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Issaou Gadp
Cleveland State University

Geeta Verma
University of Colorado Denver, geeta.verma@ucdenver.edu

Doris Simonis
Kent State University - Kent Campus

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Middle Grade Teachers' Perceptions of their Chemistry Teaching Efficacy: Findings of a One year long Professional Development Program

Issaou Gado
Cleveland State University
igado@kent.edu

Geeta Verma
Georgia State University
Middle/Secondary Education and Instructional Technology Department
Atlanta, GA
gverma@gsu.edu

Doris Simonis
Kent State University
dsimonis@kent.edu

Abstract: A professional development (PD) program, Conceptual Chemistry for Middle School Teachers, was designed to facilitate teachers' learning and teaching of basic chemistry concepts. This study explored (a) whether the PD increased teachers' self-efficacy and teaching outcome expectancy and (b) how the PD program influenced teachers' chemistry content knowledge and attitudes toward learning chemistry concepts. Thirty-six teachers (N = 36; 26 women, 10 men) who taught grades 5-9 were selected from a population of science teachers in north eastern Ohio. A mixed method approach was used in the study and qualitative and quantitative data were collected and analyzed simultaneously. The quantitative findings revealed no significant difference in teachers' self-efficacy beliefs using the STEBI-A questionnaire. The qualitative findings indicated that participants became more knowledgeable about chemistry concepts and science process skills and became more confident about their ability to teach those chemistry concepts to students in their classes.

> *To be prepared for the 21st century, it is critical that all students have sufficient knowledge of and skills in science. Studies suggest that high-quality teaching can make a significant difference in student learning. NSTA (National Science Teacher Association) believes a high-quality science teacher workforce requires meaningful, ongoing professional development.* (NSTA's position statement on professional development in science education, ¶ 1)

Professional organizations such as the National Science Teacher Association (NSTA) and reform documents (American Association for the Advancement of Science [AAAS]; 1993National Research Council [NRC], 1996) argue for meaningful and engaging professional development (PD) opportunities for in-service teachers. These PD opportunities are crucial for the success of inquiry-based teaching in the classroom as many elementary and middle school teachers do not have strong science content and pedagogy background (Archbald & Porter, 1994; Radford, 1998) and may get anxious about teaching science (Jones & Levin, 1994). Additionally, many teachers remember science from their own schooling as *drill and practice* [italics added] sessions leading to knowledge of technical vocabulary (Bencze & Hodson, 1999).

Teachers may teach in ways similar to their own learning experiences as they may not have the knowledge and confidence to use pedagogically sound strategies in their classrooms (Jones & Levin, 1994; Van Zee & Roberts, 2001). PD opportunities are organized to address these issues; however, PD programs in science education are often organized around, "lectures to convey content and technical training about teaching" (National Science Education Standards [NSES], 1996, p. 56) and are found to be ineffective.

PD opportunities should facilitate teachers' understandings about inquiry-based teaching in the classroom. Research (Gallagher, 1994) highlights that teacher enthusiasm and inquiry-based teaching in middle school years are the best predictors of student persistence in school science. Unless inquiry-oriented classes are a part of their own educational experiences, elementary and middle school science teachers typically lack ways to implement science content and inquiry processes in their classrooms (Hammer, 2000; Jones & Levin, 1994). In addition, teachers often claim that inquiry is time consuming and may be too advanced for students (Bybee, 2000). Therefore, quality PD materials and opportunities guided by research-based ideas are essential to develop robust science knowledge and skills to implement inquiry-based teaching in the classroom.

In this paper, we present data from a study to document the effectiveness of a PD program designed for middle school science teachers in Chemistry. A team of chemistry teachers and science educators participated in developing and offering a PD program called *Conceptual Chemistry for Middle Grade Teachers* through a National Science Foundation (NSF) grant. The goals of the PD program were organized to not only increase teachers' pedagogical content knowledge, but also to foster enthusiasm in chemistry teaching. The PD program used activities to model scientific inquiry, discrepant events, and research on teaching and learning science. The program was based on guidelines prepared by the American Chemistry Society (with NSF funding). This study aimed to (a) determine whether this program increased middle school teachers' self-efficacy and teaching outcome expectancy and (b) explore how the PD program influenced teachers' content and pedagogical knowledge and attitude toward learning chemistry concepts.

Conceptual Framework

The theory of planned behavior (Ajzen, 1996; Ajzen & Madden, 1986) and Bandura's (1977, 1986, &1997) theory of self-efficacy were used as the conceptual framework of this study. In the present study, the theory of planned behavior was used to investigate teachers' attitude toward the PD program (Shrigley, Koballa, & Simpson, 1988). In the past, the theory of planned behavior (Ajzen & Madden, 1986) has been "used to examine factors related to other human behaviors" (Czerniak & Lumpe, 1996, p. 355). Khourey-Bowers & Simonis (2004) argued that teacher self-efficacy beliefs affect classroom culture; therefore, PD programs should explore teachers' science teaching efficacy and their acquisition of content knowledge and pedagogical skills. Therefore, we used the self-efficacy theory to situate the overall teacher experiences in the PD.

