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ABSTRACT

This study reports on an effort to improve the teaching and learning of physical science for prospective elementary teachers. As part of the effort, a new constructivist science curriculum model was introduced for field testing at a large midwestern university. The purpose of the study was to build a research base to guide future science teaching and learning practices through the exploration of how and why students respond to the new curriculum and how the instructors reflect on the effectiveness and the obstacles of the new approach. The findings of this study suggest that it is important for preservice teachers to have some successful experience in conceptual change concept teaching. The necessity of appropriate alternative assessment techniques is also indicated. Contains 12 references. (DDR)

Resistance to the Implementation of a New Constructivist Science Curriculum for Prospective Elementary Teachers

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Objectives

Whereas the National Science Education Standards (1996) calls for the introduction of challenging science content to all elementary and secondary school children, the urgency for promoting science learning and teaching (especially in physical science) in elementary teacher education programs is getting more and more widely recognized. According to the report of the 1993 National Survey of Science and Mathematics Education, only 3 percent of grade 1-4 teachers in current elementary schools had undergraduate or graduate majors in science or science education, whereas about 80 percent majored in elementary education. When further asked about how well-prepared those science teachers in grade 1-4 perceive themselves to teach elementary sciences, most of them think themselves well prepared to teach the life and earth sciences. More than 64% of the same grade level science teachers, however, do not feel themselves well qualified to teach chemistry or physics (Weiss, I. R., Matti, M. C., & Smith, P. S., 1994).

In an effort to improve learning and teaching physical science for prospective elementary teachers, a new constructivist science curriculum model (the Powerful Ideas in Physical Science, PIPS) was introduced for field-testing in a large midwestern university, during the fall semester, 1995. The purpose of the study was to build a research base to guide the future science learning and teaching practices. As part of the whole study, the following questions were investigated in this paper:

1). How did the students respond to the new PIPS approach? Why?

2). How did the instructors reflect on the effectiveness and obstacles of the new PIPS approach?

Theoretical Framework

From a constructivist perspective, learning is an individual process which involves linking new ideas and experiences with what the learner already knows and believes. A fundamental assumption of constructivism is that learners construct understanding through personal experiences. According to the conceptual change model (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992), learning occurs when the learner recognizes a need

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In an effort to improve learning and teaching physical science for prospective elementary teachers, a new constructivist science curriculum model (the Powerful Ideas in Physical Science, PIPS) was introduced for field-testing in a large midwestern university, during the fall semester, 1995. The purpose of the study was to build a research base to guide the future science learning and teaching practices. As part of the whole study, the following questions were investigated in this paper:

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The introduced PIPS model is based upon the most up-to-date learning theories and recommendations by science education experts. It focuses on the conceptual change perspective and integrates other teaching strategies such as hands-on/minds-on, guided-inquiry and cooperative learning approaches. Five major phases of instruction are involved: eliciting and elaborating the students' ideas, testing and comparing the ideas with nature, resolving the discrepancies between ideas, applying the ideas, and reviewing and summarizing ideas. Whereas numerous previous research studies have demonstrated positive effects as well as some difficulties with the implementation of cognitive conflict-based teaching strategies on student learning (e.g., Licht, 1987; Hand & Treagust, 1991; Dreyfus, Jungwirth, & Eliovitch, 1990), this is the first study to report the impact of applying the PIPS curriculum model in real classrooms.

Methods

Subjects

The study involved one hundred twenty-one students at a large midwestern university, who enrolled in an introductory science course designed primarily for elementary education majors. Of 121 preservice teachers, 118 were Caucasian and 103 were female. They were primarily freshmen (50%) and sophomores (36%).

The course in which the subjects were enrolled, Introduction to Scientific Inquiry, was a three-credit course and was a prerequisite for students seeking entry into programs in elementary education, special education, and early childhood education. Sections of the course met for two hours and twenty minutes twice a week. Each class meeting typically involved one half hour of lectures/explanation followed by laboratory activities which lasted the remainder of the class. To help to develop a better understanding of science, the course emphasized the scientific inquiry skills (observation, classification, measurement, inference, prediction, variables, etc.) and the mathematics skills needed for success in college level science courses. The course also provided the prospective teachers with opportunities to apply the process and mathematical skills learned to some basic chemistry principles. Some of the major features of the current curriculum (Introductory Science Skills, ISS) used in this course included the use of the following: an interactive hypercard program, data collection by using computers, homework activities, interactive computer-assisted-instruction modules, cooperative learning techniques, and observation of exemplar elementary classroom science teaching videotapes. Maximum enrollment in each class section was 24 students.

