to revisit why the pursuit of this elusive dream is important to science educators.

The concept of inquiry-based science teaching gained currency as Schwab (1962) opposed the traditional teaching of science as a, 'rhetoric of conclusions'. His vision of school science curriculum was one that "more accurately represented the scientific endeavor as engaged in by practicing scientists, including active questioning and investigation" (Wallace & Kang, 2004, p. 939). The idea of students emulating the behavior of practicing scientists by "posing questions, designing experiments, collecting data, and drawing conclusions has been almost universally appealing and at the same time very difficult to implement in the classroom" (Wallace & Kang, 2004, p. 939). Despite decades of investment in this pursuit, this practice is far from being prevalent in classrooms (Singer, Hilton, & Schweingruber, 2005). The most recent reform movement, spearheaded by the National Science Education Standards breathed a new life in to the idea by making it the centerpiece of its agenda and declaring inquiry as the "Central strategy for teaching science"(NRC, 1996, p.31), along with equity and excellence. Mary Kennedy (2006) in her insightful book "Inside Teaching: How Classroom Life Undermines Reform" offers several reasons as to why the conditions in a classroom are inherently not conducive to the practice of the 'esoteric' reform-based methods. Although her work examined the reasons for failure of reform in elementary schools, these reasons are equally relevant in an urban high school context, find a very responsive chord in the findings and conclusions of this research study, and therefore are an important part of the implications for practice.

1. Teachers encounter repeated distractions in their classrooms resulting in the avoidance of “teaching difficult content to begin with, so that nothing is lost when distractions occur” (p. 232).

2. Teachers are always pressed for time and have to juggle a variety of tasks, giving the impression that “educational institutions do not provide tranquil or reliable working environments for either teachers or students” (p. 232).

3. The experiments or group projects advocated by reformers are very difficult to coordinate compared to seat work, and “often actually reduce attention to the lesson’s most important idea” (p. 232).

The solutions to all of the above problems are beyond the control of teachers. These are institutional problems. Unless the institution resolves to do something about it, the conditions will remain non-conducive to the implementation of reform practices.

Further, Kennedy (2006) maintains that in its zeal to encompass everything, the reform ideals “conflict with one another, forcing teachers to choose between, say, universal access and intellectual engagement” (p. 234), or “lesson momentum and covering content within scheduling constraints” (p.234). Additionally, some of the “non negotiable circumstances of teaching” (p. 234) are that “students are novice thinkers and are highly likely to veer off in unanticipated directions, physically active, quickly bored, and frequently restless” (p.234). Students are not adult practicing scientists (who already have a considerable knowledge base therefore their questions tend to be in focused directions) whose methods are to be implemented in the chaotic classroom environments. Therefore, if the reformers want the practices to be realized, they must be cognizant of the classroom constraints, adaptability of reform practices under these constraints, support the teachers in realizing the reform practices, and adapt the practices to suit the context.

Recommendations

Four types of recommendations are offered in this section: 1) recommendations for further research arising from this study, 2) recommendations related to the enhancement of the MCE Program or the professional development practices, 3) recommendations related to systemic factors in the context of practice, and 4) recommendations related to increasing the adaptability of reform practices in high school classrooms.

Recommendations for further research arising from this study:

Some connection was indicated between the teacher's level of implementation of the practices and year of graduation from the program. A correlational study between these variables may show if they are related, and may lead to recommendations for appropriate corrective action.

1. It will be interesting to conduct a similar study of suburban teachers from matched cohorts, to see the similarities and differences in the two contexts of practice. This study will be useful in shedding light on how teachers exposed to the same content and practices in the MCE Program implement and adapt based on the contexts of their practice.

2. One of the puzzling findings in this study was the high level of implementation that the teachers attributed to their practices on the survey, perhaps to be socially desirable. One of the ways social desirability effects are reduced in the literature is by changing the questions on the survey from direct to indirect. This change may be successful in eliciting a more realistic response from the participants, and may contribute towards providing an explanation for the puzzling finding.

3. In this study, the teacher concerns were ascertained once, at the beginning of the study. A more common method is to administer the concerns survey both at the beginning and at the end of the study to see if the teachers' concerns had shifted in the duration of the study. Analysis of this additional data has the potential to enrich the knowledge base for conditions conducive or inhibitory to the implementation.

Recommendations related to the enhancement of the MCE Program or the professional development practices:

Based on this research, several gaps need to be filled in the MCE Program or any in-service professional development program whose goal is to activate (to a high level) the reform-based practices in the practitioners and to deliver (to a high level) the same in their high school classrooms. The recommendations are divided into 3 stages, before, during, and after the enrollment in the program, and the corresponding actions that need to be taken at each stage are described below.

Before the enrollment in the program:

1. The primary motivation for participating in the MCE Program for the majority of teachers in the study was a tuition free Master's degree from a prestigious University and this higher qualification translating in to an upward movement on the salary scale.

Any idea of changing their teaching methods to reform-based, or even an awareness of such a need, was far from their minds, if it existed. This, in combination with other factors, could have been a contributory factor in the low level of implementation of reform-based practices in the classrooms. Therefore, if the purpose of the professional development program is to promote reform-based methods in the classrooms of teachers, it is imperative that the teachers' prior knowledge and beliefs on the matter be explored before admittance in the program, since beliefs determine actions (Nespore, 1987; Pajares, 1992). Based on this exploration, the starting point for the concerned teachers will be either to reinforce the existing belief structures or to turn them in a new direction.

2. The teachers in the study decided individually to enroll in the Program. As a result, four out of six teachers were the only graduates of the program in their respective schools. They expressed the need for collaboration with other practitioners, and how this could have improved their level of implementation (Fullan & Steigelbauer, 1991). In future, teams of teachers rather than an isolated teacher should be accepted from the schools. For this to happen, the school community must be involved and deem the professional development worthwhile for its goals. Additionally, in small high schools, typically there is one chemistry teacher and this teacher must be found a suitable team mate with opportunities for regular interaction.

3. Administrators from the schools must be involved, so that they understand the reform-based methods, why is it important to implement these, i.e., they need to experience a paradigm shift (if necessary), and are supportive of the practicing teachers (Nelson, 1997). This is taking place in the reform-based professional development program for middle school teachers run by the host University.

4. Enlist the support of school administration to ensure adequate resources, such as materials, equipment, planning time, and double laboratory period to afford sufficient time to conduct inquiry labs are available and scheduled (Spillane, 1998).

During the enrollment in the program:

The most important way this professional development program (learning to implement the reform-based practices in their respective classrooms) is different from others is that it is transformative, rather than additive (an extension of existing structures). It must address two aspects of teachers' abilities to achieve the goal: 1) activation, which involves building the teachers' knowledge and skills to conduct reform-based practices, and 2) delivery, which involves practicing the acquired abilities in their classroom contexts, reflecting, and refining to improve the practice. As very clearly delineated by Thompson and Zeuli (1999), it is a four step approach.

1. Creation of a "sufficiently high level of cognitive dissonance" (Thompson & Zeuli, 1999, p. 355) that disrupts the teachers' associations of current beliefs and practices with subject matter, teaching and learning (Nelson & Hammerman, 1994) through deliberate interventions. In other words, teachers need to be presented with strong enough reasons to change their practices and internalize the need for change, and the resolution of the dissonance through discussion, reading, and related activities. Time, contexts, and support to think through the dissonance are essential here.

2. "Ensure that dissonance-creating and dissonance-resolving activities are connected to the teachers' own students and contexts, or something like them" (Thompson & Zeuli, 1999, p. 356). The presence of the teachers' contexts of practice (the

classrooms) is crucial, otherwise the exercise is "like trying to learn to swim on a sidewalk" (Ball & Cohen, 1999, p. 12).

3. Although conceptual understanding of subject matter is essential, it is not sufficient for teaching. Professional development must help teachers develop classroom practices consistent with the conceptual understanding of the content, in the process of teaching, not isolated from it (Huberman, 1995). This is an iterative or cyclical process.

4. Provide continuing help to teachers as the cyclical process of; new problems arising in the context of classroom practice, development of new understandings from these, and the translation of new understandings in to corresponding practices, continues.

After the enrollment in the program:

In keeping with the intent of the statement "Professional development for a teacher of science is a continuous, lifelong learning process" (NRC, 1996, p.57), the professional development of teachers must be sustained even after the enrollment in the program ends. The sustenance can take many forms such as networking among the participants and providers, development of a collaborative culture in the school, partnership with institutions of higher learning, and membership and participation in professional organizations. The school needs to play its part in crystallizing a learning organization by aligning its resources and evaluation practices etc. to support the propagation of reform-based practices in its classrooms.

Recommendations related to systemic factors in the context of practice:

Teachers in this study provided some of the reasons for not implementing the practices in their classrooms as: there wasn't a push from the administration, they did not care about it, other things needed to be done, school district's emphasis on testing, administrators only cared about students' success on benchmark tests, lack of materials/equipment etc. As the reform documents point out (AAAS, 1990: NRC, 1996), implementation of reform-based methods requires a systemic change that includes an alignment of teachers' sustained professional development, policies at various levels, administrative support, and adequate resources. Policies include teachers' supervision and evaluation. If teachers' evaluation is not based on the implementation of reform practices but other factors such as test scores, there is little likelihood that the implementation of reform practices in the classrooms will occur (Darling-Hammond, 1990). If it is important to implement the reform-based practices (school district's curriculum espouses inquiry-based methods), policies, supports, and resources need to be examined to ensure that the intent is realized in practice in the classrooms.

Recommendations related to the adaptations of reform-based practices in high school classrooms:

It is not sufficient to demand that teachers adopt the methods of practicing scientists in their classrooms. Teachers must be enabled to understand the reform ideas, intent, and practices. Further, if reform methods are to be implemented in the high school classrooms, experienced science educators (at high school and university levels) along with science education researchers need to collaboratively explore and provide guidance on how this can be achieved given the variety of constraints present in urban high school classrooms and the characteristics of students (Kennedy, 2005).

Research on "a systematic understanding of patterns of practice in classrooms where teachers are trying to enact reform" (Spillane and Zeuli, 1999, p. 20) and the role played by contextual/other factors is necessary to help shape the feasibility of implementation of reform methods in classrooms.

Teachers and researchers should work together, in the process of developmental research. During this collaboration the teacher-researcher team should develop context specific theories that shed light on how the reform-based methods map on to the real classrooms. The focus of conversations should be centered on "where there is a need for translation and where there are unrealistic assumptions" (Olson, 1981, p. 272)-the assumptions of adequacy of reform methods or inadequacy of traditional methods-whereby both dialectically assist each other. Once common patterns are discerned in the context specific theories, broader and encompassing theories of implementation of reform-based practices may emerge (Lijnse, 1995).

Five of the six teachers in the study believed that their students were unprepared and/or unwilling to engage in student-centered inquiry methods, the quintessential methods of the reform movement in science and those of practicing scientists. Possibly, the prevalent deeply entrenched teacher-centered traditional practices are the cause of this disengagement. Therefore, an important avenue for research towards implementation of reform methods will be to explore the root causes of student disengagement in urban classrooms and how to reorient it into practices more conducive to the reform-based methods.

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APPENDICES

APPENDIX A

LIST OF 25 RESEARCH-BASED TEACHING PRACTICES

List of 25 Research-based Teaching Practices

1. Teacher encourages students to share their responses and questions them in depth.
2. Teacher uses cooperative learning strategies and small to large group format.
3. Teacher encourages students to provide evidence and justification for their answers.
4. Teacher discusses students' data.
5. Assessment is related to applications and extension of learning.
6. Lesson emphasizes fundamental concepts, makes connections to other topics and skills and is embedded within a bigger picture of the unit.
7. Concepts within lessons are accurate and connected to other units.
8. Students determine and justify what counts as evidence.
9. Students can move freely between micro, macro, and symbolic representations of chemistry.
10. Teacher uses inductive strategies to emphasize and facilitate student-centered discussion.
11. Students can move readily among representations to analyze information.
12. Students make conjectures and devise methods to test them.
13. Students are actively engaged in investigations, understand its basis, and make predictions.
14. Teacher encourages students to reflect on their thinking.
15. Teacher encourages students to generate alternative solutions to problems with accompanying evidence.
16. Students verbally communicate their ideas, critique their own and others' ideas for accuracy and validity.
17. Teachers' questions are scaffolded and elicit divergent thinking.
18. Students' facilitate discussion among each other, with minimal assistance from the teacher.
19. Teacher acknowledges students' questions and ensues student-centered discussion/exploration.
20. Teacher seeks students' responses and opens them for discussions/ elaborations with the class.
21. Teacher encourages productive discussion between and among students.
22. Teacher encourages students to generate conjectures and a variety of ways to interpret evidence.
23. Teacher facilitates students' construction of ideas through a variety of strategies such as, allowing adequate time for reflection, providing additional experiences, and guidance as needed.
24. Teacher allows students a voice in classroom procedures.
25. Teacher elicits students' prior knowledge, promotes understanding through questioning.

