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A Study of the Impact of Inquiry-Based Professional Development Experiences on the Beliefs of Intermediate Science Teachers about "Best Practices" for Classroom Teaching

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Abstract

Open-ended interviews were used to study differences in Grade 7-8 teachers' beliefs about exemplary classroom practices produced by exposure to in-service professional development programs based on different theoretical frameworks. Teachers who had participated in an intensive, inquiry-based, in-service professional development program that focused on preferred teaching methodologies from a constructivist, inquiry-based perspective described in the "best practices" literature were compared with teachers who had been through traditional in-service professional development workshops. Analysis of interviews based on the teachers' responses to both conceptual and algebraic questions that involved the concept of density revealed insight into the teachers' preferred teaching methodologies, their beliefs about how students learn, their attitudes toward their own learning, and their depth of understanding of the concept of density. This study suggests that, for some teachers, extensive in-service professional development can produce a substantive change in teachers' beliefs about optimum teaching practice. But this change can have unforseen consequences; in this case, the formation of a set of beliefs or values that forgot the importance of building quantitative skills as well a conceptual understanding of the concepts being taught.

Key words: In-service, professional development, best practices, middle-school, intermediate science, teachers' beliefs

Introduction

Recent attempts to reform science and mathematics education can be traced back at least 30 years to the report entitled *A Nation at Risk* (NCCE, 1983). There is abundant evidence, however, that the "best practices" described in the extensive collection of documents calling for reform are not being translated into real life practice in our schools (Porter, 2002: Schmidt, McKnight, & Raizen, 1997; Shulman, 1987; Suter, 1995). In spite of extensive efforts to shift classroom practice toward a constructivist, inquiry-based classroom environment, many teachers still follow a traditional approach (Lotter, Harwood & Bonner, 2007; Shymansky & Kyle, 1992; Shymansky, Kyle, & Alport, 2003).

In order to achieve lasting changes in the teaching/learning process it is important to listen to and reflect upon the implications of teachers' voices because teachers' beliefs have a strong influence on their classroom practice (Brickhouse & Bodner, 1992; Nespor, 1987; Pajares, 1992; Richardson, 1996). Teachers' beliefs about teaching and learning have been shown to have an effect on the implementation of both pedagogical and content-specific reforms (Keyes & Bryan, 2001; Luft, 2001; Lotter, Harwood & Bonner, 2007; Roehrig, Kruse & Kern, 2007; Sunderman, et al., 2004; Tobin & McRobbie, 1996; Toolin, 2004). Teachers' beliefs are particularly important within the context of professional development programs because teachers who question whether the content or practices being recommended will be useful are not likely to incorporate this content or practices in their classrooms (Richardson, 1996).

This study used in-depth interviews based on both conceptual and algebraic questions that involved the concept of density to compare the effects of an inquiry-based, in-service professional development program on teachers'

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perceptions of what constitutes an effective teaching/learning environment with equally intensive professional development activities that lacked the same coherent link. This study built on the foundation provided by Marton (1981), who differentiated between first-order studies that attempt to describe the reality of the world in which the studies are done and second-order studies that focus on people's ideas or experiences of the world. This study was not an attempt to describe the reality of the classroom practices employed by the intermediate science teachers involved in the research that was done. It focused on the teachers' beliefs about "best practices" for teaching intermediate science that resulted from exposure to professional development activities.

Background Information

With support from the NSF Statewide Systemic Initiative, the Puerto Rico Department of Education has tried to reform the way science is taught at the K-12 level. This reform involved both the creation of inquiry-based curriculum materials based on the constructivist theory of knowledge (Bodner, 1986; Bodner, Klobuchar, & Geelan, 2001; von Glasersfeld, 1984) and the development and implementation of extensive teacher professional development activities that focused on appropriate teaching methodologies based on a constructivist, inquiry-based approach to teaching and learning.