The social psychology-based theory of planned behavior provides a relationship among beliefs, intentions, and behavior. In addition, the theory of planned behavior postulates three directly measurable constructs—attitude toward behavior (AB), subjective norm (SN), and perceived behavioral control (PBC). These constructs influence a person's intent to engage in a particular target behavior (behavioral intention) and directly correlates with the person's actual behavior (Crawley III, 1990; Crawley III & Coe, 1990; Czerniak & Lumpe, 1996; Lumpe, Czerniak, & Haney, 1998). For example, in this study, we wanted to explore how the teachers envisioned using the PD experiences (target behavior) in their classroom, and how they were actually able to implement the experiences. In previous studies, the theory of planned behavior has been used (a) to determine factors influencing teachers' intentions to implement the four strands (inquiry, knowledge, conditions, and applications) of a State Competency Based Science Model (Haney, Czerniak, & Lumpe, 1996); (b) to examine factors influencing K-12 teachers' intentions to use cooperative learning in their science instruction (Lumpe, et al., 1998); and (c) to predict factors associated with students' intentions to engage in science learning activities (Beck, Czerniak, & Lumpe, 2000; Butler, 1999).

Bandura's Personal self-efficacy theory has been extensively investigated in the literature (Bandura, 1977, 1986, 1997; Guskey & Passaro, 1994; Riggs & Enochs, 1990). According to Bandura (1997), personal self-efficacy "is a judgment of one's ability to organize and execute given types of performances…"(p. 21). Self-efficacy is composed of two distinct facets: personal science teaching self-efficacy (PSTE) and outcome expectancy (OE) (Bandura, 1986), and are shown to be uncorrelated with each other (Khourey-Bowers & Simonis, 2004). Bandura (1997) cites four sources of efficacy beliefs – mastery experiences, physiological and emotional states, vicarious experiences, and social persuasion – which can be utilized in the design of professional development intervention to specifically address change in both PSTE and OE.

Personal teaching self-efficacy is the belief in one's own ability to effectively present the knowledge, perform the processes, and guide students toward understanding (Bandura, 1986). It emphasizes perceptions of competence, which may vary from actual competence that one may be able to demonstrate (Tschannen-Moran, Hoy, & Hoy, 1998). Outcome expectancy, on the other hand, is the individual's perception of the possible consequences of performing a task at the expected level of competence. Outcome expectancy (OE) can provide incentives and disincentives for a given behavior (Bandura, 1986) in the form of social compensations, recognitions, or self-evaluations. For teachers, Ashton and Webb (1994) have described OE as the teacher's perception of which students are able to learn. In science education, Riggs and Enochs (1990) developed an instrument specifically for science self-efficacy, the Science Teaching Efficacy Belief Instrument (STEBI). The two subscales of the STEBI – the personal science teaching self-efficacy (PSTE) and science teaching outcome expectancy (STOE or OE) – have been widely applied to empirical studies with in-service and pre-service teachers. We used STEBI to understand in-service teachers' experiences with the Conceptual Chemistry PD experiences, though the instrument is designed to measure science teachers' efficacy beliefs in science.

In summary, the two theories used in the conceptual framework served different purposes. The theory of planned behavior examined teachers' attitudes toward the PD program, whereas Bandura's theory of self-efficacy allowed us to explore teachers' acquisition of content knowledge and pedagogical skills.

Review of Professional Development Approaches

In the past two decades various approaches to teacher PD have emerged. An overview of the literature indicated that some PD models are more behaviorist in their approach (Tytler, Smith, & Grover, 1999) while others emphasize cognitive development. The behaviorist models focus on demonstration or modeling to transmit techniques or strategies, where as the cognitively guided PD programs (Borko & Putnam, 1995) explore the use of research into children's learning, emphasize the importance of collaborative reflection, link theory and experience, and train professionals to act in complex situations of practice. *Conceptual Chemistry* was a cognitively guided PD program that included chemistry content and pedagogical experiences to build teachers' knowledge, understandings, and abilities (Khourey-Bowers & Simonis, 2004). Table 1 presents PD approaches and situates the Conceptual Chemistry PD program within these categories.

Table 1

Situating Conceptual Chemistry (CC) in teacher PD approaches

Goals of PD approaches	Format used in PD approaches	Duration of PD approaches
• Build the knowledge focus (CC) • Develop Awareness • Translate research into practice • Practice teaching (CC) • Reflection (CC)	• Coaching and mentoring programs • Inquiry models (CC) • Teacher self-assessment (CC) • Experiential learning	• One shot workshops • Intense short term PD in the summer • Intense short term PD in the summer followed by academic year follow up • PD started and spread over academic year (CC)

We discuss each of these categories to situate the *Conceptual Chemistry* PD program in the research literature. For example, the goals of a PD program could be diverse such as (a) develop awareness (designed to elicit thoughtful questioning on the part of teachers concerning new information); (b) build the knowledge focus (opportunities for teachers to deepen their understanding of content and teaching practices); (c) translate research into practice (engaging teachers in drawing on their knowledge base to plan instruction in improving their teaching); (d) practice teaching (helping teachers learn to use a new approach with their students); and (e) reflect (engaging teachers in assessing the impact of the changes on their students, encouraging teachers to think about ways to improve, and encouraging teachers to reflect on others' practice, adapting ideas for their own use) (Loucks-Horsley, Hewson, Love & Stiles, 1998). The *Conceptual Chemistry* PD program aligned with three out of five goals (see Table 1) to meet the needs of the PD program participants. The focus of the PD program was addressing teachers' pedagogical content knowledge base (Shulman 1986, 1987), presenting trends and issues in curriculum (Tytler, Smith, & Grover, 1999), and introducing (but not translating) research on teaching and students' learning (Broekhuizen, David, & Dougherty, 1999). This PD program was designed keeping in mind that sustained PD that focuses on content-specific pedagogy is the strongest predictor of teaching efficacy and student achievement (Darling-Hammond, 2000; NSDC, 1995).