This list captures the essential elements of research-based teaching practices. This is by no means an exhaustive list. Effective teaching practices are at the heart of good science education. By implementing these practices science teachers create environments in which they and their students work together as active learners and cocreaters of knowledge (NSES, 1996).

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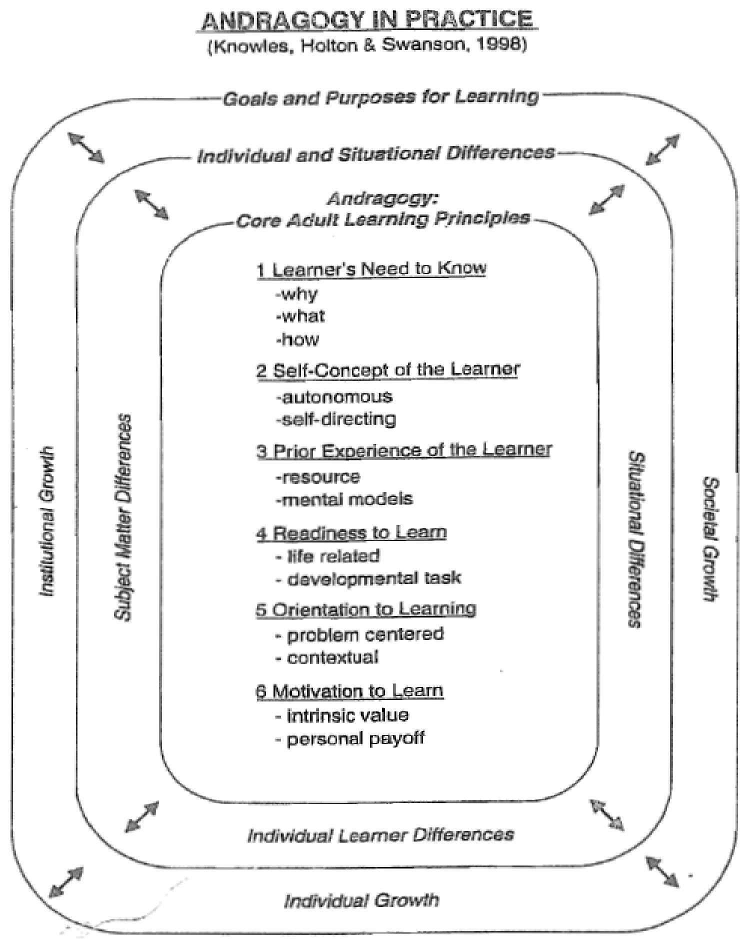
APPENDIX B

ANDRAGOGY – A PROCESS MODEL



Andragogy in practice model (from Knowles, Holton, and Swanson, 1998).

APPENDIX C

PROCESS ORIENTED GUIDED INQUIRY LEARNING (POGIL)
&
PENN INSTRUCTIONAL/INQUIRY MODEL (PIM)

Process Oriented Guided Inquiry Learning (POGIL)

POGIL is a research based learning environment where students are actively engaged in mastering course content and in developing essential skills by working in self-managed teams on guided inquiry activities.

In addition to learning, understanding, and applying new concepts, students also develop important process skills in the areas of information processing, critical thinking, problem solving, teamwork, communication, management, and assessment. The instructor facilitates student learning by appropriately guiding and questioning the teams as they work through the specially designed activities.

As of 2007, over 700 instructors have adopted a POGIL approach in their high school, college, and university classrooms and laboratories.
POGIL is a classroom and laboratory technique that seeks to simultaneously teach content and key process skills such as the ability to think analytically and work effectively as part of a collaborative team.

A POGIL classroom or lab consists of any number of students working in small groups on specially designed guided inquiry materials. These materials supply students with data or information followed by leading questions designed to guide them toward formulation of their own valid conclusions - essentially a recapitulation of the scientific method. The instructor serves as facilitator, observing and periodically addressing individual and classroom-wide needs.

POGIL is based on research indicating that a) teaching by telling does not work for most students, b) students who are part of an interactive community are more likely to be successful, and c) knowledge is personal; students enjoy themselves more and develop greater ownership over the material when they are given an opportunity to construct their own understanding.

It is found that a discovery-based team environment energizes students and provides instructors with instant and constant feedback about what their students understand and misunderstand. Students quickly pick up the message that logical thinking and teamwork are prized above simply getting "the correct answer." This emphasizes that learning is not a solitary task of memorizing information, but an interactive process of refining one's understanding and developing one's skills.

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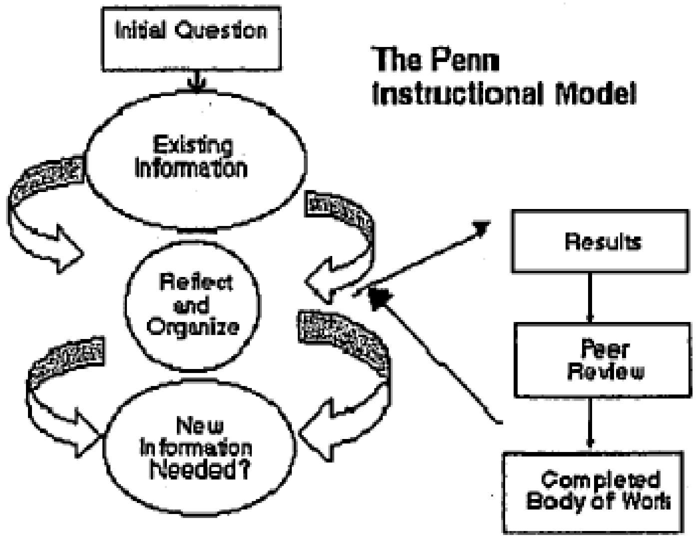
Penn Instructional/Inquiry Model (PIM)



Initial Question
What is our initial question? A question posed by an instructor, a student, a text, a group
Existing Information?
What personal information do we already have about this question? What knowledge do we need from other sources (e.g., library, on-line, experiments, experts) to help answer this question?
Reflect and Organize
Reflect on the knowledge that we have gathered. Ask ourselves how we can integrate this knowledge and organize it so that it makes sense to us. This will probably lead us to ask additional questions that require more information--even doing experiments that create new knowledge--and will probably start the cycle over again. Include others in our questioning, reflecting and organizing--outside input is invaluable! It helps us to determine what we do and do not understand.
Results and Peer Review
When we think we have results, i.e., understanding, present our knowledge claims to our colleagues. Let them question us. We will need to justify our knowledge claims and in the process of this justification, our peers might lead us to change or reject some of our arguments, or they might accept our ideas.
Completed Body of Work
In the process of defending our claims within a community of learners we build up our knowledge and at the same time the community builds its knowledge. Only then will we have learned. We will probably always have some new questions as a result, so just be ready to keep repeating the entire cycle!

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APPENDIX D

PEDAGOGY AND ANDRAGOGY

	Pedagogy	Andragogy
Philosophical Underpinnings	Behaviorism/connectionism	Pragmatism, humanism, behaviorism, and constructivism
Salient Features	Content-driven,	Process-driven, problem-centered
Role of the Teacher	Controller of learners/learning	Facilitator of learning, a resource person
Role of the Student	Submissive recipients, dependant on the teacher	Active participants, move towards independency
Assumptions	Knowledge is transmitted, students' experiences are not important for learning, motivated by external rewards	Knowledge is constructed, adults' experiences are valuable for learning, motivated by internal rewards
Learner' need to know	Not of importance. People have no need to know how the learning will apply in their lives	Is important. Adults have a need to know why they are leaning something
The learner	Dependent. Teacher directs what, when, how a subject is learned and tests that it has been learned	Moves towards independence. Self-directing. Teacher encourages and nurtures this movement
The learner's experience	Of little worth. Hence teaching methods are didactic	A rich resource for learning. Hence teaching methods include discussion, problem-solving etc.
Readiness to learn	People learn what society expects them to. So that the curriculum is standardized.	People learn what they need to know, so that learning programmes are organised around life application.
Orientation to learning	Acquisition of subject matter. Curriculum organized by subjects.	Learning experiences should be based around experiences, since people are performance centred in their learning
Learners' motivation	External. People are motivated to learn by external factors, e.g., grades, rewards etc.	Internal. Internal factors like satisfaction, self-improvement, desire to improve/grow etc. are the primary motivators.

Brookfield, S. D. (1986). *Understanding and Facilitating Adult Learning. A comprehensive analysis of principles and effective practice.* Milton Keynes: Open University Press.

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APPENDIX E

MASTER OF CHEMISTRY EDUCATION (MCE) PROGRAM DETAILS

Selection of Applicants, Certification, and Demographics
Secondary school science teachers are eligible to apply. Applicants are chosen based on their academic preparedness, as determined by the level of college courses taken in recent times. If the preparation of candidates is deemed inadequate to succeed in the MCE program, they are advised about the course/s to take prior to admission. Candidate interview is an essential component of the selection process. Due to the depth of content knowledge acquired in the courses, the teachers are very well prepared to take the praxis exam and receive certification in chemistry. Many, *not all*, choose to do so. So far 85% of teachers admitted to the program since 2000, have completed it and earned their degrees. Among the five cohorts that have graduated from the program, 33 teachers worked in the School District of Philadelphia (SDP) at the time of admission, and 23 have successfully completed the program. Of these 23, only 15 are currently teaching in the SDP, 8 have left the district. Of the 15 MCE graduates still working in the school district, 7 have at least one chemistry course in their roster. All but one, of these seven, are the subjects of the proposed study. Other 8 MCE graduated teachers working in the SDP are teaching various non-chemistry science courses, such as biology, physical science, environmental science etc. partly because they may not be certified in chemistry or they hold multiple certifications.

Incentives
Every participant receives a full scholarship that covers the tuition, and costs of books and transportation. Funding and support are provided by; National Science Foundation, Rohm and Haas Company, Bristol-Myers-Squibb, DuPont, and Penn's School of Arts and Sciences. Additionally, the teachers are provided access to Penn libraries and the Chemistry Education Resource Center, run by the Penn Science Teacher Institute (STI), that allows teachers to borrow materials (printed, electronic and other), and equipment for classroom use. Teachers are also eligible to apply for a $1000 grant for classroom materials and resources. They showcase the utilization of the grant money to enhance instruction in their classes at a poster session every summer.

Evaluation
The program is evaluated annually, both through internal and external evaluators. Some of the components and instruments used are; administering surveys, focus groups, videotaping of MCE program classes, interviews with instructors, monthly meeting of evaluators and instructors, videotaping some classrooms of teachers, examination of materials produced by the teachers for their classrooms etc. for evidence of implementation of content and methods experienced in the program. Feedback from the evaluators is used to make changes in the program. Some of the recent changes are; requirement that the teachers pass a qualifying exam after the completion of courses to demonstrate their content knowledge, teachers maintain and present a portfolio to show their evolution in using inquiry methods in the classrooms, integration of more math in the courses, and to invite graduated teachers to participate in poster sessions to communicate their utilization of $1000 grant towards classroom instruction.

MCEP Course Descriptions

- The MCEP includes 10 courses, 8 in chemistry content and 2 in chemistry education.
- All courses are specially designed for secondary science teachers, meaning they emphasize connections within and among chemistry topics, "real-life" examples, and include assignments such as creating lesson plans based on the course material.
- Because the course instructors are situated at a major research institution, whenever possible state-of-the-art research topics are also included.
- All courses in the MCE program are 1 credit unit (which is equivalent to 3 credit hours each).

Course Sequence:

- **Summer 1:** Chem 501 -- General and Organic Chemistry I and Chem 502 -- Information Technology and Experimental Chemistry
- **Academic Year 1:** Chem 503 -- Organic Chemistry II and Educ 536 -- The Teaching and Learning of Chemistry
- **Summer 2:** Chem 505 -- Environmental Chemistry and Chem 506 -- Inorganic Chemistry
- **Academic Year 2:** Chem 507 -- Molecular Spectroscopy and Educ 636 -- Advanced Topics in the Teaching and Learning of Chemistry
- **Summer 3:** Chem 504 -- Biochemistry and Molecular Biology and Chem 508 -- Seminar in Chemistry

Course Descriptions:

GENERAL AND ORGANIC CHEMISTRY I -- CHEM 501

The goal of this course is to provide participants with a sound background in the structures and physical and chemical properties of organic compounds using an inquiry-based instructional model which they can implement in their own classrooms. The prerequisite is one year of college-level general chemistry, and most participants will enter the program with this course. Because of the anticipated diversity of participants' backgrounds, concepts from general chemistry which are relevant to organic chemistry will be reviewed and used as a framework for understanding organic chemical concepts.