The professional development program consisted of three components: an intensive two-week summer workshop, monthly daylong workshops during the subsequent academic year, and visits to the classrooms by the university professors who taught the summer workshops. The teachers who worked together during these workshops were encouraged to continue their interactions within the school environment as a community of learners (Brown, Collins, & Duguid, 1989; Macklin, 2007; Wenger, 1998, 2000). The constructivist-based science teaching reform began with intermediate-level classes (Grades 7-8), and, thus, it is at this level that we expected to find teachers who were most likely to have developed "constructivist" beliefs.

The structure of the professional development program contained many of the features recommended for successful PD efforts: intensive and sustained training with opportunities for active learning during which the teachers were able to practice the skills and knowledge developed; active modeling of the strategies the teachers were expected to use; the creation of a supportive network for implementation of the reform; and a PD environment in which teachers beliefs were actively considered (Barnes, 2005; Garet, Porter, Desimone, Birman & Yoon, 2001; Jeanpierre, Oberhauser & Freeman, 2005; Lotter, Harwood & Bonner, 2007; Loucks-Horsley, Hewson, Love & Stiles, 1998; Peers, Diezmann & Watters, 2003; Roehrig, Kruse & Kern, 2007; Supovitz & Turner, 2000; van Driel, Beijaard & Verloop, 2001). The professional development program therefore focused on teaching methods based on the "best practice" literature, rather than on the development of content knowledge within the domain of science.

Elements of Constructivist and Traditional Teaching

Many attempts have been made to differentiate between "traditional" and "constructivist" teachers (see, for example, Wright, 2008). Fraser (1994) argued that: "Traditionally, teachers have conceived their roles to be concerned with revealing or transmitting the logical structures of their knowledge and directing students through rational inquiry toward discovering predetermined universal truths expressed in the form of laws, principles, rules, and algorithms." Driver (1989) has argued that teachers who adopt the constructivist theory question students' answers, whether they are right or wrong, to make sure that they and their students are using the same words to describe the same phenomena; insist that students explain the answers they give; do not allow students to use words or equations without explaining them; and encourage students to reflect on their answers, which is an essential part of the learning process.

Constructivist approaches to instruction require a subtle shift in perspective for the individual who stands in the front of the classroom. A shift from someone who "teaches" to someone who "facilitates learning"; from teaching by imposition to teaching by negotiation (Herron, 1984). While traditional teachers tend to create teacher-centered or content-centered classrooms, constructivist teachers are more likely to produce student-centered classrooms (Simmons, et al., 1999).

The literature on the constructivist theory of knowledge provides a basis for categorizing teachers as "constructivist" or "traditional" by observing their classroom practice. But we believe that it also provides us with the basis for predicting into which of these categories a teacher belongs by asking them to describe how they would design instruction to confront students' misconceptions, which was the approach used in this study.

Method

An ethnographic lens (Anderson, 1989; Brandt, 1992; Bhattacharrya, 2007; Fetterman, 1989; Garfinkel, 1967; Wolcott, 1980) was used to guide this research because it provided a method for interpreting findings from a cultural perspective (Patton, 2002). This theoretical framework was deemed appropriate because the group labeled as "constructivist" teachers had been involved in a systemic reform project for more than five years, and in the process had created their own culture that guided their approach to the teaching/learning process. The group of traditional teachers with whom the reform-movement teachers were compared had also been exposed to extensive professional development activities, but these activities lacked the coherence and articulation of the systemic reform project.

There is reason to assume that the beliefs the traditional teachers brought to their classroom practices were the result of a combination of the culture of teaching that permeated their school years, their experiences going through a teacher preparation program, and subsequent in-service professional development. This assumption is based on the results of the Salish Project (Simmons, et al., 1999), which concluded that students graduate from teacher preparation programs with a well-established collection of beliefs about the nature of science, about how students learn, and how best to teach science. It is also consistent with the work of Thomas and Pederson (2003), who argued that some of these beliefs are "well-formed" before students enter pre-service teacher programs, while Calderhead and Robson (1991) concluded that these beliefs are influenced by their experiences as teachers.