Design

The study employed a nonequivalent pretest-posttest control-group design (Campbell & Stanley, 1963). Three instructors (who were graduate students with at least one-year previous teaching experience of the same course) and students enrolled in six class sections participated in the study. After considering such factors as the class meeting schedule, students' test scores prior to the study, three class sections were assigned to the experimental treatment (PIPS approach) whereas the other three sections served as the comparison group. Each instructor taught two class sections (one with the PIPS approach and the other with the ISS approach).

To obtain in-depth understanding of the process of science learning and teaching for the preservice elementary teachers, the study adopted a quantitative as well as a qualitative research design. According to Merriam (1988), whereas the experimental design is appropriate for a cause-and-effect investigation, "how" and "why" questions would be best answered by a qualitative study. In this research project, the qualitative research framework was used to help to understand the outcomes or results obtained from the quantitative data analysis. In addition, some trends or patterns identified in the qualitative data analysis part could become hypotheses for further studies.

Procedures and Data Analysis

The study started at the twelfth week of the fall semester of 1995 and lasted for four weeks. Before the new curriculum model was employed, all subjects were exposed to a currently adopted lecture-lab type teaching approach (ISS) as previously described. Starting from the twelfth week, the students in the experimental group were exposed to the PIPS curriculum model (the "Nature of Matter" unit) while students in the control group used the same curriculum as before. The subject content was the same for both groups. The paper-pencil tests and surveys (test on conceptual understanding of science concepts, science teaching self-efficacy survey, and chemistry attitude survey) were administered before and after the intervention for all the participating students.

To get insights into the process of learning and teaching science for the preservice teachers, six "typical" cooperative learning groups were selected as the cases for videotaping and interviewing, by using the purposeful sampling technique (Patton, 1980). One group of students (three or four people) in each class which met the following criteria was recommended by the instructors as the "typical" group for videotaping: 1) the group involved students who were willing to participate in the study and be videotaped; 2) the group was heterogeneously mixed with respect to their prior knowledge; 3) the group involved members usually working together cooperatively.

Then, two students (one with higher past science performance and the other with lower past science performance) from each of the six cooperative learning groups were selected and interviewed for examining changes in their understanding of the target science concepts, their personal beliefs about learning and teaching science, and their perceptions on the teaching approaches employed. All three participating instructors were also interviewed at the completion of the study.

While the results on student conceptual understanding and personal beliefs about science learning and teaching were documented in a full technical report of the study, this paper will focus on the analysis of the impact of implementation of the new PIPS curriculum perceived by students and their instructors. To answer the aforementioned research questions, interviews of students and instructors were audiotaped and transcribed and then analyzed by employing a constant comparative method (Glaser & Strauss, 1967).

Results and Discussions

During the post-instructional interviews, students' and their instructors' reflections on the implementation of the new PIPS curriculum were probed in a semi-structured format. Interpretation of the interviews (pseudonyms were used) are presented and discussed as a series of interpretations.

Interpretation 1. While the preservice teachers in the conventional ISS group were bored with the instructor's lecturing, those in the PIPS group had mixed feelings about the new approach: "interesting," "stimulating," "challenging," as well as "frustrating."

The PIPS model had forced a switch of the teacher's role from the "sage on the stage" to the "guide on the side." Of the six preservice teachers in the PIPS group, four mentioned that with the elimination of the lecture phase, their instructors had tried not to give direct answers to their questions and were more available than in the conventional approach.