The sequencing of topics is closely correlated with the course Information Technology in Chemistry which will use many of those topics as a vehicle for information searching and laboratory experiments. The concepts developed will provide a foundation for understanding how the chemistry is applied to societal needs in medicine, industry, agriculture, and basic research and also for understanding the health, environmental, and economic issues to which those applications lead . (top)

INFORMATION TECHNOLOGY and EXPERIMENTAL CHEMISTRY -- CHEM 502

The goals of this course are to develop in participants skills in information technology and experimental chemistry which enable them to introduce meaningful reforms in their own curricula. Specific objectives include the following:

-- To make use of participants' first-hand knowledge of the interactive learning model being employed in GOCI and to learn ways to transfer this model to their own classroom setting.

-- To obtain basic computer literacy skills and the ability to develop and maintain their personal web page using HTML editors and other tools.

-- To develop the ability to find chemical and other scientific information efficiently on the internet using various search engines and databases.

-- To develop critical evaluation skills needed to sort through this large amount of data.

-- To learn about materials that are available in printed form in chemistry libraries and to develop skills in accessing and sorting through this information.

-- To use some modern computational programs employed by active research chemists and to develop, with these programs, demonstrations that will be appropriate for their own classroom setting.

-- To develop skills for presenting and defending material before an audience.

-- To carry out a representative set of laboratory experiments which will provide the background for developing experimental programs in their own curricula.

The course is intended to be taken concurrently with General and Organic Chemistry I (GOCI) and will draw heavily on topics in that course for exercises in information searching and laboratory experiments. Participants will undertake two major projects which will impact on their own teaching, i.e., creation of a continuing personal web page and creation of a plan for introduction of innovations in their own curricula to be implemented in the ensuing academic year. (top)

ORGANIC CHEMISTRY II -- CHEM 503

The objectives of this course are to develop an understanding of the fundamental reaction types of organic chemistry, how these reactions are used in synthesis, and the role of organic synthesis in creating the compounds and materials used in modern society. The fundamental reaction types include addition to alkenes and alkynes, electrophilic and nucleophilic aromatic substitution, oxidation and reduction, nucleophilic addition to carbonyl compounds, free radical reactions, and cycloadditions. Reactions will be exemplified through syntheses used in research and industry.

The development of topic material will be based to a great extent on a "need to know" approach in which participants will be presented with a synthetic target and asked to develop ideas for producing it by consulting web/library sources. Emphasis will be placed on working out strategies for accessing the information needed to work out a rational synthesis. Examples to be explored include syntheses of antibiotics, anticancer drugs, detergents, old and new generation insect control agents, and condensation polymers, and the use of solid phase synthesis and combinatorial chemistry in drug discovery. Societal issues relating to the substances studied will also be explored.

Each participant will undertake an individualized project in which the synthesis of a compound or material of public interest will be examined through information searches, and the environmental, health, and/or economic consequences of use of the substance are analyzed. (top)

BIOCHEMISTRY AND MOLECULAR BIOLOGY -- CHEM 504

The goals of this course are to establish an understanding of the three-dimensional structures of nucleic acids and proteins and of how these structural entities interact in biological processes. The biotechnology revolution based on this knowledge has lead to fundamentally new approaches to solutions to problems in medicine, agriculture, and the chemical industry, all of which are changing society.

The course will be organized around the central dogma of molecular biology and its modifications for genetic engineering, tissue engineering and biological catalysis.

As in earlier courses, participants will use previously learned information- searching skills to undertake an individualized study and analysis of an application of knowledge in this field to solving some problem of public interest. (top)

ENVIRONMENTAL CHEMISTRY -- CHEM 505

The goals of this course are to expand the participants' understanding of current environmental issues and the centrality of chemistry in providing solutions to environmental concerns.

The course will provide an in-depth look at environmental issues impacted, both negatively and positively, by chemistry. This will include the chemistry of "pollutants" in air, water, and soil; their transport and fate in the environment; how they are detected and analyzed, and methods of remediation. Concepts of risk assessment will also be studied. (top)

INORGANIC CHEMISTRY -- CHEM 506

The goals of this course are to expand participants' understanding of modern concepts of bonding, structure, and chemical reactivity among inorganic compounds and of the impact of newly developed inorganic compounds and materials on society.

Coverage will include a general treatment of ionic and covalent bonding across the periodic table including bonding in coordination compounds, hard and soft acids and bases, chelation therapy, the electrical properties of metals, semiconductors, and insulators, organometallic chemistry, catalysis in chemical industry, nitrogen fixation, zeolites, and inorganic superconductors.

Once again participants will undertake individualized projects using information-searching skills and will explore various aspects of the interface of inorganic chemistry with matters of public interest. (top)

MOLECULAR SPECTROSCOPY -- CHEM 507

The goals of this course are to establish participants' understanding of the principles of molecular spectroscopy, to broaden their knowledge of the many types of molecular spectroscopy in use today, and to make them aware of the ways in which various spectroscopic techniques are applied in society.

Coverage will include infrared spectroscopy and the greenhouse effect, UV-visible spectroscopy, ozone depletion, and the design and use of dyes, mass spectrometry and the determination of molecular formulas and structure, NMR spectroscopy, the determination of molecular structure, magnetic resonance imaging, lasers and their use in medicine and commerce, and X-ray crystallography.

Individualized projects as described in previous courses will be carried out. (top)

SEMINAR IN CHEMISTRY -- CHEM 508

In this capstone course each participant will undertake the study of a topic which is of interest to them and is relevant to some aspect of forefront scientific research. The selected topic will also contain a significant chemical component.

Each participant will prepare a "teaching/learning resource module" on their topic. This module will include an abstract, paper and appropriate information searches. These modules will be made available to all MCE students both in a print version to be kept in the CERC and an electronically available version. Additionally, participants will present a talk on their topic to an audience of peers, staff and invited guests.

It is expected that many of the topics selected will coincide with current departmental research programs and that consultation and interaction with faculty and staff conducting the research will enrich the educational experience. The opportunity for highly motivated and qualified participants to collaborate with a faculty mentor and participate in the research will be possible and will be encouraged. (top)

THE CHEMISTRY EDUCATION COURSES

Chemistry education courses will be offered in the fall-spring semesters that separate the three summer sessions. Each of the courses will focus on teaching and learning chemistry in the classes of the participants. The goal in each course is to build change, personal changes in teaching and curriculum as well as systemic change in departments and buildings of the participants. Because these courses meet monthly over an entire academic year, communication within the MCE community of learners is facilitated by the use of the on-line communications tool Blackboard©.

THE TEACHING AND LEARNING OF CHEMISTRY -- EDUC 536

The course will examine issues associated with curriculum planning and enactment. Issues such as representations of chemistry concepts, the nature of chemistry, the role of models and the effect of socio-cultural issues on the teaching and learning of chemistry will be examined. In addition, in order to integrate their learning with their professional practice the participants will undertake research in their own chemistry classrooms. A core goal of the course is to establish and maintain a community of learners of chemistry and chemistry education.

Most classes will consist of laboratory activity, seminar/discussion and lecture. Laboratory activity will provide an environment for the examination of specific issues related to the teaching and learning of chemistry and will require both written pre-lab and post-lab reports. Discussion and lecture will provide contexts for examination of broader issues associated with the teaching and learning of chemistry. Participants may be expected to contribute to and to lead the discussions using their written analysis of the readings.

Participants are required to demonstrate the methods that they are using to integrate their social, cultural and conceptual understandings in their own classrooms by organizing site visits. (top)

ADVANCED TOPICS IN THE TEACHING AND LEARNING OF CHEMISTRY -- EDUC 636

This course will attempt to implement some of the topics presented in the previous education and chemistry courses of the MCE program in typical high school chemistry classrooms. This information will be presented to students using a teaching method informed by the knowledge of how students learn as presented in the MCE education courses. In order to make the knowledge gained in this course meaningful to the participants, a joint research project will be planned and executed to examine the effects on students of implementing a new approach to teaching chemistry. Therefore, the goal of this course is to use the knowledge already gained in the MCE program to implement a research project that will have meaningful results in the participants' school community. This course is designed as a collaboration between experts —chemical education (course staff) and teaching (participants) experts. Each member of the course is considered a full participant in the direction and results of the course.

Blasie, C., & Palladino, G. (2005). Implementing the Professional Development Standards: A Research Department's Innovative Master's Degree Program for High school Chemistry Teachers. *Journal of Chemical Education, 82*(4), 567-570.

http://www.sas.upenn.edu/PennSTI/mcep description.shtml. Retrieved 12/25/06.

APPENDIX F

STAGES OF CONCERN QUESTIONNAIRE

(with 3 Amended Open-ended Questions)

Stages of Concern Questionnaire

(Reprinted with permission of Southwest Educational Development Laboratory)

Name (optional): ____

The purpose of this questionnaire is to determine what people who are using or thinking about using MCE programs practices are concerned about at various times during the adoption process.

The items were developed from typical responses of school and college teachers who ranged from no knowledge at all about various programs to many years' experience using them. Therefore, **many of the items on this questionnaire may appear to be of little relevance or irrelevant to you.** For the completely irrelevant items, please circle "0" on the scale. Other items will represent those concerns you do have, in varying degrees of intensity, and should be marked higher on the scale.

For example:

This statement is very true of me at this time.	0	1	2	3	4	5	6	**7**
This statement is somewhat true of me now.	0	1	2	3	**4**	5	6	7
This statement is not at all true of me at this time.	0	**1**	2	3	4	5	6	7
This statement seems irrelevant to me.	**0**	1	2	3	4	5	6	7

Please respond to the items in terms of **your personal concerns,** or how you feel about your involvement with **the implementation of MCE program practices**. We do not hold any one definition of the MCE program practices, so please think of it in terms of your own perception of what it involves. Phrases such as "this approach" and "the new system" all refer to the MCE program practices. Remember to respond to each item in terms of your present concerns about your involvement or potential involvement with the MCE program practices.

Thank you for taking time to complete this task.

In the following questionnaire, please record your score for each of the 35 items by underscoring it (highlight the number and click the underscore button on the toolbar).

0	1 2	3 4 5	6 7
Irrelevant	Not true of me now	Somewhat true of me now	Very true of me now

1. I am concerned about students' attitudes towards the MCE program practices.	0 1 2 3 4 5 6 7
2. I now know of some other approaches that might work better.	0 1 2 3 4 5 6 7
3. I am more concerned about another set of practices.	0 1 2 3 4 5 6 7
4. I am concerned about not having enough time to organize myself each day.	0 1 2 3 4 5 6 7
5. I would like to help other faculty in their use of the MCE program practices.	0 1 2 3 4 5 6 7
6. I have a very limited knowledge of the MCE program practices.	0 1 2 3 4 5 6 7
7. I would like to know the effect of reorganization on my professional status.	0 1 2 3 4 5 6 7
8. I am concerned about conflict between my interests and my responsibilities.	0 1 2 3 4 5 6 7
9. I am concerned about revising my use of the MCE program practices.	0 1 2 3 4 5 6 7
10. I would like to develop working relationships with both our faculty and outside faculty using the MCE program practices.	0 1 2 3 4 5 6 7
11. I am concerned about how the MCE program practices affect students.	0 1 2 3 4 5 6 7
12. I am not concerned about the MCE program practices at this time.	0 1 2 3 4 5 6 7
13. I would like to know who will make the decisions regarding MCE program practices.	0 1 2 3 4 5 6 7
14. I would like to discuss the possibility of using the MCE program practices.	0 1 2 3 4 5 6 7
15. I would like to know what resources are available if I decide to adopt the MCE program practices.	0 1 2 3 4 5 6 7
16. I am concerned about my inability to manage all that the MCE program practices require.	0 1 2 3 4 5 6 7
17. I would like to know how my teaching or administration is supposed to change to be able to implement MCE program practices	0 1 2 3 4 5 6 7
18. I would like to familiarize other departments or persons with the progress of this new approach (the MCE program practices).	0 1 2 3 4 5 6 7

0	1 2	3 4 5	6 7
Irrelevant	Not true of me now	Somewhat true of me now	Very true of me now