The PD literature suggests that teachers benefit most from experiences that integrate active participation and have components of experiential learning (Fiszer, 2004; Louckes-Horsely et al., 1998). Therefore, integrating these aspects should make any PD format robust and meaningful to participants. Some of the formats available in the literature are: (a) coaching and mentoring programs for teachers where proficient teachers serve as role models, and classroom visits from the mentors are used to broaden teachers' exposure to multiple models; (b) inquiry models where national conferences or PD courses provide teachers with models of inquiry activities, engaging nationally or locally known experts in local teacher workshops and/or action research study groups in area schools; (c) designing a PD format and providing explicit opportunities for teacher self-assessment. These assessment opportunities could be used to inform teachers of their own success in the PD program as well as the effectiveness of the PD program itself; and (d) experiential learning approach (Boud, Keog, & Walker, 1985; Fiszer, 2004) where teachers participate in PD opportunities offered in informal learning settings such as museums, an aquarium, a zoo, or a botanical garden. The *Conceptual Chemistry* PD program utilized the inquiry model to build teachers' knowledge, understandings, and abilities (Khourey-Bowers & Simonis, 2004) and integrated opportunities for teachers to implement the PD experiences in their classrooms. The teachers also reflected on their experiences during the inquiry-oriented PD program and engaged in self-assessment opportunities by sharing success and challenges in implementing their experiences.

The last category of the PD approaches focuses on the duration or the length of a PD program. The duration and the format categories can overlap in certain PD approaches, but we decided to keep them separate to map the *Conceptual Chemistry* PD program. The duration of PD programs can range from (a) one shot workshops where teachers get to participate in a PD opportunity in a half/full day set-up. The PD program may be centered around a district-wide goal that may or may not directly provide pedagogical activities for classroom adoption; (b) summer only PD programs using intense training in blocks and lets the participants immerse in the PD experiences; (c) summer PD programs followed by academic year follow-up allowing for training in blocks of intense learning such as week-long summer workshops combined with academic year follow-up; and (d) academic year PD programs where teachers participate in blocks of full-Saturdays and/or during school/after school hours during one semester. *Conceptual Chemistry* PD program was designed using blocks of weekly participation in the PD program during spring semester (9 all-day Saturday classes) with 2-week gaps between each session for the teachers to implement the ideas in their classroom. This was followed by an in-school follow-up (all-day fall semester "reunion" sessions).

Additional criteria used to meet the needs of the specific in-service teacher population included (a) the alignment of the PD content with the district goals and state standards to make the PD program appealing to the participating teachers (Hoffman &Thompson, 2000); (b) opportunities for teachers to not only be active participants in their own professional growth but to also take the *newly acquired knowledge base* [italics added] into their classroom practice; and (c) designing the PD program in a way that it was not perceived as an 'add-on' outside the scope of teachers' work by addressing the pedagogical needs of the participating teachers (Sandholtz, 2002).

Description of the Program

Overview of the Program

The PD program, *Conceptual Chemistry,* was designed to be robust and inclusive of the current trends in the science education literature by including conceptual frameworks (such as curriculum organizers) and insights from research on children's naïve ideas related to chemistry concepts. The PD program used in the present study was designed using a set of activities prepared by the American Chemical Society (1992-1996) for middle grade teachers (American Chemical Society, Operation Chemistry, ¶). The instructors modeled a daily learning cycle incorporating hands-on activities, interactive lecture, individualized group instruction, discussions, role-play, and demonstrations that provoked interactive questioning.

The PD program, made possible by an Ohio Board of Regents' Eisenhower grant, was advertised through flyers. The participants volunteered to attend the PD program. These 36 participants were admitted into a graduate program and given graduate course credit for taking part in the PD program. These participants were selected from a population of north eastern Ohio public school science teachers of grades 5-9 who applied to participate in the PD program. There were 100 applications, but only 36% were selected, owing to space availability. Priority in the selection of participating teachers was given to new teachers and those with little or no chemistry background who were recently reassigned to teach science. In addition, those teachers were selected from poorly funded suburban schools with little or no teaching resources.

Before recruiting our participants, we shared the PD opportunity with the administrators, curriculum specialists, and the teachers. This allowed us to not only have district wide buy-in and participation but also allowed us to communicate with stakeholders about the goals and benefits of the PD program. For example, it was clearly communicated that the PD program was designed to enhance teachers' professional growth, provided explicit strategies to integrate the PD experiences into their classrooms, and allowed teachers to critically examine their work through collaborative and open communication.

The program was designed to be conducted as a series of 9, all-day, Saturday classes in the spring semester followed by an all-day fall semester "reunion" session to allow the participants to share their mastery and vicarious experiences (Bandura, 1997). The 2-week intervals between classes were intended to allow teachers to try the chemistry activities with their own students. This also facilitated conversations about their successes and challenges in implementing the PD ideas to address the *physiological and emotional states* [italics added] component of personal self-efficacy (Bandura, 1997). The participants further brainstormed ideas about overcoming the challenges in their classrooms to meet the *social persuasion* [italics added] component of personal self-efficacy (Bandura, 1997). One Saturday morning was reserved for *Science Fun Day* [italics added] when teachers could practice *Conceptual Chemistry* activities with students recruited from local school districts. The overall program was designed to provide participants with research information about how children learn science concepts.

Instructional Framework

The PD program was based on an instructional framework articulated around three interrelated components:

1. *Course content.* Demonstrations, instructions, analogies, graphics, and background information were provided on specific chemistry concepts appropriate for middle school teachers.
2. *Hands-on activities.* Participation in hands-on activities was designed to help teachers raise their own questions, to model and practice inquiry skills, and to develop lab techniques using locally available materials. A few specialty items were provided for the participants to take back to their own classroom.
3. *Research articles on teaching and learning science.* Children's naïve ideas about selected topics in chemistry were explored through discussion, examples, and children's responses to selected activities and questions.