This study was based on four guiding research questions.

- How do the teaching methodologies of intermediate school teachers who participated in a systemic reform project differ from those of traditional teachers?
- Are beliefs about the learning process different for reform-movement and traditional intermediate school teachers?
- Are attitudes toward learning different for reform-movement and traditional intermediate school teachers?
- How does the depth of both conceptual and algebraic understanding of reform-movement and traditional intermediate science teachers compare?

Data were collected using a qualitative research methodology based on a series of semi-structured interviews conducted in Spanish by the first author. The "reform-movement" teachers were selected using purposeful sampling (Patton, 2002). Letters describing the research to be conducted were sent to teachers at thirty schools who had been involved in the Puerto Rico curriculum reform project for at least five years. From the teachers who expressed interest in participating in the project, five were selected on the basis of three criteria: (1) they had been teaching in one of the curriculum reform schools for at least five years, (2) they had gone through the intensive initial two-week summer workshop, and (3) they expressed the belief that their teaching was based on a constructivist methodology as a result of the curriculum reform movement.

Five "traditional" teachers were selected from among schools that had not participated in the reform project. These teachers were selected on the basis of the following criteria: (1) they had more than five years of experience teaching science at the intermediate level, (2) they were teaching science at that level when the study was being done, and (3) they had participated in more than five professional development experiences in the previous five years.

The centerpiece for this study was a set of seven questions related to the concept of density adapted from questions generated by the Physics Education Group at the University of Washington (L. C. McDermott, personal communication). The questions differed in level of difficulty, ranging from those that only required a basic understanding of the concept of volume, to those that required a qualitative understanding of density, and, finally, those that required a quantitative understanding of this concept. Three of the questions were used as a warm-up experience to introduce the teachers to the interview process. The other four questions were used to collect the data analyzed in this study.

The interview protocol was structured around the set of four questions for which English translations are given in Table 1. Each of the four interview questions was presented on a separate sheet that contained a simple diagram illustrating the basic elements of the question. For each question, the teachers were asked to: (1) predict the most common answer their students would give, (2) answer the question for themselves, and (3) describe what they would do if their answer was not the same as the answer they expected their students would give if this question was asked in class.

Table 1. Interview Questions

(1) An aluminum block, A, and a bronze block, B, are tied to pieces of string and lowered into two identical cylinders. The blocks have the same size and shape, but block B has more mass than block A. The initial water level in both cylinders was the same. Is the final level of water in the cylinder that contains block B higher, lower, or equal to the water level in the cylinder with block A? Explain
(2) A student determines the mass and the volume of a wax block. He then cuts the block into two unequal pieces so that piece A has twice the volume of piece B. Is the mass of piece A, larger, smaller, or equal to the mass of piece B? Explain your reasoning. Is the density of piece A, larger, smaller, or equal to the mass of piece B? Explain your reasoning
(3) A glass containing water and ice is shown below. What makes the ice float and not sink, as many other solids would sink? Explain your answer.
(4) Lead has a density of 11.3 g/cm3. What does "g/cm3" mean? A piece of lead has a mass of 70 g. By how much would the volume increase if 30 g more of lead is added to this piece? Explain.

The teachers were interviewed at their own schools during their regular hour for preparation, with the exception of one teacher who was interviewed after school hours. The interviews were done in Spanish, audio-taped, and then transcribed by the first author. The analysis of the interview transcripts focused on overall patterns that would provide insight into observable differences between the two groups of teachers. Coding of interview transcripts focused on recognizing patterns in the teachers' responses that were related to the four research questions. A constant comparative approach (Strauss & Corbin, 1990) was used in the analysis of the data that produced four general categories into which results could be organized: (1) teaching methodologies, (2) beliefs about how people learn, (3) attitude toward learning, and (4) depth of conceptual understanding of density. The narrative vignettes quoted in this paper were translated into English by the first author.