19. I am concerned about evaluating my impact on students.	0 1 2 3 4 5 6 7
20. I would like to revise the MCE program's practices.	0 1 2 3 4 5 6 7
21. I am preoccupied with things other than the MCE program practices.	0 1 2 3 4 5 6 7
22. I would like to modify our use of the MCE program practices based on the experiences of our students.	0 1 2 3 4 5 6 7
23. I spend little time thinking about the MCE program practices.	0 1 2 3 4 5 6 7
24. I would like to excite my students about their part in these practices.	0 1 2 3 4 5 6 7
25. I am concerned about time spent working with nonacademic problems related to the MCE program practices..	0 1 2 3 4 5 6 7
26. I would like to know what the use of the MCE program practices will require in the immediate future.	0 1 2 3 4 5 6 7
27. I would like to coordinate my efforts with others to maximize the effects of MCE program practices.	0 1 2 3 4 5 6 7
28. I would like to have more information on time and energy commitments required by the MCE program practices.	0 1 2 3 4 5 6 7
29. I would like to know what other faculty are doing in this area.	0 1 2 3 4 5 6 7
30. Currently, other priorities prevent me from focusing my attention on the MCE program practices.	0 1 2 3 4 5 6 7
31. I would like to determine how to supplement, enhance, or replace the MCE program practices..	0 1 2 3 4 5 6 7
32. I would like to use feedback from students to change the program.	0 1 2 3 4 5 6 7
33. I would like to know how my role will change when I am using the MCE program practices.	0 1 2 3 4 5 6 7
34. Coordination of tasks and people is taking too much of my time.	0 1 2 3 4 5 6 7
35. I would like to know how the MCE program practices are better than what we have now.	0 1 2 3 4 5 6 7

Please complete the following:

1. (a) In your use of the MCE program practices, do you consider yourself to be a:

   non-user___ novice___ intermediate___ old hand___ past user___

   (b) On a scale of 0 to 10, where do you place your level of implementation of the MCE program practices? (0=no implementation, 10=full implementation)

Please answer the following questions in as much detail as you can. Use more space, if needed.

2. What is helping you to implement the MCE program practices?

3. What is inhibiting you from implementing the MCE program practices?

SOUTHWEST EDUCATIONAL
SEDL
DEVELOPMENT LABORATORY 211 East Seventh Street Austin, Texas 78701.3281 Voice: 512 / 476.6861 Fax: 512 / 476.2286 Web: www.sedl.org/
Building Knowledge to Support Learning

TO: Uma Jayaraman (Licensee)

FROM: Nancy Reynolds
Information Associate, Information Resource Center
Southwest Educational Development Laboratory
211 East Seventh Street
Austin, TX 78701-3253

SUBJECT: Permission to reprint and distribute SEDL material

DATE: December 4, 2006

Thank you for your interest in using the instrument ***Stages of Concern Questionnaire*** published by the Southwest Educational Development Laboratory as Appendix A, pages 79-82 in *Measuring Implementation in Schools: The Stages of Concern Questionnaire* written by Archie A. George, Gene E. Hall, and Suzanne M. Stiegelbauer in 2006 and on pages 48-49 of the SEDL publication *Taking Charge of Change*, revised ed., also published in 2006 and written by Shirley M. Hord, William L. Rutherfod, Leslie Huling, and Gene E. Hall. The questionnaire will be referred to as the "work" in this permission agreement.

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Thank you, again, for your interest in SEDL's ***Stages of Concern Questionnaire***. If you have questions, please contact me at (800) 476-6861, ext. 226 or by e-mail at nreynold@sedl.org.

Sincerely,

Nancy Reynolds

Nancy Reynolds for Southwest Educational Development Laboratory

Agreed and accepted:

Signature: Uma Jayaraman Printed Name: UMA D. JAYARAMAN

Date signed: 12/8/06

copy of 2006 version of Stages of Concern Questionnaire sent as a PDF document via e-mail to licensee at ujayaraman@

Renewal of Permission to Use SoCQ

Re: SEDL's Stages of Concern Questionnaire

From: **Nancy Reynolds** (nancy.reynolds@sedl.org)
Sent: Wed 1/16/08 9:52 PM
To: uma jayaraman (ujayaraman@)
Dear Uma,

Thank you for your continued interest in using SEDL's Stages of Concern Questionnaire (SoCQ). By way of this e-mail, I am letting you know that I extend permission for your use of the SoCQ for an additional year to accommodate your data collection for research toward your doctorate at Temple University. I will update your signed license in my files to reflect that your revised ending date for use of the SoCQ is now January 16, 2009.

Please let me know if I can help you in any other way to provide SEDL's research or publications.

Sincerely,

Nancy Reynolds

Information Associate

SEDL

Information Resource Center

4700 Mueller Blvd.

Austin, TX 78723

512-391-6548 (voice)

512-476-2286 (fax)

nancy.reynolds@sedl.org

http://www.sedl.org

Advancing Research, Improving Education

APPENDIX G

REFORMED TEACHER OBSERVATION PROTOCOL (RTOP)

Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada — External Evaluator
Michael Piburn — Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher ____________________ Announced Observation? ____________________ (yes, no, or explain)

Location of class ____ (district, school, room)

Years of Teaching ____________________ Teaching Certification ____________________ (K-8 or 7-12)

Subject observed ____________________ Grade level ____________________

Observer ____________________ Date of observation ____________________

Start time ____________________ End time ____________________

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Record here events which may help in documenting the ratings.

Time	Description of Events

2000 Revision

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred				Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

Continue recording salient events here.

Time	Description of Events

2000 Revision

V. CLASSROOM CULTURE

Communicative Interactions		Never Occurred				Very Descriptive
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	There was a climate of respect for what others had to say.	0	1	2	3	4

Student/Teacher Relationships						
21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Additional comments you may wish to make about this lesson.

Permission to Use RTOP

from Jo Vasquez <Jo.Vasquez@asu.edu>
to ujayaram@
date Tue, Jan 22, 2008 at 5:55 PM hide details 1/22/08 Reply
subject **Re: RTOP**

Hi Uma,

You can certainly use this instrument in your research it is not public domain yet; however I would be very interested in seeing how you modify it as we are struggling with modifying these as well and did have permission from the original researchers. Hopefully you will share.

Best Wishes, Jo Anne

Jo Anne Vasquez, Ph.D.

Director of Professional Development, Policy and Outreach

CRESMET, Center for Research on Education in

Science, Math, Engineering and Technology

Arizona State University

jo.vasquez@asu.edu

Phone: 480.965.7820

Cell: 602.818.3739

APPENDIX H

SAMPLE LESSON PLAN

LESSON PLANS

SUBJECT: Chemistry
WEEK OF: 1 – 1 /08

Monday

Do Now – How do you solve a jigsaw puzzle?
Text Ref – p. 199 - 202
Classwork (Teacher Led) ① Draw LDS of elements 1-20
(Individual) ② Draw LDS w/ single bonds
Worksheet "LDS single bonds"
Homework – Complete Worksheet
Read p. 199-202

Tuesday

Text Ref – p. 203
Classwork – Review "LDS single bonds"
– Begin "LDS polyatomic Ions" Worksheet
Homework – Read p. 203
– Complete "LDS polyatomic Ions"

✓ **Wednesday**

Text Ref – p. 204-205
Classwork – Review "LDS polyatomic Ions"
– Begin "LDS multiple bonds"
Homework – Read p. 204-205
– Complete "LDS mutiple bonds"

Thursday

Text Ref – p. 199-205
Classwork – Review "LDS multiple bonds"
– Worksheet "Mixed Review LDS"

Friday

Do Now – Quiz (open note)
Classwork – Review notes on p. 199 - 205
– Extra Review time

APPENDIX I

RTOP TEACHER SURVEY (RTOPTS)

RTOP Teacher Survey (RTOPTS)

	Never Occurs				Very Descriptive
LESSON DESIGN AND IMPLEMENTATION					
1. My instructional strategies and activities respect students' prior knowledge and the preconceptions inherent therein.	**0**	**1**	**2**	**3**	**4**
2. My lessons are designed to engage students as members of a learning community.	**0**	**1**	**2**	**3**	**4**
3. In my lessons, student exploration precedes formal presentation.	**0**	**1**	**2**	**3**	**4**
4. My lessons encourage students to seek and value alternative modes of investigation or of problem solving.	**0**	**1**	**2**	**3**	**4**
5. The focus and direction of my lessons are often determined by ideas originating with students.	**0**	**1**	**2**	**3**	**4**
CONTENT					
Propositional Knowledge					
6. My lessons involve fundamental concepts of the subject.	**0**	**1**	**2**	**3**	**4**
7. My lessons promote strongly coherent conceptual understanding.	**0**	**1**	**2**	**3**	**4**
8. I have a solid grasp of the subject matter content inherent in the lesson.	**0**	**1**	**2**	**3**	**4**
9. Elements of abstraction (i.e., symbolic representations, theory building) are encouraged when it is important to do so.	**0**	**1**	**2**	**3**	**4**
10. Connections with other content disciplines and/or real world phenomena are explored and valued.	**0**	**1**	**2**	**3**	**4**
Procedural Knowledge					
11. Students use a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	**0**	**1**	**2**	**3**	**4**
12. Students make predictions, estimations and/or hypotheses and devise means for testing them.	**0**	**1**	**2**	**3**	**4**
13. Students are actively engaged in thought-provoking activity that often involves the critical assessment of procedures.	**0**	**1**	**2**	**3**	**4**
14. Students are reflective about their learning.	**0**	**1**	**2**	**3**	**4**
15. Intellectual rigor, constructive criticism, and the challenging of ideas are valued.	**0**	**1**	**2**	**3**	**4**
CLASSROOM CULTURE					
Communicative Interactions					
16. Students are involved in the communication of their ideas to others using a variety of means and media.	**0**	**1**	**2**	**3**	**4**
17. My questions trigger divergent modes of thinking.	**0**	**1**	**2**	**3**	**4**
18. There is a high proportion of student talk and a significant amount of it occurs between and among students.	**0**	**1**	**2**	**3**	**4**
19. Student questions and comments often determine the focus and direction of classroom discourse.	**0**	**1**	**2**	**3**	**4**
20. There is a climate of respect for what others have to say.	**0**	**1**	**2**	**3**	**4**
Student/Teacher Relationships					
21. Active participation of students is encouraged and valued.	**0**	**1**	**2**	**3**	**4**
22. Students are encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	**0**	**1**	**2**	**3**	**4**
23. In general I am patient with students.	**0**	**1**	**2**	**3**	**4**
24. I act as a resource person, working to support and enhance student investigations.	**0**	**1**	**2**	**3**	**4**
25. The metaphor "teacher as listener" is very characteristic of my classroom.	**0**	**1**	**2**	**3**	**4**

Permission to use RTOPTS

Dear Ms. Vasquez,
Thank you for your permission to use the RTOP. I have attached the modified RTOP (called RTOP Teacher Survey or RTOPTS). The only difference between RTOPTS and RTOP is the perspective. RTOP is from the perspective of the observer (researcher), whereas the RTOPTS is from the perspective of the practitioner himself/herself, a self-assessment tool for the lesson's alignment with the reform practices . In keeping with this perspective, the statements in RTOPTS are first person singular.
I hope I will have your permission to use RTOPTS also.
Thank you.
Regards,
Uma

RTOP Teacher Survey.doc
76K View as HTML Open as a Google document Download

Jo Vasquez show details 1/27/08 Reply

to me

Dear Uma,
Sorry for the delay. I think as long as you are using this instrument in your research for your doctoriate and nothing else this is fine to make it for the teacher. You certainly have our permission.
Best of luck,
Jo Anne

Jo Vasquez show details 1/27/08 Reply

to me

sorry I meant to correct the spelling of doctorate before I sent it. .
.late night and I've been traveling.

APPENDIX J

SEMI-STRUCTURED INTERVIEW – GENERALIZED QUESTIONS

Semi-Structured Interview – Generalized Questions

Note: These questions were generated by the researcher of the proposed study.

1. What were the several reasons behind your decision to enroll in the MCE program?

2. What supports will help you in implementing the MCE program practices?

3. What is lacking that prevents you from implementing the MCE program practices?

Questions about the **peaks** of the Concerns Profile

4. Your concerns profile has the highest peak at the "unconcerned" stage. What are the other activities/tasks/initiatives that are of greater concern to you at this time?

5. Your concerns profile has the second highest peak at the "management" (as an example) stage. What are your concerns regarding organizing time/resources/other responsibilities etc. in order to enable you to implement the practices?

6. Your concerns profile has the third highest peak at the " collaboration" stage. What are your concerns regarding working with others/finding how others are implementing the practices etc., that will enable you to implement the practices?