> Stella: "In the first part, when we asked her [instructor] a question, she would tell us, but on the second method, when we asked her a question, she would say more like a teaser for us to get started thinking, and I thought that was effective." [Student, L]

> Ava: "I think he [instructor] was always more available [in the PIPS approach]. I'll say now that he's less direct about asking questions. If you ask him one, he usually comes right back at you with another one. So, he's changed in that respect. And he does less lecturing which is pretty good... I don't like the lecture part at all--it's awful." [Student, H]

Whereas the control group students felt comfortable with the conventional approach but described the lecture part as "boring," four out of six preservice teachers in the PIPS group reported that the new curriculum model had stimulated their thinking and been more interesting than the conventional one. Meanwhile, all these six preservice teachers also felt various degrees of frustration during the implementation of the new curriculum, and they thought that the cause of their frustration was a lack of directions and advance reading for each class unit. They suggested that the instructor or textbook should introduce to them some basic concepts or terms before they do the lab. This clearly indicated that these preservice teachers have been trained by the conventional teaching method for such a long time so that they did not believe that they could really learn something without teacher's instruction.

> Ava: "The last three weeks labs have been more thinking, but my problem has been that it's all based on stuff that I learned long ago that I am now being asked to do years later. The worksheets with the homework reading, those are very helpful, but maybe give those to people, say 'this is for lab 5.1, read it before you get here, and then do the lab.' Because the reading talks about concepts and it refreshes my mind." [Student, H]

> Max: "I didn't hate it [PIPS model]. I just think that you should have either something to read that is going to explain what you are trying to do beforehand, and then like not give the answers of what it's going to be, but just tell them what the experiment is about... If you don't have any concepts as to what's going on to start with, it's almost impossible to learn it like this. Like the sheets you passed out afterwards, pass those out first and let us read them, and then when we come in to do the experiment we can kind of form our opinions through the experiment and from what we've read. I think it helps a lot more." [Student, L]

> Stella: "In the new method, at times I felt like there were lack of directions, we didn't really know what we were going to be doing, while in the old methods, with the lecture we knew we were learning about this and that. We had already been introduced to the formulas and stuff like that."[Student, L]

> Alice: "[In the new unit,] there were times we don't even know what the question is asking you or what it is looking for? Because we hadn't really had any background on what that was... I think we ought to have the teacher go over the basic ideas of what we're looking for first. Maybe give us some definitions or some terms, so that we have an idea of what we're looking for. That way we can apply it to the lab." [Student, L]

Interpretation 2. Alternative assessment techniques are needed to demonstrated the differential effects of the new PIPS curriculum on student learning outcomes.

Of the six preserve teachers in the PIPS group, five reported that they had more group discussion and better cooperative work than they did in the ISS approach.

> Alice: "I think we discuss more in the new method because we're all doing it ourselves, and then when we come to the question that says 'What does the group think?' We've already figured out what we think, we're not waiting for just someone to finish the lab to say 'OK, this is what I think. It's finished.' Then turn it in. We all sit back and discuss it. And it's not 'you're wrong,' it's what everybody thinks, so before it was what one person thought was right, and now it's what everyone just thinks, not whether it's wrong or right.

In the first part of the class, it was, you did your job, and they did their job, and then we just put it in the lab. It wasn't we discussed anything. Now, it's a little bit more where we discuss things. I think we cooperated a lot more the second time around." [Student, L]

Stella: "In the first part of the class, we didn't really work as a group. I mean, we did, but it was just kind of like always whatever one person would say. We'd take that. We'd never conversed at all on what each of us thought. We didn't all share our input at all. In the second part, it was quite the opposite. Where everyone was involved and we really cooperated and worked together-- especially with the group's ideas." [Student, L]

For preservice teachers with lower past science performance, the PIPS approach left them more room for self-reflection on the development of understanding of science concepts compared to the ISS approach. In the ISS classes, the preservice teachers with lower past science performance usually could not have their voice heard within their cooperative groups. They tended to rely on those with a stronger science background, who would determine what to do and what to write on the lab report.

With the PIPS approach, however, a more supportive learning environment had been created and allowed more peer interactions. After experiencing the self-reflexive process, the individuals were more responsible for their own learning in the PIPS approach than in the ISS teaching.