Instructors used inquiry-based teaching strategies and cooperative learning as the basis of the PD curriculum, followed by a synthesis and summarization of the important points in the program. Extensive explanations of science concepts always followed the activities. Everyday life examples allowed participants to contextualize the PD experiences in their own classrooms.

Textual Materials and Teaching Supplies

Throughout the PD program, participants received teaching materials (books, activity guides, and equipment) to aid them during the PD activities and implementation with their own students. Equipment included litmus paper, micro well plates, thermometers, balance scales, graduated cylinders, multi-shape liter sets, density cubes, flashlight generators, metric rulers and tapes, etc. In addition, participants learned to make chemistry teaching materials from common household supplies. Participants also received four binders of *Conceptual Chemistry* activities, booklets on Vitamin C Testing, and a book on Forensic Chemistry. Copies of *Conceptual Chemistry* activities (about 800 pages) were selected from Operation Chemistry units originally prepared 1992-1996 by the American Chemical Society (American Chemical Society, Operation Chemistry, ¶)) for teacher training with NSF funds. Instructors of the course added self-developed conceptual outlines, presented information on children's naïve ideas about specific chemical concepts, and made suggestions for applications and further illustrations of selected contents. The chemistry topics covered and their brief descriptions are indicated in Appendix A.

Group and Collaborative Work

Participants were divided into seven groups corresponding to seven stations. There were 4-6 participants per group. Prior to the arrival of participants, the instructors set up the materials and continued to set up during the activities. Using the discussion method, participating teachers collaborated in small groups to learn and explain chemistry concepts to each other, make sense of the materials, design an experiment, and report their findings to the rest of the participants. Placing the teachers in a group provided opportunities for them to work collaboratively, to utilize each other's strengths, and to talk through problems when doing the activities.

Instructors

Five science educators were involved in the preparation of the PD activities and served as instructors. These five instructors included: (a) a Professor Emeritus of Science Education at a suburban university in northeast Ohio, (b) a chemistry professor at a suburban university in northeast Ohio; (c) a high school chemistry teacher who had been a research chemist, (d) a high school physics and chemistry teacher, and (e) a multi-grade elementary school science teacher. All members had had successful presentation experience, demonstrated teaching ability, and other professional activities prior to involvement in the *Conceptual Chemistry* program.

Research Questions

Two research questions guided the study:

1. Do *Conceptual Chemistry* PD activities influence middle school science teachers' self-efficacy and chemistry teaching outcome expectancy?

2. What are participants' attitudes toward *Conceptual Chemistry* PD activities and learning pedagogical content knowledge after taking the PD program?

Research Methods

Researcher Roles

The first author attended 9 out of 11 *Conceptual Chemistry* sessions, observed participants for periods ranging from 2-4 hours each time, conducted semi-structured interviews on site, and collaborated in data analysis. The second author created the literature review, collaborated in data analysis and in preparing the manuscript. The third author was part of the instructional team and collected and summarized the post-session evaluation forms.

Setting and Participants

The study took place over a series of Saturdays over a period of one year in the cafeteria of a large suburban public high school. The participants of the study were 36 teachers who were admitted into the PD program and came from a population of teachers in northeast Ohio. All teachers taught middle school (grades 5-9) and volunteered to participate in the study. Seventy-two percent of participants were female and 28% were male. Participating teachers originated from 20 school districts and served a total of 22,676 students.

Methodology

A mixed-method research design (Creswell, 2002; Creswell & Clark, 2007) was used in the study. The study drew its strength from using qualitative data to provide a fuller understanding of participants' responses and to elucidate quantitative data (Bogdan & Biklen, 1998; Patton, 2002). Both qualitative and quantitative data were collected simultaneously from the beginning to the end of the project. Using Creswell and Clark's recommendation, we used the following notation system to explain the design of this study: QUAL (quan), indicating that quantitative methods were embedded within qualitative methods. The upper-case notation QUAL indicates that this study primarily used qualitative data collection tools; however quantitative data (lower-case notation) were used to further expound the participants' experiences with the PD program.

Data Collection

The quantitative data were collected using the Science Teaching Efficacy Belief Instrument (STEBI-A, Riggs & Enochs, 1990). We used the STEBI-A to measure participants' self-efficacy beliefs and teaching outcome expectancy (Riggs & Enochs) due to lack of availability of a specific instrument to measure teachers' self-efficacy in Chemistry. The instrument is widely used to measure teachers' efficacy beliefs in science and we found it to be the closest fit for the purpose of the study. The instrument has two subscales: personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE). The study used a Pre-Posttest design and the participating teachers completed the STEBI-A at the beginning of the first day of the PD program and then after the PD program had been completed. The coefficient alpha reliability is .92 for the PSTE subscale and .77 for the STOE subscale. The independent variable was the PD experiences for the teachers where as the dependent variable was the participants' scores on the STEBI-A.

The qualitative data were gathered using; a) individual interviews; b) post-session evaluation forms; and c) participant observations during the PD program. Participant interviews began on the third (out of 10) class meeting and continued throughout the end of the project. Twelve participants out of 36 were conveniently selected for the interviews. The guiding interview questions were as follows: (a) How have the PD activities changed your teaching strategies? (b) What is your effectiveness in transferring *Conceptual Chemistry* units to your classroom? (c) How did you implement *Conceptual Chemistry* units in your classroom? and (d) How do students benefit from the Conceptual Chemistry PD activities? Post-session evaluation forms were collected from participants at the end of each session; participants responded to the following questions: What I learned today was, the best part of today's class was; a question I have about today's topic; and other comments. Participants were observed during their participation in the PD program.