Questions about the **valleys** of the Concerns Profile

7. Your concerns profile has the deepest valley at the "informational" stage. What concerns do you **not** have and why about knowing how the program works/what kinds of resources it will require etc.?
8. Your concerns profile has the second deepest valley at the "consequence" stage. What concerns do you **not** have and why about knowing what your students' attitude towards it will be/how will it impact my students?

9. Would you like to comment on anything?

Fixed questions on lesson planning and content:
1. How do you plan your lesson?
2. What is important to you when planning your lesson? Doyou have a certain format for it?
3. What do you do to make sure that students develop the depth of understanding of content?

Thank you for your cooperation.

APPENDIX K

SOCQ QUICK SCORING DEVICE

Stages of Concern Quick Scoring Device

SoCQ 075

A

Date: ____________________

Site: ________ SS#: ____________

Innovation: ____________________

B

Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
3 ___	6 ___	7 ___	4 ___	1 ___	5 ___	2 ___
12 ___	14 ___	13 ___	8 ___	11 ___	10 ___	9 ___
21 ___	15 ___	17 ___	16 ___	19 ___	18 ___	20 ___
23 ___	26 ___	28 ___	25 ___	24 ___	27 ___	22 ___
30 ___	35 ___	33 ___	34 ___	32 ___	29 ___	31 ___

Raw Score Totals **C** ___ ___ ___ ___ ___ ___ ___

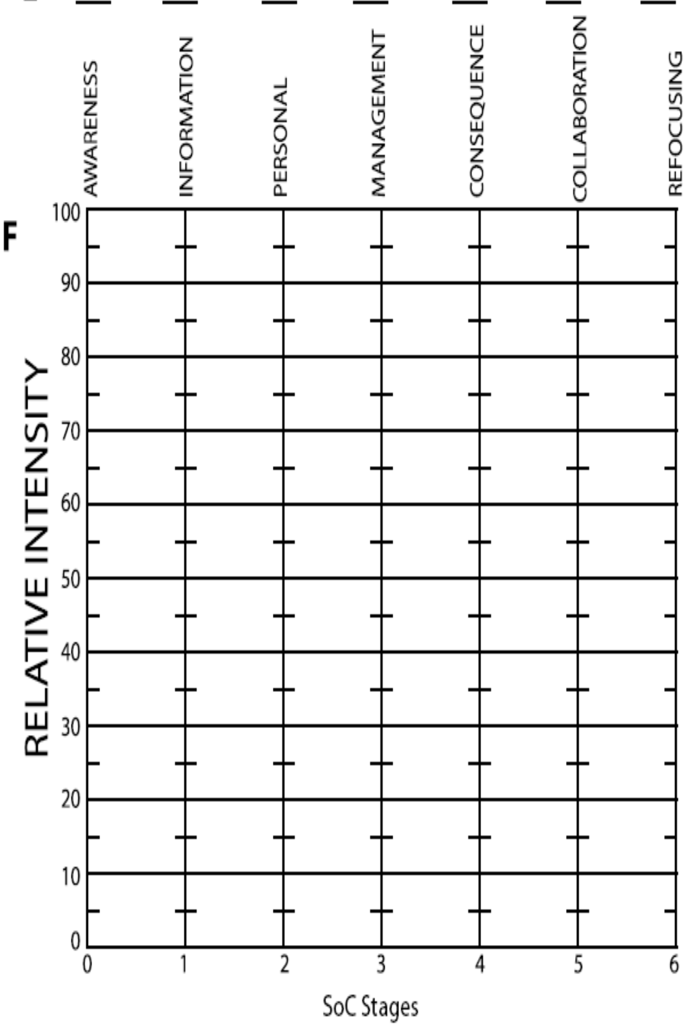
Percentile Scores **E** ___ ___ ___ ___ ___ ___ ___

D

Five Item Raw Scale Score Total	Percentiles for:						
	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
0	0	5	5	2	1	1	1
1	1	12	12	5	1	2	2
2	2	16	14	7	1	3	3
3	4	19	17	9	2	3	5
4	7	23	21	11	2	4	6
5	14	27	25	15	3	5	9
6	22	30	28	18	3	7	11
7	31	34	31	23	4	9	14
8	40	37	35	27	5	10	17
9	48	40	39	30	5	12	20
10	55	43	41	34	7	14	22
11	61	45	45	39	8	16	26
12	69	48	48	43	9	19	30
13	75	51	52	47	11	22	34
14	81	54	55	52	13	25	38
15	87	57	57	56	16	28	42
16	91	60	59	60	19	31	47
17	94	63	63	65	21	36	52
18	96	66	67	69	24	40	57
19	97	69	70	73	27	44	60
20	98	72	72	77	30	48	65
21	99	75	76	80	33	52	69
22	99	80	78	83	38	55	73
23	99	84	80	85	43	59	77
24	99	88	83	88	48	64	81
25	99	90	85	90	54	68	84
26	99	91	87	92	59	72	87
27	99	93	89	94	63	76	90
28	99	95	91	95	66	80	92
29	99	96	92	97	71	84	94
30	99	97	94	97	76	88	96
31	99	98	95	98	82	91	97
32	99	99	96	98	86	93	98
33	99	99	96	99	90	95	99
34	99	99	97	99	92	97	99
35	99	99	99	99	96	98	99