Alice: "The **new unit** I liked a lot more because we each were responsible for our own labs. In this way, I could write down what I thought and what I meant. I wasn't depending on one person to write down exactly what I thought. That way, I could go back, read the question, and do it my self. Instead of, just saying, "well, OK, you can write it up and I'll just sit here. the **first half** of the course, it wasn't a collective effort, it was who thought was right, and that was written down. And I felt a lot of times, my comments weren't heard, and they weren't voiced in the labs, whether they were wrong or right, I still think that had a lot to do with it. The **second part**, I had a little bit more of a voice that actually went into the lab. Since the new method was more based on what you thought, and not just 'this is the way it had to be.' I understood a little bit better in the new method." [Student, L]

Both interview and classroom observation confirmed that a better cooperative learning environment had been promoted in the PIPS class. During the interviews on conceptual understanding, all the three preservice teachers with lower past science performance had demonstrated a higher gain scores than their ISS counterparts. The interviewees in the PIPS group also mentioned that they had achieved the desired learning outcomes with better quality.

Stella: "I like the new method. Sometimes I felt kind of lost, not lost but because I wasn't very sure if I was doing the right thing. But afterwards, when Jenny [the instructor] started to us more, taking us through it, then I understood it more after I had already done the lab. I think I learned more in this. For some reason, it just sticks in my head better after doing the labs." [Student, L]

However, the written test scores on the understanding of the target concepts, and the attitude survey scores of the preservice teachers did not demonstrate any statistically significant improvements for the PIPS group, compared to the ISS group counterparts.

> I'm not sure that just on a multiple choice kind thing that I would expect to see any differences, uhm, just because if we're all trying to get to the same concept, hopefully, they all got to the same concept by the two methods, and they both know, both groups know that concept and some of the underlying pieces. But the logical processes, and the thinking processes, and the way, the way that's conceptualized, or mapped into the student's minds I would think would be different. But multiple choice measurement doesn't get us there. [Instructor-3]

Of the six class sections, the ISS class taught by instructor 3 scored significantly higher in the multiple choice items than its PIPS counterpart did; whereas no statistically significant differences were found for the other four classes taught by the remaining two instructors. However, no significant differences on free response concept test items were found between the two treatment groups for class sections. The lack of differential significance in the free response concept test indicated that students with higher multiple choice test scores did not necessarily have better understanding of the target science concepts. This interpretation was confirmed by instructor 3 during the interview. Instructor 3 did not think that her ISS class had real better understanding of the concept than the PIPS class did although the ISS class had higher scores on the multiple choice test. "My impression is that most of the students are regurgitating words at me. Not real understanding." Her impression mainly came from her reading of her students' answers for the free response test items. In fact, the mean score on the free response items for her PIPS class was slightly higher than that for her ISS class.

Therefore, in order to reveal the differential effects of the PIPS curriculum model on multiple student learning outcomes, alternative assessment techniques as well as retention tests and longitudinal case studies are needed.

Interpretation 3. The time issue, the students' motivation, and the instructors' sense of efficacy about the constructivist teaching were major factors which undermined the potential of the new curriculum in this study.

The time issue involved in implementing the new curriculum was two-fold. Number one, there were too many activities crammed in each class session to leave enough room for class discussion. Number two, a four-week period was too short to demonstrate the superiority of the innovative teaching approach.

> Max: "I think if we would have been doing the new method from the beginning instead of just the last one unit, I may actually like the new method better. But when you've gone so long doing it one way, and then switch, you get lost. I think everyone felt lost during these last a few weeks. [Student, L]
>
> Stella: "I think with the new method, I understand more... And I don't think everyone would have disliked it as much if we had been used to this already. Like today, when we did the lab, I don't think people minded at all, because they were getting used to this method. But at first, there were a lot of labs for us to do, and everybody felt really rushes."[Student, L]
>
> If we really want to use the new method, we have to have really much less activities so that we are not rushing the students. So we have the time to really discuss those things in-depth, instead of always looking at the clock and see what activity they still have to do and rush, rush, rush. We did not have the opportunity to discuss things in-depth to really see where students have misconceptions. And I realized in the free response, especially on the last question, with the conservation of volume and conservation of mass, how much confusion there was... That is not to say that the new method is not better. But, as I said, because of the way we implemented it, it didn't work. But, I do think, if it is carefully done, and if you wait long enough for it to take root with the students and with the teacher, that it has a lot of potential. It cannot be implemented in three weeks, and expect great results in three weeks. In order for the students and the instructors to really appreciate it and become used to it and to really see the results, you would have to have at least a full semester. [Teacher-1]

Students' lack of internal motivation was another obstacle involved in implementing the new curriculum. Partially because the time period of the intervention was close to the final exam, the students' concerns about their course grades were overwhelming. One most frequently asked question the instructors received from their students was "how are we going to be tested?-- What are we supposed to do to prepare for the final exam?"