Results

Teaching Methodologies

One part of the interview protocol for each question in this study asked the teachers to describe what they would do if their students gave what the teachers believed were "wrong" answers to the question. The goal of this part of the interview was to gain insight into how the teachers would shape their classroom behavior to confront students' misconceptions of the concept of density.

A clear pattern emerged among the reform-movement teachers, who noted that they would use hands-on materials in an inquiry-based manner in order to help their students understand the concepts. Consider their answers to the first question in Table 1, for example. Four of the reform-movement teachers expected their students would predict that the water level would be higher after the bronze block was dropped into the cylinder because a larger mass would produce a larger displacement of water. When asked what they would do if their students gave this answer to this question, four of the reform-movement teachers said they would carry out the experiment in the classroom so that the students could see for themselves what happens.

The reform-movement teachers consistently noted that they would try to replicate the questions with actual materials in the classroom. They explained how they would obtain the necessary materials, how they would set up the experiments, what questions they would ask, and how they would guide the students through the process. The following is a typical description of the way these teachers would respond to students who predicted that the water level would be higher in one of the graduated cylinders in the first question.

... We would first measure the volume of different liquids and things, that's where we would start. Then they would go through the experience of determining for themselves the mass of the two blocks, then I would have them decide by themselves, once they have the aluminum and the bronze blocks, that they should measure the volume of each block ... that is the same. This they would do with a ruler, the three sides and then multiply. Then they would place it on a balance to measure the mass. I would ask them first to predict, this is something I do all the time ... have them predict. After that they would actually have the two blocks and the two water cylinders and they would measure by themselves what happens to the water level. I would have them do it without telling them the answer; I let them go through the experience. I would not even do a demonstration because they get lost.

The traditional teachers focused on the explanations they would present if the students gave what they believed to be the wrong answer to one of the questions. Although some of the traditional teachers mentioned that experiments could be done to clarify the concepts, they did not give details about how they would design or carry out these experiments. Interviews with the traditional teachers were generally shorter than those with the reform-movement teachers, and the traditional teachers spent less time explicitly reflecting on errors in their students' thinking.

Consider the way the traditional teachers responded to the first question. Three of the five traditional teachers thought their students would give the wrong answer to this question. However, only one teacher from this group clearly knew the right answer. When asked what she would do if the students gave the wrong answer, she responded that she would tell them the following:

That in this case the mass will not cause a change in the water level but the volume will. And if they have the same form and volume the final level of the water must be the same.

Another teacher in this group expected that her students would predict that the water level would be higher in the cylinder with the bronze block. When asked what she would do as a result of hearing this answer, she responded that she would tell them: "... that they are right. If they say that, they are correct, since block B has a larger mass and is going down so it will displace the water and [the level] will be higher."

Beliefs about How People Learn

The literature on teachers' beliefs is extensive, although the term "beliefs" has been described as ambiguous (Kagan, 1992; Pajares, 1992). It has been argued that teachers' beliefs about learning are based on a "folk pedagogy" acquired through their lifelong experiences (Bruner, 1996) and honed by the many years they spent as students or teachers in various classrooms (Brouwer & Korthagen, 2005; Thomas & Pederson, 2003; Zeichner & Tabachnick, 1981; Zeichner, 2005). Because their beliefs about learning have an effect on the way teachers shape the classroom environment (Brickhouse & Bodner, 1992; Nespor, 1987; Pajares, 1992; Richardson, 1996), the extent to which these beliefs can be changed is of interest to teacher educators.

The two groups of teachers who participated in this work were similar in terms of background, ethnicity, academic preparation, years of teaching experience, and quantity of professional development activities. They differed, however, in the type of in-service activities to which they had been exposed. As noted previously, the individuals who were chosen as examples of reform-movement teachers received an intensive in-service training program based on inquiry-based, constructivist teaching methodologies that focused on instructional methods, rather than course content. The other group of teachers also received extensive in-service training, but not as part of the Puerto Rico education reform initiative.