Data Analysis

Quantitative analyses included descriptive analysis and dependent t tests. SPSS (version 11.0) was used to provide the output for the analyses. A dependent t test analysis was used to determine if there was an increase in participants' teaching self-efficacy beliefs at the end of the *Conceptual Chemistry* PD program.

The analysis of qualitative data followed a procedure recommended by Miles and Huberman (1994). The procedure consisted of codifying the information involving the identification of categories and themes, checking for representativeness, triangulating the data through multiple participants and multiple observers, and making comparisons between participants' interview statements and post session evaluations to get feedback from informants. Segments of qualitative data were coded, categorized, and assembled (Bogdan & Biklen, 1998). The criteria for interpreting qualitative data were based on codes and categories generated from participating teachers' statements. The credibility and trustworthiness of the observations, post session evaluation, and interview data with teachers were documented by their long-term participation in the PD program which provided opportunities to cross-check the data over time

(Patton, 2002). The validity of data was determined by making sure that the account provided by the participants was credible, accurate, and could be trusted by using either member checking and/or triangulation of data (Creswell & Clark, 2007). Reliability was established by having two researchers code the same pieces of information and establishing inter-coder reliability.

Findings

Science Teaching Self-Efficacy Beliefs and Outcome Expectancy

The first research question explored whether the *Conceptual Chemistry* PD program increased middle school science teachers' self-efficacy beliefs and outcome expectancy. A dependent *t* test on the STEBI-A pre/post-test average scores ($M = 2.93$, $SD = 0.30$; $M = 2.93$, $SD = 0.24$) indicated that there was no statistically significant difference, $t\ (27) = .048$, $p = .96$ between participant pre-test/post-test scores. We explore participants' experiences through qualitative data to find out if they benefited from being in the Conceptual Chemistry PD program.

Exploring teachers' self-efficacy beliefs using the qualitative data. Participants' responses using the qualitative data indicated that they had increased comfort and knowledge of selected chemistry topics. Knowledge of chemistry concepts positively affected their confidence and readiness in using *Conceptual Chemistry* units in their classroom. For example, one participant stated, "[owing to the PD course] I can understand it [the chemistry concepts] and present it to [my students]... [The PD course] offers a lot of practical information" (Participant 3). In other words, this teacher gained knowledge through the PD program, which she felt would enable her to teach the concepts to her own students.

Participants also claimed they learned teaching strategies necessary to effectively teach their own students using the PD experiences. They shared that understanding of science concepts would make them more effective in teaching chemistry in their own classrooms. As one participant indicated, "I was ignorant of chemistry. I didn't know how to present it. I didn't know the content itself. In this course, I learned more about chemistry. I also learned how to present it in an experiential form" (Participant 1, post session evaluation form).

Many participants indicated that they intended to use the activities and materials presented in the PD program to employ student-centered pedagogy. Interview data indicated that 85% of participants developed confidence in transferring strategies presented in the PD program to their classrooms. Additionally, a vast majority of the participants (90%) indicated the PD activities were appropriate to the grades they teach and, therefore, were transferable and adaptable to the needs of their students. As one participant indicated, "some concepts that are usually taught to a high level of complexity are brought down to students' level of understanding. The students can understand those concepts better now" (Participant 4). In other words, participants recognized the teaching strategies and chemistry concepts presented in the *Conceptual Chemistry* PD program were appropriate for their students' level of understanding. The results indicated that although the dependent *t*-test did not show a significant difference between the participants' pre-post scores, the qualitative data did reveal that the participants' became more confident in their abilities to understand chemistry.

Exploring and informing teaching outcome expectancy using the qualitative data. We refer to teaching outcome expectancy as the participants' understandings of their teaching outcomes as a result of their participation in the PD program. We specifically looked at two components; participants' perceptions of specific PD units and participants' perceptions of how the units could be used in their own classrooms. Almost all participants (90%) indicated in the interviews and the post session evaluation forms that the PD units were appropriate or could be adapted to meet the needs of their local curriculum and in their classroom settings. Additionally, participants shared that their participation in the PD program has the potential of influencing student achievement in their classroom. As one participant stated in the post session evaluation form, "I am going to take back the hands-on activities. That means that my students will be working in groups, trying to discover things without me telling them" (Participant 5). Another participant shared that he integrated the science concepts taught in the PD program in his classroom, "Just last week I finished teaching acids and bases to my eighth grade students and I used the flower petal activity [conducted in the PD program] where we crushed up petals and then added hot water to them and painted a flower with that liquid" (Participant 4, post session evaluation).

Teaching outcome expectancy was highly influenced by the use of everyday materials in the PD program; participants also indicated that this allowed them to eliminate their reservations about using chemicals in the classroom. As one participant shared, "students will be more confident in using those chemicals like syrup, egg, vinegar, and aluminium foil" (Participant 3) and "usually the supplies that I use in chemistry are toxic chemicals. Now I know that I can get away from that and use with my students some of the everyday materials that we use here [the PD program]" (Participant 4, post session evaluation form). In summary, participants shared their comfort in being able to better explain the concepts to their students in their own classroom as a result of the PD program experiences and materials available to them. Therefore, the participation in the PD program positively impacted the perceptions of their teaching abilities in the classroom setting and asserted teachers' increased confidence in the classroom activities.

Attitudes toward the Program

The second research question was designed to explore middle school teachers' perceptions and attitudes toward the PD program. The analysis of qualitative data generated two themes centred on teaching resources and instructional strategies in the PD program: (a) availability of teaching materials through the *Conceptual Chemistry* PD program; and (b) increased confidence in chemistry pedagogical content knowledge.