Concerns Based Systems International

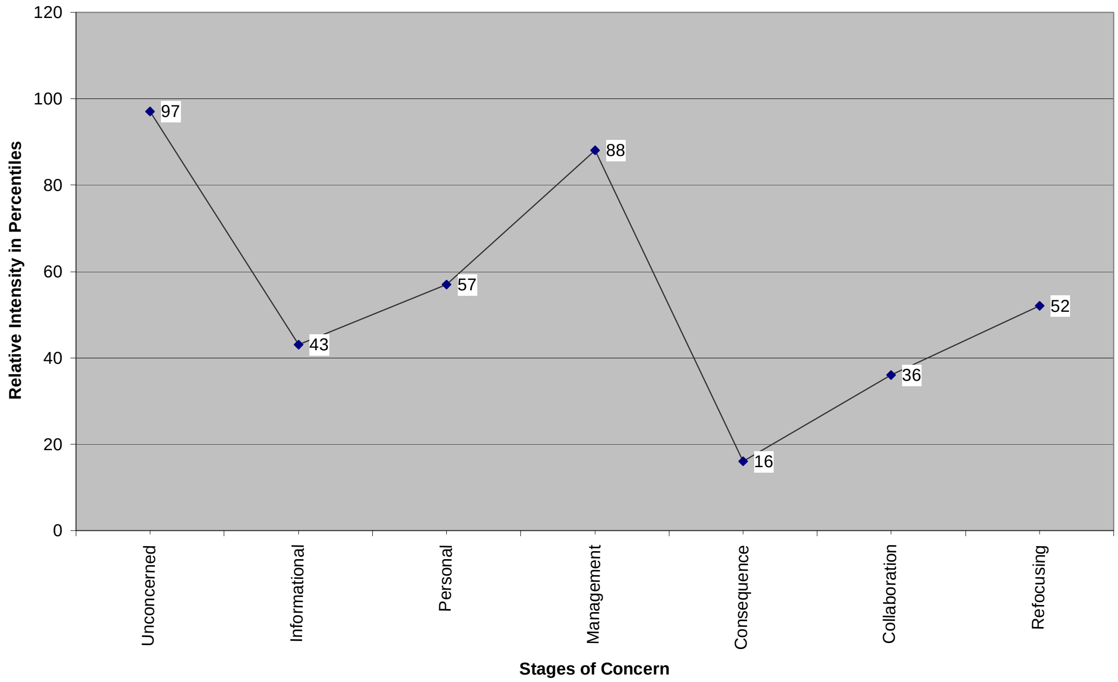
F



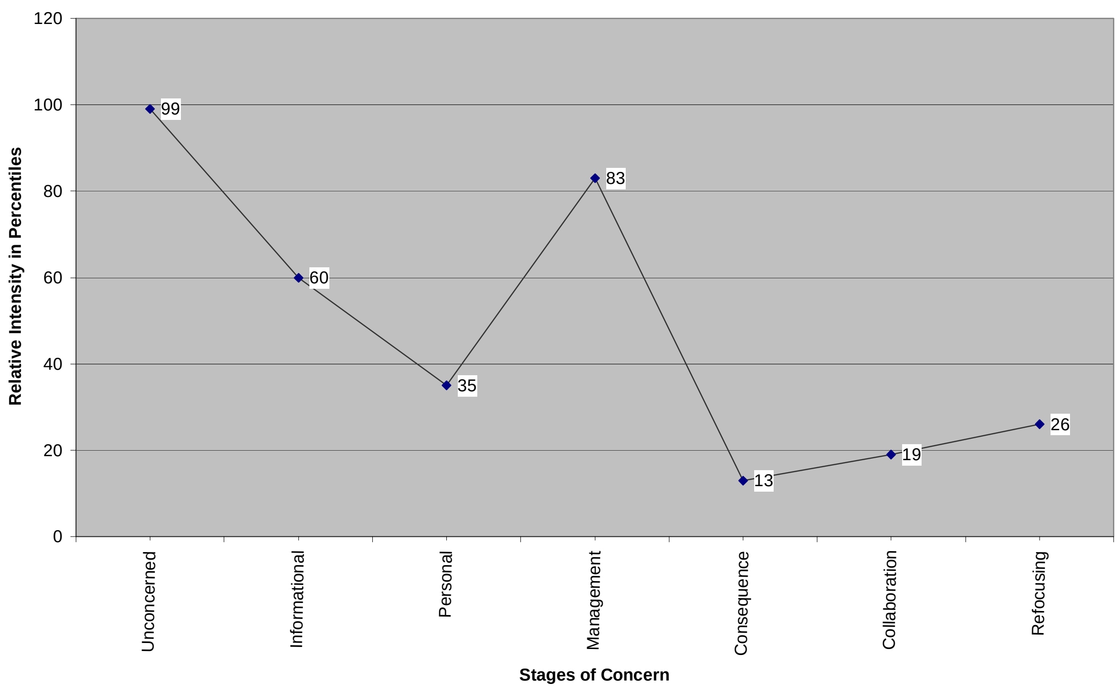
APPENDIX L

STAGES OF CONCERNS PROFILES OF TEACHERS

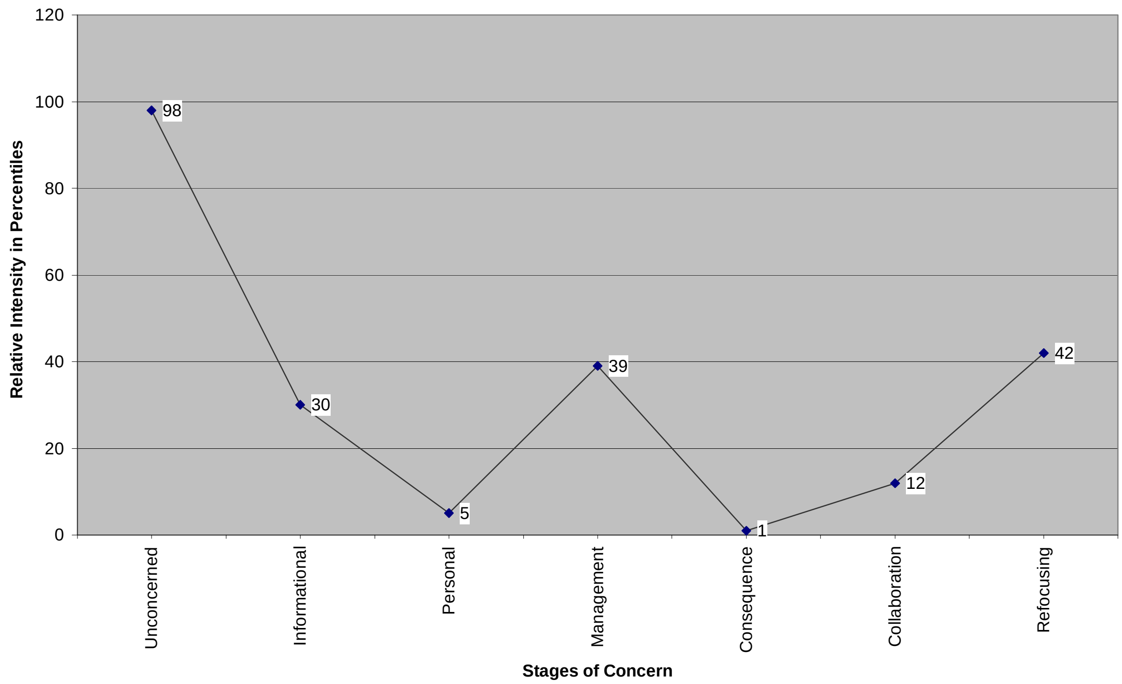
Concerns Profile for Teacher A



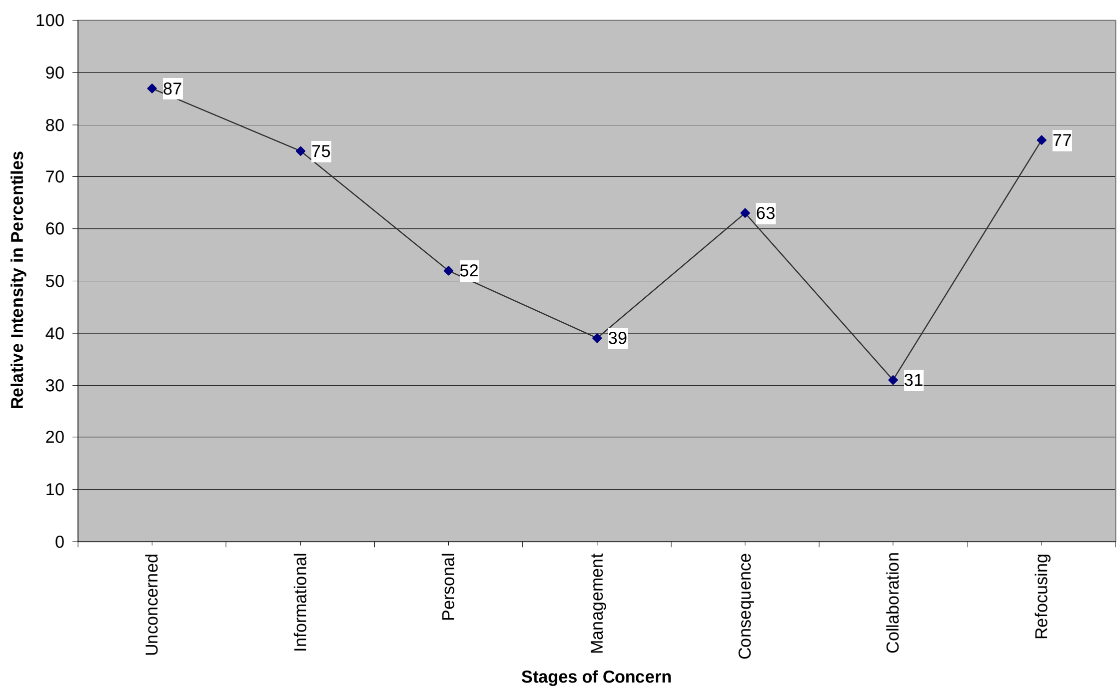
Concerns Profile for Teacher B

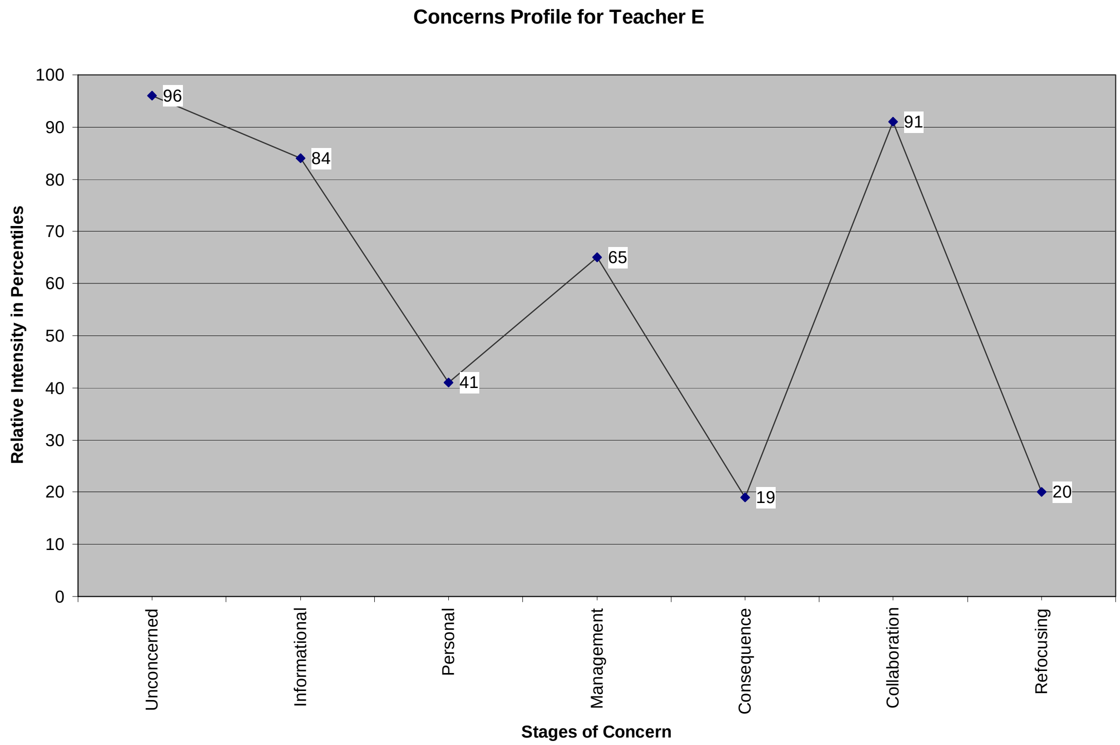


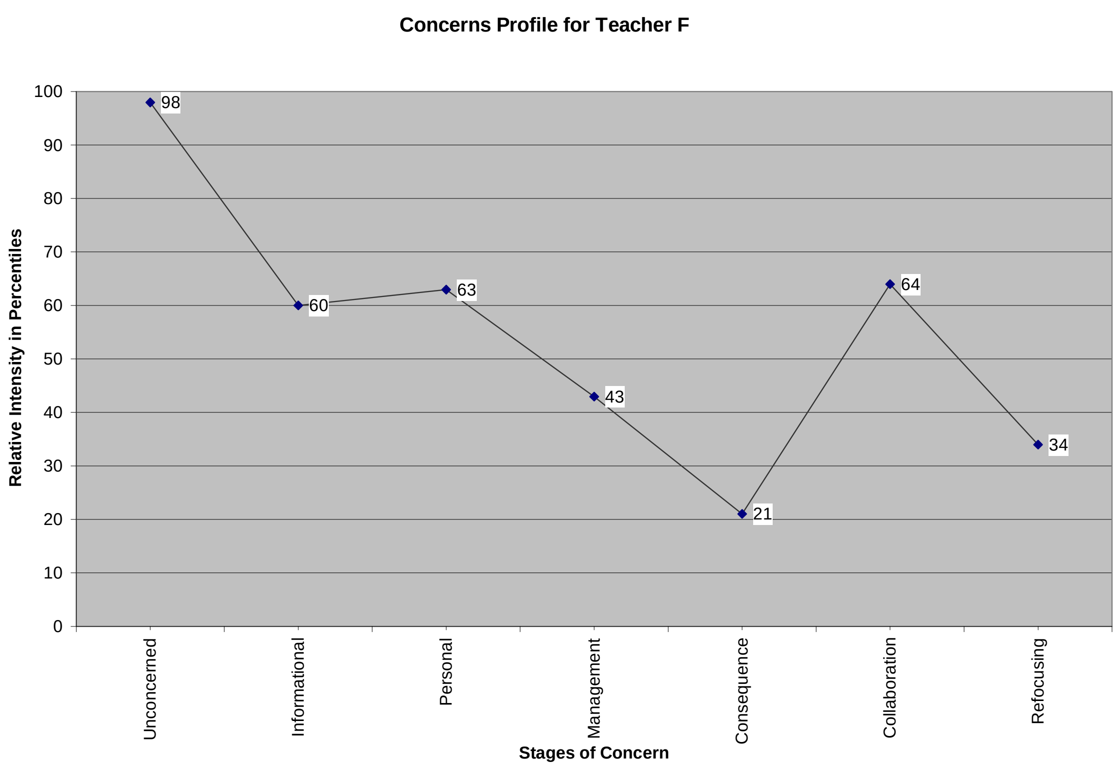
Concerns Profile for Teacher C



Concerns Profile for Teacher D




Concerns Profile for Teacher E
Relative Intensity in Percentiles
100
90
80
70
60
50
40
30
20
10
0
96
84
41
65
19
91
20
Unconcerned
Informational
Personal
Management
Consequence
Collaboration
Refocusing
Stages of Concern


Concerns Profile for Teacher F
Relative Intensity in Percentiles
100
90
80
70
60
50
40
30
20
10
0
98
60
63
43
21
64
34
Unconcerned
Informational
Personal
Management
Consequence
Collaboration
Refocusing
Stages of Concern

APPENDIX M

DATA FLOW

Data Flow and the Purpose of Each Protocol

Stages of Concern Questionnaire (SoCQ) with 3 Open-ended Questions

The 1st protocol completed by the teachers, before the commencement of classroom observations

Responses to open-ended questions 1a and 1b will be used in answering research questions 1 and 2

Responses to open-ended question 2 will be used in answering research question 3

Responses to open-ended question 3 and 35-item questionnaire will be used in answering research question 4

RTOP-Classroom Observation Protocol

Completed by the researcher during 3 classroom observations of each teacher

Will be used in answering research questions 1and 2

Teacher-generated Lesson Plans

Collected on the days of observations

Will be used in answering research questions 1 and 2

RTOPTS-Teachers' Self-reported Survey of Classroom Practices

Completed by the teachers towards the end of the observation period

Will be used in answering research questions 1 and 2

Semi-structured Interview

Conducted by the researcher as the culminating data collection activity

Responses to 3 questions on lesson design and content (fixed questions) will be used in answering research questions 1and 2

Responses to some of the rest of the questions (flexible questions) will be used in answering research questions 3 and 4

APPENDIX N

LETTER GRANTING PERMISSION FROM SDP

THE SCHOOL DISTRICT OF PHILADELPHIA
RESEARCH REVIEW COMMITTEE
Office of Accountability, Assessment & Intervention
440 North Broad Street, 2nd Floor
Philadelphia, PA 19130

OFFICE OF RESEARCH AND EVALUATION

Tel.: (215) 400-4260
FAX: (215) 400-4252

November 29, 2006

Ms. Uma D. Jayaraman

Dear Ms. Jayaraman:

Please allow this letter to serve as notice that The School District of Philadelphia, through its Research Review Committee has granted you expedited approval to commence your study entitled, ***"Classroom Implementation of the Practices Learned in the Master of Chemistry Education Program by the School District of Philadelphia's High School Chemistry Teachers."***

Any evaluator interacting directly with children in the school(s) must have both child abuse and criminal checks completed. As with all research in the District, all student data must remain strictly confidential, and entry into a school is contingent on the principal's approval. **You are required to provide a copy of the final report to the Office of Accountability and abstracts must be furnished to each cooperative school or office and region leader.**

Please contact Dr. Joanne Broder Sumerson at jbrodersumerson@phila.k12.pa.us, if you have any questions or concerns related to conducting research in the District.

Regards,

Joanne Broder Sumerson, Ph.D.
Chair, Research Review Committee

Thomas J. Clark, Ed.D.
Director, Research and Evaluation

APPENDIX O

A SAMPLE OF PRINCIPAL'S LETTER GRANTING PERMISSION

SCHOOL DISTRICT OF PHILADELPHIA
HIGH SCHOOL

Phone 215- **Fax 215-**

January 22, 2008

Investigator: Uma D. Jayaraman
Telephone: 215-
Advisor: Dr. Joseph S. Schmuckler
Telephone: 215-
CITE Department,
College of Education, Temple University
Ritter Hall, Room 452
1301 Cecil B. Moore Ave.
Philadelphia, PA 19122-6091

Dear Ms. Jayaraman:

I grant permission for you to conduct the research study entitled, "Classroom implementation of the practices learned in the Master of Chemistry Education program by the School District of Philadelphia's high school Chemistry teachers" at the High School

I understand that this permission includes the following data collection activities pertaining to the chemistry teacher Ms. , and will be cleared with her.

1) Observation of 3 classes by the investigator
2) Collection of lesson plans and other handouts by the investigator on the days of observation
3) Completion of a questionnaire and a survey by the teacher, and
4) Audio-taping an interview of the teacher by the investigator

None of these activities will interfere with Ms. 's regular job performance.

I understand that this study has the potential to reveal valuable information about how a program predicated on research-based practices gets implemented in an urban environment and what factors assist or inhibit the process.

You are required to submit the abstract of the study to the school upon its completion.