The reform-movement teachers repeatedly noted that they believed their students learn better when they discover something by themselves. Throughout the interviews, they commented on their thoughts about how their students think, and repeatedly mentioned that their students brought to their science classes many questions from everyday life. Their description of their classroom practices and the way their students behave suggested that they believed that students learn best in a student-centered environment, where the teacher provides experiences that allow the students to: (1) construct their own ideas about science, (2) bring context to the ideas being discussed in class, and (3) learn by doing, observing, and analyzing. They expressed the belief that this is a normal teaching-learning environment that they not only can, but should, promote.

The traditional teachers, on the other hand, demonstrated their belief that learning occurs when the teacher gives good, clear explanations. Their own answers to the interview questions focused on recalling the correct answer. The use of experiments was mentioned within the context of comments about their remembering something they had been told, not something that would be an effective way of teaching or learning.

Attitude Toward Learning

The term "attitude" has been defined as a positive or negative evaluation of people, objects, event, activities, or ideas in an individual's environment that affects the way that individual responds to an external stimulus (Zimbardo and Gerrig, 1999). In this study, the teachers' attitude toward learning was assessed by examining how comfortable they were when placed in a situation where they did not know the answer to a question.

Consider the second question in Table 1, for example, in which a piece of wax is cut into two parts, one of which has twice the volume of the other. The teachers all expected that their students would obtain the "right" answer when asked to compare the *mass* of the two objects, and they were confident in their own answer to this part of the question. With one exception, however, they thought their students would get the wrong answer when comparing the *density* of the two objects — they expected their students would predict that the larger piece of wax would be more dense. They also demonstrated confusion about the correct answer to this part of the question.

Four of the five reform-movement teachers demonstrated the same approach to confronting what was, to them, a difficult problem. Although it was clear that they were not sure about their answers, they expressed confidence in their ability to find the answer for themselves by calmly describing how they would go about setting up an experiment to find out the correct answer. They seemed to know what to do and how to use their knowledge to tackle the problem. Furthermore, they were explicit in expressing their own curiosity about the problem and their interest in learning the correct answer.

Consider one of the reform-movement teachers, for example, who started by expressing the belief that the larger piece would be more dense, then tried to think about the problem to reach the right conclusion.

T: Now thinking that the density is a property of the material then it would be ... thinking that the density must be the same, that is the water density is fixed, the mercury density is fixed ... Oh well, you have me thinking now. If I have more mass I have more volume and if I have less mass I have less volume. But then I will get different numbers and I understand the density should be the same for the same material. It is not supposed to change.
I: Not supposed to change.
T: In proportion.
I: You understand it should be the same and the number should be the same. How will you determine that?
T: The ratio.
I: The ratio?
T: Mass and volume. The mass and volume relation.
I: The mass and volume relation. And how does the mass-volume relation of Piece A compare with the mass-volume relation of Piece B?
T: Piece A will have more mass and more volume.
I: Will have more mass and more volume. And Piece B?
T: Has less mass because it is smaller, less volume, but then mathematically we will reach the same relation, because we have here two fractions that will eventually give the same ratio ... The same density.

While grasping for an answer to the third question in Table 1 on why ice floats on water, one of the reform-movement teachers noted: “I have thought about this before and asked other teachers in our informal meetings, but we still don’t know why this happens.” It was clear from the transcript of the interview that this teacher felt part of a community of learners in which problems related to the content area can be discussed because of a sense of trust and common interest in learning more.

The traditional teachers were more direct in their answers and seemed to be repeating what they recalled should be the correct answer. These teachers did not exhibit any interest in getting the right answer to the conceptual questions or in learning more about the concept or concepts. They exhibited a phenomenon that has been called a “problem-solving mindset” (Bodner & Herron, 2002; Gardner & Bodner, 2006); they only seemed to value tasks that had a quantitative answer.