Availability of the teaching materials. Analyses of the data indicated that the teaching materials provided by the PD program were found to be the most important attribute and outcomes of the PD program. As one participant indicated:

> When you take a normal college class, you pay for the class; you get a grade out of it and nothing else. For this course, you get something back out of it, more than a book and a grade. I can use the scales, the graduated cylinders, the other things, and these materials are expensive. Having the materials from this course and using those in the classroom are great…we can make mistakes and find our errors during the professional development course; so we know when we go back in the classroom how to do it correctly. (Participant 5)

Participant 9 shared in the post session evaluation that he used the materials in his classroom during the fall semester, "the ones [activities] that I have done in class, the students really enjoyed them. What made it easy to do the activities in class is that we are provided with a lot of materials and supplies that we needed." Similarly, another participant shared how her participation in the PD program helped her transition into teaching as a first year teacher, "I am a first year teacher and for me to sit down and look at the catalogue there will be 10,000 things to choose... but when you come here and you do the activities and they give you the materials" (Participant 6). Analysis of interview data indicated that 95% of participants used some of the materials from the PD program with their students. As one participant shared, "I did a lot of density experiments in my class with the metal cylinder that they gave us. I did also the activity with different masses but the same volume that gave students good idea of what density is" (Participant 9). In other words, participants indicated their positive attitudes toward the PD program due to materials received as a result of their participation in the course.

Increased confidence in chemistry pedagogical content knowledge. Participants shared that participation in the PD program led to sophisticated understanding of chemistry pedagogical knowledge. For example, one participant indicated:

> I know I have a major in chemistry in college, but I teach eighth grade, and so I have a whole bunch of experiments that I can do with older students who know a lot of chemistry. But as far as my simple activities with young students, I didn't have a whole lot. So the main reason I took this course is to gather good ideas for young students. This course did help me a lot in doing that. (Participant 9)

Similarly, two other participants shared the integration of content and pedagogical knowledge in the PD program to, "[support] a teacher who can do science activities in the class, explain the concepts to students, and be confident about the activities" (Participant 5, post session evaluation form) and enable the participant to, "[go] through a lot of these demonstrations and activities with my students. My students can even do [the activities] in class and at home [to understand] some of the chemistry concepts" (Participant 4). Participants continuously situated their experiences using the pedagogical content knowledge framework. As participant 3 noted in the post-session evaluation form, "I always have trouble translating what I know into information to my students. Everything [in the PD] is taking [sic] down to a level that students can understand the concepts. I can understand it and present it to them [students]."

Some participants shared their robust pedagogical understandings by sharing examples of the activities in their classroom after their participation in the PD program. As one participant shared:

> First, students observed a discrepant event of a chemistry concept that has been introduced to us during the professional development [Conceptual Chemistry] course…Then, I asked what-do-you-know type of questions… then, students went into the process of sequentially doing different hands-on activities, collecting and analyzing data. When they get down to the end of the units, they went back to the white board and the overhead transparency; then, they reinvestigated what-do-you know and what-you-want-to-know type of questions and they summarized what they learned. (Participant 1)

In other words, most participants indicated that they benefited from the *Conceptual Chemistry* PD program by integrating the chemistry content and pedagogical knowledge and by conducting more hands-on activities (using the PD materials), organizing discrepant events and generating opportunities for students to touch, see, feel, and manipulate science materials and equipment.

Discussion and Implications

The study used a mixed-methods design to explore middle school in-service teachers' experiences with the *Conceptual Chemistry* PD program. Even though no significant difference in teachers' self-efficacy and teaching outcome expectancy was found using the quantitative data, the qualitative data showed that the impacts and benefits of the PD program were perceived in four areas: (a) middle grades teachers' acquisition of knowledge of selected chemistry concepts and strategies to teach their students; (b) participants' confidence in own self-efficacy and reduction in teachers' anxieties about teaching chemistry; (c) abilities to integrate pedagogical content knowledge and teaching strategies; and d) use of materials provided through the PD program in participants' classrooms.

Notably, the statistical results show no statistically significant difference in participating teachers' self-efficacy beliefs and outcome expectancy. The failure to find statistically significant differences in comparing participants' self-efficacy and teacher outcome expectancy in the beginning and at the end of the PD program could be attributed to the mismatch between the use of STEBI- A and the goals of this PD program as well as the length of the study. In this study, the STEBI-A may not have been effective at measuring changes in self-efficacy in chemistry over the period of one year. A longitudinal study (Khourey-Bowers & Simonis, 2004) of middle grades PD programs in chemistry (based on a four-year, four-cohort study) found significant differences in personal science teaching efficacy and outcome expectancy during the 4-year study. Therefore, we recommend that future studies should consider using an instrument that focuses specifically on the teaching of chemistry concepts in a longitudinal study.

In addition, Khourey-Bowers & Simonis (2004) recognized that qualitative data in the form of written and oral comments positively supported the quantitative findings thus indicating that the participants' self-efficacy can be effectively gauged using qualitative measures as well. As they indicated, "comments supporting the gain in PSTE were characterized by acknowledgements of using workshop materials, content, or strategies in their own classrooms" (Khourey-Bowers & Simonis , p. 192). The qualitative data analysis showed that the primary outcome of this PD program included changes in teachers' attitudes toward chemistry instructional practices.