Regards,

Principal

APPENDIX P

LETTER GRANTING CONSENT FROM TEACHERS

College of Education
TEMPLE UNIVERSITY

Curriculum Instruction and Technology in Education - CITE
1301 Cecil B. Moore Avenue
Philadelphia, PA 19122

phone 215-204-2117/8377
fax 215-204-1414
web www.temple.edu

Teacher Consent Form

Title: Classroom implementation of the practices learned in the Master of Chemistry Education program by the School District of Philadelphia's high school Chemistry teachers.

Investigator's Name:	Uma D. Jayaraman
Department:	CITE, College of Education
Telephone:	(215)
Advisor:	Dr. Joseph Schmuckler
Department:	CITE, College of Education
Telephone:	(215)

Introduction/ Purpose/ Selection Criteria
We are currently engaged in a study of the classroom practices of the teachers who have successfully completed the MCE program for 1-6 years, and are currently teaching chemistry in the School District of Philadelphia's high schools. There are 6-8 teachers meeting the above criteria, teaching in 6-8 different high schools in the city. These teachers are potential subjects for this study.

Experimental Procedures
To help us gain insight into this topic, we are requesting your permission to conduct the following data collection activities:

1) Observation of 3 of your chemistry classes by the investigator
2) Completion of a questionnaire (35 Likert-type and 3 open-ended questions) by you
3) Submission of the lesson plan and other handouts, if any, on the days of observation by you
4) Completion of a 25 item survey by you
5) Participation by you in an interview to be audiotaped by the investigator

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IRB (COMMITTEE B) APPROVAL
FEB 19 2008
VALID FOR NO MORE THAN ONE YEAR

Details of the Experimental Procedures

For the observation of your lessons, the investigator will visit 3 of your chemistry classes, in a span of 3-5 months, according to a schedule set by you. You may reschedule or cancel the visits. During these visits, the investigator will complete an observation protocol, and take notes on what transpires in the classroom. We recognize that the presence of the investigator in the classroom can be stressful and she will make every effort to be as unobtrusive as possible. The investigator will not interact with the students or interrupt your lesson in any manner.

You will be asked to submit your lesson plans and handouts, if any, on the 3 days of classroom visits. You can do this before or during the visit, either electronically or as hard copies.

At the beginning of the 3-5 month data collection period, the investigator will send you a questionnaire with 35-item items with Likert-type responses and 3 open-ended response items. This will be sent to you as either an e-mail attachment or a hard copy, the method of transmission will be determined by you. You will have at least 2 weeks to complete this questionnaire.

Similarly, after the 3 classroom observations, you will be asked to complete a survey with 25 statements requiring a Likert-type response, following the same procedure as for the questionnaire.

The culminating data collection activity for this study will be the audiotaping of your interview by the investigator/investigator at the end of the 3-5 month period. A separate consent form for this activity will be sent to you.

Risks

Your participation in this study does not involve any physical or emotional risk to you. If at any time you feel uncomfortable with any of the procedures, you may withdraw from the study.

Benefits

There may be no direct benefit to you by your participation in this research study. The potential benefit to you from participation in the study may include an improved understanding of your extent of implementation, in your classroom, of the research-based practices you were exposed to in the MCE program as well as an understanding of the similarities and differences of implementation among the teachers in the study.

Alternatives

You have the alternative to choose not to participate in the research study. You may withdraw from the study at any time. Both of these actions will not prejudice future interactions with the investigator or Temple University.

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THAN ONE YEAR

Confidentiality
Participation in this study may result in a loss of privacy, since persons other than the investigator may have access to the data supplied by you or collected in your class by the investigator. Unless required by law, only the study investigator, her advisor, and the Temple University Institutional Review Board will have the authority to review the aforementioned data. They are required to maintain confidentiality regarding your identity. All the information, analysis, and results pertaining to the study will be stored in a locked file cabinet in the investigator's secure office. Only the investigator will have immediate access to these. However, you can request for review of only your material in the investigator's presence. All the documents will be stripped of any identifying information and assigned a pseudonym and/or code to protect the privacy of all records. The computer file that allows the investigator to match the pseudonym/code to the teacher identifying information will also be kept in a password-protected centralized computer in the investigator's secure office accessible only to the investigator. Additionally, at no time will any information provided by a teacher, or arrived at by the investigator will be shared with another teacher in the study or anyone other than the principal investigator. Results of this study may be used for teaching, research, publication, or presentation at scientific meetings.

Financial Information
You will not incur any financial obligations because of your participation in the research study. Further, there is no compensation for participation in the study.

Subjects' Rights
Your participation in this research study is voluntary and you are free to withdraw at any time. Participation or withdrawal will not affect any of the rights you are entitled to. If you choose to withdraw from the study prior to its completion you will not incur any penalty, risk, or loss of benefits. You may ask not to be observed or complete the survey or the questionnaire for any reason at any time and your wish will be honored. If you wish further information regarding your rights as a research subject, you may contact Richard Throm, Program Manager and Coordinator at the Office of the Vice President for Research of Temple University by contacting (215) 707-8757.

Questions
We welcome questions about the study at any time. Please direct your questions to the investigator, Uma Jayaraman at (215) or (215)

Title: Classroom implementation of the practices learned in the Master of Chemistry Education program by the School District of Philadelphia's high school Chemistry teachers

Consent

The investigator has explained the research study to me and I have read this form. I have been given the opportunity to ask questions and my questions have been answered satisfactorily. If I have additional questions, I will contact the investigator.

I agree to participate in the research study described in this document and will receive a copy of the consent form after my signature. Another copy of this (signed) consent form will be securely retained by the principal investigator (the advisor) of the research study in his confidential files for a period of at least five years after the completion of the study.

____

Subject's Signature Date

____

Investigator's Signature Date

College of Education
TEMPLE UNIVERSITY

Curriculum Instruction and Technology in Education - CITE
1301 Cecil B. Moore Avenue
Philadelphia, PA 19122

phone 215-204-2117/8377
fax 215-204-1414
web www.temple.edu

Permission to Audiotape

Investigator's Name:	Uma D. Jayaraman
Department:	CITE, College of Education
Telephone:	(215) (215)
Advisor:	Dr. Joseph S. Schmuckler
Department:	CITE, College of Education
Telephone:	(215)

Project Title: Classroom implementation of the practices learned in the Master of Chemistry Education program by the School District of Philadelphia's high school Chemistry teachers.

Subject: ________________________________ **Date:** ___________

Log #:

I give Uma D. Jayaraman permission to audiotape me. This audiotape will be used only for the following purpose:

Education
This audiotape will be used as a part of a research study (see the title above) by the investigator at the CITE department, Temple University. I have already given written consent for my participation in this research study. At no time will my name be used.

Other
I can request for a review of the audiotape in the presence of the investigator. Additionally, a transcribed copy of the audiotaped interview will be sent to me by the investigator for my review and comments.

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THAN ONE YEAR

When will I be audiotaped?
I agree to be audiotaped during the time period: 3/1/08 to 12/1/08

How long will the tapes be used?
I give my permission for these tapes to be used from: 3/1/08 to the completion of the study.
Additionally, the tapes will be stored in a secure place for three years after the completion of the study.

What if I change my mind?
I understand that I can withdraw my permission at any time. Upon my request, the audiotape will no longer be used. This will not affect my care or relationship with the investigator in any way.

Other
I understand that I will not be paid for being audiotaped or for the use of the audiotapes.

For further information
If I want more information about the audiotape, or if I have questions or concerns at any time, I can contact:

Investigator's Name: Uma D. Jayaraman

Department: CITE

Institution: Temple University

Street Address:

City: **State:** **Zip Code:**

Phone: (215) (215)

This form will be placed in my records and a copy will be kept by the person named above. A copy will be given to me.

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THAN ONE YEAR

2

Title: Classroom implementation of the practices learned in the Master of Chemistry Education program by the School District of Philadelphia's high school Chemistry teachers.

Subject's Name: ____________________________________

Date: ____________________________________

Address: ____________________________________

Phone: ____________________________________

Subject's Signature: ____________________________________
Date

Investigator's Signature: ____________________________________
Date

TEMPLE UNIVERSITY
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FEB 1 9 2008

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THAN ONE YEAR

APPENDIX Q

CODES AND TEACHERS' SAMPLE RESPONSES TO THE INTERVIEW'S FIXED QUESTIONS
(3 questions pertaining to lesson design and content)

Research Question 1--- Codings for Teachers' Responses to 3 Questions on lesson planning
Domain: Lesson Design and Implementation

Statement 1 Code: Addressing students' preconceptions/prior knowledge

Teacher Response: My preclass activity will be based on the prior knowledge they should have.

Statement 2 Code: Engaging students as community

Teacher Response: I plan some activities to make sure they understand it, and sometimes, or most of the time, I make them work in pairs or make them work individually.

Statement 3 Code: Exploration before formal presentation

Teacher Response: My preclass activity will be based on the prior knowledge they should have so that I can continue my lesson.

Statement 4 Code: Alternative modes of problem solving encouraged

Teacher Response: It is important to me is that they be able to critically think and apply the information and to use it in other situations.

Statement 5 Code: Students' ideas determine lesson focus

Teacher Response: If this technique doesn't work I'm not going to just give up. I'm going to tweak it a bit and try it again.

Domain: Content

Statement 1 Code: Fundamental Concepts

Teacher Response: I just try to start from the basic level.

Statement 2 Code: Teacher promoted coherent conceptual understanding

Teacher Response: I just try to show them what a coefficient is, what a subscript is, how do you count the number of atoms-----slowly build it up.

Statement 3 Code: Teacher had strong grasp of content

Teacher Response: I have a good understanding of the chemistry from the courses.

Statement 4 Code: Teacher promoted elements of abstraction

Teacher Response: No response

Statement 5 Code: Teacher promoted connections with other disciplines & real world

Teacher Response: Try to bring in environmental issues, I try to tie it in with biology.

Statement 6 Code: Students used variety of representations

Teacher Response: Different ways in which they can look at it.

Statement 7 Code: Students made predictions and devised means to test

Teacher Response: They had to explain why the trends were there.

Statement 8 Code: Students actively engaged in critical assessment of procedure

Teacher Response: Give them activity so they learn whatever I am teaching.

Statement 9 Code: Students were reflective

Teacher Response: Webb's DOK because it's a process that requires time for them to think, for them to comprehend.

Statement 10 Code: Rigor, challenging of ideas valued

Teacher Response: I try to make the students think higher at a higher level of thinking.

Domain: Classroom Culture

Statement 1 Code: Student communicate with a variety of means/media

Teacher Response: Journal entries that would be relevant--- to do writing---- use four types of questions, different things.

Statement 2 Code: Teacher questions triggered divergent thinking

Teacher Response: What is important to me is that they be able to critically think and apply the information and to use it in other situations.

Statement 3 Code: High degree of communication between/among students

Teacher Response: ----group activity because they can help one another in a social aspect of bits and pieces of the information that they may not understand as individuals.

Statement 4 Code: Student comments determined classroom discourse

Teacher Response: If I think they need to understand more about a topic or I'll even go back and do another lab that ties in with---

Statement 5 Code: Climate of respect

Teacher Response: No response.

Statement 6 Code: Active student participation valued/encouraged

Teacher Response: I might do two or three labs on one topic if I have some that are engaging the kids.

Statement 7 Code: Students encouraged to conjecture/alt. solutions/interpret

Teacher Response: I gave them a handout and had them explain the trends, how you can figure out if it's polar or non-polar, emphasize using what you learned in some way

Statement 8 Code: Teacher was patient with students

Teacher Response: We usually spend two to four days sometimes on a Web DOK because it's a process that requires time for them to think.

Statement 9 Code: Teacher acted as resource person

Teacher Response: During the activities I'm also available for them.

Statement 10 Code: Teacher listened to student ideas

Teacher Response: I make sure they understand what I am doing.