The traditional teachers all predicted that their students would think that ice floats on water because it is “lighter” or has less mass. Four of these teachers then immediately responded that ice floats because it is less dense. When the interviewer asked them to explain *why* ice is less dense than water, they appeared confused and exhibited frustration at not being able to recall the right answer. The largest number of misconceptions and invocation of concepts unrelated to the phenomenon under discussion occurred among this group. One teacher used the words “cohesion” and “adhesion,” for example, without relating them to an actual explanation.

... it has to be because of the arrangement of the water particles. In addition, water has other particularities like cohesion and adhesion were they tend to stick to the surface where they are and this tends to change somewhat the state of the water.

The way these terms were used suggests that they were what Vygotsky (1986) called verbalisms, “... a parrot-like repetition of words ... simulating a knowledge of the corresponding concepts but actually covering up a vacuum.”

Another traditional teacher, who noted that she was convinced that she had the correct answer, explained that ice floats because of “air trapped in the ice ...” The one traditional teacher who did not respond to this question immediately noted that the students would not know what to say, but neither did she. She then noted that ice floats because it is less dense, but she did not want to pursue the dialogue because she knew she was confused: “I understand it floats because of its density. But then I get confused because it is a solid.” The traditional teachers all had explanations for this phenomenon, and did not seem to be interested in understanding it. They seemed to believe that all they had to do was state what they recalled as the correct answer.

Two of the reform-movement teachers began their answer to the ice-water question the same way as the traditional teachers. They answered that the ice would float because it was less dense, and recalled from their own instruction that this was the “correct” answer. With only one exception, however, the reform-movement teachers eventually became aware that they were confused and exhibited a fundamentally different attitude toward the question; they wanted to find out the answer. In each case, the interviewer was asked to stay with the reform-movement teachers after the interview was over, to discuss this question further.

Depth of Conceptual Understanding of Density

Both their comments and their nonverbal communication suggested that the reform-movement teachers were not sure of the correct answer to many of the conceptual questions in Table 1, but they were secure in their belief that the answer was easy to find out by doing the appropriate experiments. With only one exception, they clearly explained how they would prepare the materials to do the experiments, what questions they would ask the students, and how they would guide the students in their construction of knowledge.

The traditional teachers all gave the wrong answer to the first question, which dealt with blocks of bronze and aluminum metal being dropped into water. In the two cases where the teachers predicted that the students would expect the water level to be the same, they went on to explain why the students would be wrong. With one exception, the traditional teachers seemed comfortable with their answer to the question, even though it was wrong.

Depth of Algebraic Knowledge of Density

Three of the questions in this study were conceptual; the fourth is often described as “algorithmic.” A better label, however, would be “algebraic” (Bodner & Herron, 2002) because the answer is seldom obtained by the application of a rehearsed algorithm. Some problem solving behavior involving the manipulation of algebraic symbols is necessary.

The teachers all agreed that their students would have difficulty understanding what the symbol g/cm^3 means. The reform-movement teachers described density experiments their students had done in which they measured the volume of a cube by measuring its sides with a ruler, measured the mass of the cube with a balance, and then divided the mass by the volume. The reform-movement teachers were confident that they could design an experiment to predict the increase in the volume when the amount of lead was increased from 70 to 100 grams in the last question in Table 1. But only one of the reform-movement teachers demonstrated the ability to use the known density of lead to calculate the new volume. The other four explicitly noted that they would have to do an experiment to get the right answer.

Whereas only one of the reform-movement teachers could do the mathematical calculations needed to answer the fourth question in Table 1, four of the five traditional teachers were able to calculate the new volume from the density of lead. They had to work hard to get the answer, but they demonstrated a willingness to do this because the question was algebraic, which they valued, unlike the previous three conceptual questions, which they did not value.