The Theory of Planned Behavior posits that belief based factors (attitude toward the behavior, subjective norm, and perceived behavior control) influence people's behavioral intentions which in turn are correlated with actual behavior (AB) (Czerniak & Lumpe, 1996). In this study, the participants intended to improve their understandings of chemistry concepts by volunteering to attend the PD program. The study explored the participants' belief-based factors of AB by evaluating the outcomes of their behavior (participation in the PD program). The participants' outcome evaluations indicated that the *Conceptual Chemistry* PD program influenced the participants as it focused on concrete classroom applications of chemistry concepts and exposure to actual practice rather than merely a description of practice. Belief-based measures of subjective norms (SN) are measured by aspects, such as perceptions, of what others think and by motivation to comply with others (Czerniak & Lumpe, 1996). The PD program involved opportunities for participants to observe each other and reflect on their observations, opportunities for group collaboration and deliberate evaluation, and opportunities for feedback by skilled practitioners. These learning opportunities in the PD program created a place where participants could not only refine their pedagogical content knowledge but also reflect on the implications of these experiences for their students in the classrooms.

Belief-based measures of perceived behavioral control (PBC) are measured by the perception of aspects that facilitate or inhibit participation in the behavior (participating and implementing PD ideas in the classroom). In this study, specific components that seem to make *Conceptual Chemistry* an effective PD program were the duration of the course, follow-up, sustained support, participation and collaboration, connections to classroom practices, infusion of content and pedagogy, and involvement in active learning in all aspects of the PD program. The findings of this study not only corroborate the conditions for effective PD (Elmore, 1995; Guskey, 1995; Kennedy, 1999) but also indicate that these factors are crucial for the success of implementing the PD ideas in the classroom.

The qualitative findings in the present study indicated that participants' experiences in the PD program dealt with nuances, details, and subtle, yet unique, aspects of the PD program, thus facilitating a shift in the participants' teaching confidence and their abilities to implement the PD activities in their own classrooms. Furthermore, the results highlight that when teachers become more confident in their science background and teaching strategies, they may bring meaningful and engaging science activities into their classes. PD in chemistry for teachers is critically important as there are many teachers, similar to the participants in the study, who are not confident of their own science content and pedagogical mastery. Therefore, this type of PD for in-service middle grade teachers may enhance teachers' conceptual backgrounds in chemistry as well as equip them with effective instructional strategies and materials. Prior studies support that many elementary and middle school in-service teachers who do not have a strong science background and have had little or no training in conducting science inquiry activities (Archbald & Porter, 1994; Radford, 1998) fail to implement them successfully in their classrooms.

The results of this study suggest that teachers who experienced learning about chemistry concepts through the *Conceptual Chemistry* PD program became more knowledgeable not only in chemistry concepts but became more confident about their abilities to put their experiences into practice in their classes. Therefore, we strongly recommend integration of the four salient features of the *Conceptual Chemistry* PD program in future training for middle grade teachers in Chemistry: (a) presenting science concepts appropriate for novices in the discipline using a variety of activities and groupings; (b) providing examples and demonstrations of how students learn chemistry content; (c) involving teachers as professionals in doing and evaluating both content and process skills as they engage in conducting science activities; and (d) reducing "no equipment, no supplies" constraint by providing basic start-up materials during the PD program. Providing teachers with the opportunity to attend graduate level professional growth opportunities such as the *Conceptual Chemistry* PD program may be one way to facilitate teachers' understandings of Chemistry concepts and teaching skills that could have a significant impact on teaching outcomes.

References

American Association for the Advancement of Science (1993). *Project 2061: Benchmarks for Science Literacy*. New York: Oxford University Press.

American Chemical Society (n.d). Operation Chemistry. Retrieved June 27, 2008, from http://www.nas.edu/rise/examp8.htm.

Ajzen, I. (1996). The directive influence of attitudes on behavior. In P. M. Gollwitzer & J. A. Bargh (Eds.), *The psychology of action: Linking cognition and motivation to behavior* (pp. 385-403). New York: Guilford Press.

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22*, 453-474.

Archbald, D. A., & Porter, A. C. (1994). Curriculum control and teachers' perceptions of autonomy and satisfaction. *Educational Evaluation and Policy Analysis, 16*(1), 21-39.

Ashton, P., & Webb, R. (1994). *Making a difference: Teachers' sense of efficacy and student achievement*. New York: Longman.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review, 84*, 191-215.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.

Beck, J., Czerniak, C. M., & Lumpe, A. T. (2000). An exploratory study of teachers' beliefs regarding the implementation of constructivism in their classroom. *Journal of Science Teacher Education, 11*, 323-343.

Bencze, L. & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching, 36,* 521-539.

Bogdan, R. C., & Biklen, S. K. (1998). *Qualitative research for education: An introduction to theory and methods* (3rd ed.). Boston, MA: Allyn and Bacon.

Borko, H., & Putnam, R. (1995). Expanding a teacher's knowledge base: A cognitive psychological perspective on professional development. In T. Guskey & M. Huberman (Eds). *Professional development in education: new paradigms and practices,* (pp. 35-65) New York: Teachers College Press.

Boud, D., Keogh, M., & Walker, D. (1985). Reflection: Turning experiences into learning. London: Kogan Page.

Broekhuizen, V., David. L., & Dougherty, B. (1999). Teacher diversity: Implications for professional development. *Pacific Resources for Education and Learning, Honolulu, HI: Office of Educational Research and Improvement learning activities*.

Butler, M. B. (1999). Factors associated with students' intentions to engage in science learning activities. *Journal of Research in Science Teaching, 36*(4), 455-473.

Bybee, R.W. (2000). Teaching science as inquiry. In J. Minstrell & E.H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 20-46). Washington, DC: American Association for the Advancement of Science.

Crawley, F. E. III. (1990). Intentions of science teachers to use investigative teaching methods: A test of the theory of planned behavior. *Journal of Research in Science Teaching, 27* (7), 685-697.