> Stella: "... really everyone is only studying for the test. I don't really think they're studying to learn it." [Student, L]
>
> Becky: "The second part of the class really frustrated me. This really upsets me because I don't want to botch my grade up because of it." [Student, H]

The third obstacle was that the teachers were trained for and by means of conventional teaching. Whereas all three instructors interviewed embraced the philosophy of the PIPS curriculum, none of them felt that they were very confident with the PIPS teaching approach. The availability of resources and sufficient training of instructors were two big concerns for them. In order for them to help their students to go through the conceptual change toward the scientific framework, they themselves should have both a solid subject-matter knowledge base as well as a constructivist pedagogy. Otherwise, in a constructivist classroom, a teacher would either avoid confronting students' questions raised in classroom activities, or would end up with lecturing or answer telling. Both the two situations were observed in classroom teaching videotapes and reported during the preservice teacher interviews.

> Becky: "The second part of the class was just really strange. I mean, nobody coming around, helping you, asking questions, I thought was really bad. I mean, a teacher would not do that just throw you something and say 'go at it!' I think there needs to be somebody helping you, prodding you along. 'Oh, you're doing a good job.' 'Oh, right, that looks good.' Instead of 'Em! Emmmmmm. Em!'" [Student, H]
>
> We, the instructors, did not know very well what we were doing. I think for such a thing, we would have to practice and be trained well. [Instructor-1]
>
> They [instructors] should be trained or should be coached for a sufficient period of time. Because if the instructors are trained on traditional method, and we ask them to change, they may eventually end up lecturing. [Instructor-2]
>
> The PIPS method is so new to actually see how does it work and how does it actually get implemented, how do we apply it in the classroom... One big limitation of the constructivist approach for me as a future high school teacher is that there are no much resources there... at least, PIPS is the only one I'm aware of... The instructor's manual of the PIPS curriculum, did not help much either in my own conceptual understanding or in the classroom implementation. [Instructor-3]

Conclusions and Implications

The major problems noted by the students and instructors in implementing the PIPS curriculum involved the following: Students devoted most of class time on the exploratory activities presented in the PIPS curriculum, which prevented sufficient classroom discussion. PIPS students themselves could not make sense or make connections from what they had done. After eliminating the lecture phase, what can instructors do to help to bridge the gap between students' current mind-set (i.e., taking notes and memorizing the facts for tests) and the desired "higher-order thinking skills" which are emphasized in the PIPS curriculum? This issue should be considered by both the curriculum developers and instructors who are responsible for classroom teaching.

Teachers were trained for and by means of conventional teaching. To help the instructors to implement the PIPS curriculum more successfully, a sufficient training of the instructors and a more detailed PIPS instructor's manual which will help instructors' conceptual understanding as well as their constructivist classroom teaching, are needed.

Research has revealed that prospective teachers who experienced conceptual change pedagogy not only understood the science content better, they were more likely to use conceptual change instruction to teach students (Stofflett & Stoddart, 1994). The above assertion was partially confirmed in this study. However, two of the six preservice teachers interviewed in the PIPS classes, claimed that they would not adopt the constructivist based approach (like the PIPS) in the future because of their personal frustrating experiences during the study. Therefore, to foster preservice teachers' sense of self-efficacy in implementing constructivist teaching, it is important for them to have some successful experience in conceptual change content learning. This is consistent with the conclusion made in a study by Stofflett (1994). The results of this study also indicate the necessity of appropriate alternative assessment techniques and the importance to free students from the burden of test grades, in order to make the PIPS curriculum work better in real classrooms. Otherwise, a student may choose not to undergo cognitive struggle but to memorize the facts which are expected on the conventional tests.

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