Conclusion

While both groups of teachers in this study had been exposed to in-service professional development experiences, they showed clear differences in the way they translated these experiences into their beliefs about appropriate ways to present this material in their classroom. The reform-movement teachers stated that they preferred using hands-on materials to promote discussions among their students. Two of the words used most often by these teachers were *prediction* and *observation*. A typical phrase was: “... have the students do and see by themselves and reach their own conclusions based on these observations.”

The reform-movement teachers expressed the belief that they should actively involve their students in the learning process by starting with a question and keep questioning during the learning process to guide the students in their own thinking. They expressed the belief that "best practices" for classroom teaching would involve hands-on activities by students working in groups, leaving questions unanswered with the intention that students would be sufficiently motivated to keep experimenting and reach their own conclusions. The classroom environment depicted by the reform-movement teachers in this study might best be described as student-centered in the sense of this term was used in the Salish project (Simmons, et al., 1999).

The teachers in this study who had been exposed to traditional professional development activities, on the other hand, expressed beliefs about teaching practice one would expect of traditional teachers. They seemed to value relying on explanations and direct answers to students' questions. They expressed the opinion that the optimum classroom environment would include providing ample opportunities for students to ask questions, but that less time should be devoted to probing their students' understanding. They noted that they would be less likely to use hands-on materials and more likely to rely on the blackboard, drawings, and oral explanations. The classroom environment depicted by the traditional teachers in this study can best be described as teacher-centered, once again using the term in the sense proposed by the Salish project (Simmons, et al., 1999).

Both groups in this study expressed beliefs about appropriate classroom practices that were consistent with their beliefs about how students learn. The reform-movement teachers repeatedly mentioned that their students learn best when they discover knowledge by themselves within the context of their everyday lives. Although the traditional teachers did not explicitly mention that explaining and giving direct prompt answers to questions was the "correct" methodology to get students to learn, it was implicit in their interviews that this is the best way to teach. The traditional teachers did not provide any evidence to suggest that they reflected on the learning process of their students, or on the teaching/learning process going on in their classrooms.

There was a significant difference between the reform-movement and traditional teachers' attitude toward their own learning. The reform-movement teachers demonstrated an interest in learning more when they perceived they did not know. They exhibited curiosity about the answers to the conceptual questions and carefully described how they would go about finding out the right answer to a difficult problem. They tended to discuss difficult problems with other teachers in order to help each other find the right answer.

The traditional teachers were less likely to be aware of errors in their approach to unfamiliar problems. They tended to give what they felt was the "correct" answer and seldom pondered out-loud whether they were right. When confronted with an unfamiliar problem, the reform-movement teachers' attitude was "let's find out" or "please let's discuss this after the interview," while the traditional teachers were more likely to appear anxious and say "I don't know."

The traditional teachers were somewhat more likely to give the "correct" answer to a question, but they demonstrated confusion when asked to describe how they knew that answer was correct. As a rule, they did not know how to obtain the right answer and, in general, "knew" but did not "understand" the answers. When faced with a numerical calculation, they were able to answer the question with moderate difficulty. None of the reform-movement teachers, on the other hand, could solve the quantitative part of the last problem and most of them expressed the need to do an experiment in order to be able to answer the question.

This work suggests that the reform-based professional development experiences may have had unforeseen implications that might be of interest to science educators involved in both pre-service and in-service teacher preparation programs. In trying to emphasize a constructivist, inquiry-based approach to teaching that promotes conceptual understanding, the unintended lesson the teachers seemed to receive is that traditional, quantitative problems that require a numerical, algebraic approach to the solution are not important. In the future, professional development programs in science and mathematics in Puerto Rico will explicitly model activities that emphasize the importance of promoting both conceptual understanding and the solution of numerical problems. These programs will focus not only on "new" or "different" methods of teaching science, but also discuss traditional approaches the teachers need to continue doing. The next generation of professional development experiences will attempt to be "authentic" in terms of modeling the teaching methodologies that effectively develop all types of knowledge; be it declarative, procedural, conceptual, analogical, or logical (Farnham-Diggory, 1994).

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