Crawley F. E., & Coe, A. S. (1990). Determinants of middle school students' intention to enroll in a high school science course: An application of the theory of reasoned action. *Journal of Research in Science Teaching, 27* (5), 461-476.

Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Columbus, OH: Merrill, Prentice Hall.

Creswell, J. W., & Clark, V. P. (2007). *Designing and conducting mixed-methods research*. Thousand Oaks: California: Sage Publications.

Czerniak, C. M., & Lumpe, A. T. (1996). Predictors of science fair participation using the theory of planned behavior. *School Science and Mathematics, 96*(7), 355-361.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence [Electronic Version]. *Education Policy Analysis Archives, 8*. Retrieved June 27, 2008 from http://epaa.asu.edu/epaa/v8n1/.

Elmore, R. (1997). *Investing in teacher learning: Staff development and instructional improvement in community school district # 2, New York City*. Retrieved June 27, 2008, from http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/29/bc/5a.pdf.

Fiszer, E. P. (2004). *How teachers learn best: An ongoing professional development model*. Lanham, MD: Rowman & Littlefield Publishing Group, Inc.

Gallagher, S. (1994). Middle school classroom predictors of science persistence. *Journal of Research in Science Teaching, 31*, 721-734.

Guskey, T. R., & Passaro, P. D. (1994). Teacher efficacy- A study of construct dimensions. *American Educational Research Journal*, *31*, 627-643.

Guskey, T. R. (1995). Professional Development in Education: In search of the optimal mix. In T. Guskey & M. Huberman (Eds.), *Professional development in education: New paradigms and practices* (pp. 114-131). New York, Teachers College Press.

Hammer, D. (2000). Teacher inquiry. In J. Minstrel & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 184-215). Washington, DC: AAAS.

Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching, 33,* 971-993.

Hoffman, E., & Thompson, G. (2000). Putting the research to work: Professional development models from Michigan. *TechTrends, 44(2)*, 20-23.

Jones, C., & Levin, J. (1994). Primary/elementary teachers' attitudes toward science in four areas related to gender differences in students' science performance. *Journal of Elementary Science Education*, *6*, 57-59.

Kennedy, M. M. (1999). Form and substances in mathematics and science professional development. *NISE, Brief*, *3*(2), 1-6.

Khourey-Bowers, C., & Simonis, D. G. (2004). Longitudinal Study of Middle Grades Chemistry Professional Development: Enhancement of Personal Science Teaching Self-Efficacy and Outcome Expectancy. Journal of Science Teacher Education, 15(3), 175-195.

Loucks-Horsely, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press.

Lumpe, A. T., Czerniak, C. M., & Haney, J. J. (1998). Science teacher beliefs and intentions regarding the use of cooperative learning. *School Science and Mathematics*, *98*, 123-135.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook.* Thousand Oaks, CA: Sage Publications.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

National Staff Development Council (1995). *Standards for staff development: Middle level edition.* Oxford, OH: National Staff Development Council.

National Science Teachers Association. (2006). NSTA Position Statement: Professional Development in Science Education Retrieved June 26, 2008, from http://www.nsta.org/about/positions/profdev.aspx

Patton, Q. M. (2002). *Qualitative research and evaluation methods* (3rd ed). Thousand Oaks, Ca: Sage.

Radford, D. L. (1998). Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science of Teaching, 35*, 73-88.

Riggs, I. M., & Enochs, L. M. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

Sandholtz, J. H. (2002). Inservice training or professional development: Contrasting opportunities in a school/university partnership. *Teacher and Teacher Education, 18,* 815- 830.

Shrigley, R. L., Koballa, T. R., & Simpson, R. D. (1988). Defining attitude for science educators. *Journal of Research in Science Teaching, 25,* 659-678.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching, *Educational Researcher, 15,* 4-14.

Shulman, L. (1987). Knowledge and teaching; foundation of new reform. *Harvard Educational Review, 1,* 1-22.

Sparks, G. M. (1983, November). Synthesis of research on staff development for effective teaching. *Educational Leadership, 41*(3), 65-72.

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*, 202-248.

Tytler, R., Smith, R., Grover, P., & Brown, S. (1999). A comparison of professional development models for teachers of primary mathematics and science. *Asia-Pacific Journal of Teacher Education, 27*, 193 -214.

Van Zee, E. H., & Roberts, D. (2001). Using pedagogical inquiries as a basis for learning to teach: Prospective teachers' reflections upon positive science learning experiences. *Science Education*, *85*, 733-757.

Appendix A

Table 1

Topics Covered in the Conceptual Chemistry PD Program

Session	Concepts	Brief description
1	Properties of matter	Physical and chemical properties of matter and models.
2	Density and concentration	Mass, volume, and dilution were introduced in order to develop the derived concept of density.
3	Solutions, mixtures, and compounds	Activities helped clarify the chemical differences between materials that are not single elements.
4	Chemical reactions	Activities revealed evidence of chemical changes and the conservation of matter.
5	Particle theory and the periodic table	A mini-history of ideas about atoms and classifications of elements were themes of participatory lessons.
6	Acids and bases	Experience with acids and bases, their practical uses.
7	Energy	An introduction to various forms of energy and energy transformations was developed.
8	Chemistry of food	Consumer-oriented activities explored the mixtures of basic chemicals in processed food.
9	Chemistry of life	Some chemical principles were developed after seeing behaviours of carbohydrates, lipids, and proteins.
10	Forensic chemistry	Chromatography, fingerprints, fiber analyses, and pH differences in crime scene beverages were some clues teachers used to make some judgments about suspects.