APPENDIX R

SUMMARY OF FINDINGS FOR ALL AND INDIVIDUAL TEACHERS

Table 18: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for ALL the Teachers (N=6)*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a				1(N)	5(I)		
Open-ended Q. 1b				2(0)	1(5)	3(7,8)	
2. RTOP							
Total					5	1	
		Lesson Design & Implementation		1	4	1	
		Content			3	3	
		Classroom Culture		2	2	2	
3. 3 Interview Qs							
Total				2	1	3	
		Lesson Design & Implementation		2	1	1	2
		Content		2	2	2	
		Classroom Culture		2	1	3	
4. RTOPTS							
Total							6
		Lesson Design & Implementation				4	2
		Content					6
		Classroom Culture				1	5

* Full = MCE Program Intention

Table 19: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher A*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a					X		
Open-ended Q. 1b					X		
2. RTOP							
Total					X		
		Lesson Design & Implementation			X		
		Content				X	
		Classroom Culture		X			
3. 3 Interview Qs							
Total						X	
		Lesson Design & Implementation					X
		Content			X		
		Classroom Culture				X	
4. RTOPTS							
Total							X
		Lesson Design & Implementation					X
		Content					X
		Classroom Culture					X

* Full = MCE Program Intention

Table 20: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher B*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a				X			
Open-ended Q. 1b				X			
2. RTOP							
Total					X		
		Lesson Design & Implementation			X		
		Content				X	
		Classroom Culture			X		
3. 3 Interview Qs							
Total					X		
		Lesson Design & Implementation				X	
		Content			X		
		Classroom Culture			X		
4. RTOPTS							
Total							X
		Lesson Design & Implementation				X	
		Content					X
		Classroom Culture					X

* Full = MCE Program Intention

Table 21: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher C*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a					X		
Open-ended Q. 1b				X			
2. RTOP							
Total					X		
		Lesson Design & Implementation		X			
		Content			X		
		Classroom Culture		X			
3. 3 Interview Qs							
Total				X			
		Lesson Design & Implementation		X			
		Content		X			
		Classroom Culture		X			
4. RTOPTS							
Total							X
		Lesson Design & Implementation				X	
		Content					X
		Classroom Culture					X

* Full = MCE Program Intention

Table 22: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher D*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a					X		
Open-ended Q. 1b						X	
2. RTOP							
Total					X		
		Lesson Design & Implementation			X		
		Content			X		
		Classroom Culture			X		
3. 3 Interview Qs							
Total						X	
		Lesson Design & Implementation					X
		Content				X	
		Classroom Culture				X	
4. RTOPTS							
Total							X
		Lesson Design & Implementation				X	
		Content					X
		Classroom Culture					X

* Full = MCE Program Intention

Table 23: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher E*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a					X		
Open-ended Q. 1b						X	
2. RTOP							
Total						X	
		Lesson Design & Implementation				X	
		Content				X	
		Classroom Culture				X	
3. 3 Interview Qs							
Total				X			
		Lesson Design & Implementation		X			
		Content		X			
		Classroom Culture		X			
4. RTOPTS							
Total							X
		Lesson Design & Implementation					X
		Content					X
		Classroom Culture				X	

* Full = MCE Program Intention

Table 24: *Summary of Findings from All Applicable Data Sources for Research Question 2 and Contributory Questions 2a, 2b, and 2c, for Teacher F*

Data Source		Data Source		Level of Implementation			
		Domains		Absent	Low	High	Full*
1. SoCQ							
Open-ended Q. 1a					X		
Open-ended Q. 1b						X	
2. RTOP							
Total					X		
		Lesson Design & Implementation			X		
		Content			X		
		Classroom Culture				X	
3. 3 Interview Qs							
Total						X	
		Lesson Design & Implementation			X		
		Content				X	
		Classroom Culture				X	
4. RTOPTS							
Total							X
		Lesson Design & Implementation				X	
		Content					X
		Classroom Culture					X

* Full = MCE Program Intention

APPENDIX S

CODES AND TEACHERS' SAMPLE RESPONSES TO SOCQ'S 2ND OPEN-ENDED QUESTION

(Question: What is helping you to implement the MCE program practices?)

Research Question 3--- Codings for Responses to SoCQ's amended Q. #2 on Enabling Factors

Category: MCE Program Practices

Enabling factor: Depth of Content Knowledge

Teacher Response: Now I have a deeper scientific knowledge base

Enabling Factor: Formal Laboratory Exercises and Reports

Teacher Response: I do labs every week. Another practice I implement from MCE program is the use of formal lab report write-ups.

Enabling Factor: Hands-on Problem-solving Activities

Teacher Response: Students ready to solve problems scientifically

Enabling factor: Group Work

Teacher Response: Students do more group work

Category: Student Characteristics

Enabling factor: Good Behavior

Teacher Response: Students were well behaved

Enabling factor: Self-motivation

Teacher Response: Students were motivated

Enabling factor: Basic Skills to follow Instructions

Teacher Response: Students had the basic skills to follow the instruction and carry out activity

Category: Administrative Support

Enabling factor: Supportive Department Head

Teacher Response: Department head who will help you out to implement new practice

Enabling factor: Laboratory Assistant as Teacher Aide

Teacher Response: Lab assistant who will help you out to implement new practices

Enabling factor: Adequate Supplies

Teacher Response: Supplied materials in class as needed

Category: Other

Enabling factor: Nothing

Teacher Response: Nothing

Enabling factor: Not Using the MCE Program Practices

Teacher Response: I currently do not use the program

APPENDIX T

CODES AND TEACHERS' SAMPLE RESPONSES TO INTERVIEW QUESTIONS ON ENABLING FACTOR

Research Question 3--- Codings for Responses to Interview questions on Enabling Factors

Category: MCE Program Practices

Enabling Factor: Lab work

Teacher Response: I feel that doing labs is very engaging for students. So I do that.

Enabling Factor: Less preps to allow more time for inquiry

Teacher Response: Less subjects because then I could do some type of inquiry in the classroom for that

Enabling Factor: Use of POGIL and PIM

Teacher Response: Use of POGIL that I learnt in MCE and the use of Penn Instruction Model (PIM)

Enabling Factor: Less lecturing/more of students taking ownership of learning

Teacher Response: Let them do it by themselves kind of guided the instruction, it makes more sense and be able to learn much better than lecture, rather than me being the main speaker all the time.

Enabling Factor: Use of internet and technology

Teacher Response: For example like the use of internet and the use of technology

Enabling Factor: Use of inquiry methods

Teacher Response: The practices that I found in the program, that I do truly use and I really enjoy is the inquiry method of teaching

Enabling Factor: Students' focus on writing

Teacher Response: It allowed the students to write formal lab reports. I think they valued it

Category: Student Characteristics

Enabling Factor: Higher level

Teacher Response: I think as the students move on to higher level classes it's very easy to implement Penn program

Enabling Factor: Eager/willing to embrace inquiry methods

Teacher Response: inquiry methods (work well) when you have students who don't mind to investigate

Category: Administrative Support

Enabling Factor: Support from administrators

Teacher Response: I think the administration, the principal that I currently have he would be supportive (of MCE practices)

Category: Other

Enabling Factor: Adequate time and training for the students

Teacher Response: It takes time, you cannot implement PIM right away. You have to train them.

Enabling Factor: Adjusting teaching strategies to student needs

Teacher Response: So even in mid stream you may have to turn horses because if you look out and it's not getting across, that night you better come up with a way to get it across

Enabling Factor: Teachers writing the curriculum aligned to MCE knowledge/practices

Teacher Response: Teachers be able to take that knowledge and be able to control the curriculum process ourselves

Enabling Factor: Information on differentiating curriculum

Teacher Response: Tailor mine teaching or my methods of giving instructions to students here and students elsewhere who are economically up

Enabling Factor: Teachers' personal motivation

Teacher Response: One of the things that is helping me is my personal motivation actually

Category: MCE Program

Enabling Factor: Connecting with other MCE program participants

Teacher Response: If I was checking back with my colleagues at MCE to discuss my classroom practice with them. I think that would have helped.

APPENDIX U

CODES AND TEACHERS' SAMPLE RESPONSES TO SOCQ'S 3RD OPEN-ENDED QUESTION

(Question: What is inhibiting you from implementing the MCE program practices?)

Research Question 4--- Coding for Responses to SoCQ's amended Q. #3 on Hindering Factors

Category: School District Mandates

Hindering Factor: Core Curriculum and Pacing Schedule

Teacher Response: The (core curriculum) timeline issued by the school district does not allow the teacher to spend sufficient amount of time to cover some topics thoroughly and it limits the development of skills for students to become independent and critical thinkers.

Hindering Factor: Test Preparation (Standardized, Benchmark, AP, and IB)

Teacher Response: The need to cover a lot of material and prepare students for tests takes precedence.

Hindering Factor: Policies

Teacher Response: School district policy

Hindering Factor: Administrative Paper Work

Teacher Response: There is a lot of paper work and obligation during prep time (i.e., CSAP meetings, performance reviews etc.)

Hindering Factor: Large Class Size

Teacher Response: Large class sizes

Category: Student Characteristics

Hindering Factor: Unprepared for Student-centered Work

Teacher Response: Lack of student preparation makes student centered work unproductive.

Hindering Factor: Poor Math and Reading Skills

Teacher Response: Poor math and reading skills of our students

Hindering Factor: Lack of Motivation

Teacher Response: Demotivated students

Hindering Factor: Lack of Basic Skills to Follow Instruction

Teacher Response: Classes where students don’t follow the instruction and your priority becomes classroom management

<u>Category: Administrative Support</u>

Hindering Factor: Unsupportive Department Head

Teacher Response: No support from the department head

Hindering Factor: Unsupportive Administration

Teacher Response: Nobody to complain to because when you complain about something you are the ‘bad’ person and the only outcome will be that you are in trouble

Hindering Factor: Lack of Resources

Teacher Response: Poor or lack of resources

APPENDIX V

CODES AND TEACHERS' SAMPLE RESPONSES TO INTERVIEW QUESTIONS ON HINDERING FACTORS

Research Question 4--- Coding for Responses to Interview questions on Hindering Factors

Category: School District Mandates

Hindering Factor:	Parental calls
Teacher Response:	I have to do a lot of parental calls for a large amount of students

Hindering Factor:	Many classes/Preps/Duties/Lack of time
Teacher Response:	We don't have the time to analyze and reflect on things, the way they want to do it

Hindering Factor:	Single lab period
Teacher Response:	We actually don't have double lab periods we only have 50 minute periods

Category: Student Characteristics

Hindering Factor:	Students who cannot focus
Teacher Response:	Sometimes I get a class with students who cannot focus

Hindering Factor:	Low level
Teacher Response:	If you get a very low level class it takes time, you cannot implement PIM right away

Hindering Factor:	Need to train how to work in a group
Teacher Response:	Start working with them and teach them how to work in groups

Hindering Factor: Do not reflect on previous knowledge

Teacher Response: Students do not want to go back and look (at) what they already learned

Hindering Factor: Often require reteaching

Teacher Response: I end up teaching or reviewing everything one more time

Hindering Factor: Need more time to learn the basics

Teacher Response: So by the time you teach basics you're lagging behind

Hindering Factor: Work only for credit

Teacher Response: If I'm not going to collect it in some way shape or form, frequently they won't even attempt the problem

Hindering Factor: Resistance to learn/Explain

Teacher Response: You know sometimes kids refuse change

Category: Administrative Support

Hindering Factor: Unconcerned administrators

Teacher Response: It wasn't a push from the administration. The administration didn't care about that (MCE practices)

Hindering Factor: Unsupportive NTA

Teacher Response: We need more support from the Non Teaching Assistants (NTA)

Hindering Factor: Unsupportive lab assistant

Teacher Response: lab assistant is not cooperating

Hindering Factor: No/restricted access to computer lab/technology

Teacher Response: There is not a computer lab for academic teachers

Category: MCE Program

Hindering Factor: Lack of networking with MCE staff/students

Teacher Response: I don't think there's anything that they have in the program that allows you to maybe call them up like a hotline or something or ask questions its nothing like a forum

Hindering Factor: Not realistic for high school classroom

Teacher Response: I think it would have been a lot helpful if they just implemented some things that are more high school related

Hindering Factor: Professors out of touch with high school environment

Teacher Response: I think a lot of the teachers were at the college level. They didn't have any high school teaching experience

Hindering Factor: Two pedagogy courses not helpful

Teacher Response: I think their education end of the course for lack of many things is lacking a whole lot

Hindering Factor: Teachers in education courses substandard

Teacher Response: The teachers of the educational end of it basically had no clue what they were doing

Category: Teachers' Characteristics/Limitations

Hindering Factor: Other priorities took precedence

Teacher Response: I just became preoccupied with other things that needed to be done

Hindering Factor:	Class management/control problems
Teacher Response:	Kids are almost taking control of the classroom. I am really concerned about classroom management

Hindering Factor:	Inability to engage students
Teacher Response:	I don’t always have time to come up with a way to present the information that is as engaging as I’d like it to be

Hindering Factor:	Lack of collaboration with other teachers in school
Teacher Response:	I would like to collaborate more and show him

Hindering Factor:	Not enough time to develop understanding/thinking skills
Teacher Response:	Other responsibilities that I have in the school prohibit me to get into those fundamental topics on a deeper level.