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ABSTRACT

This paper describes a model for utilizing national science reform initiatives in an elementary science methods course. By focusing particularly on Project 2061 benchmarks, the reform movement initiated by the American Association for the Advancement of Science (AAAS), teacher candidates were able to successfully analyze, integrate, and utilize both "content" and "pedagogy" in the design of lessons and the curriculum. This background provided the teacher candidates with the skills and knowledge to incorporate the benchmarks in the development and implementation of teaching 4th grade science. Teacher candidates were also invited to lead and facilitate an in-service program showing elementary teachers how to incorporate the benchmarks in their science classes. The teacher candidates' reflections revealed support for the use of this model in demonstrating the importance of the benchmarks in promoting scientific literacy for both students and teachers. Contains 33 references. (Author)

Teaching for Excellence in K-8 Science Education: Using Project 2061 Benchmarks for More Effective Science Instruction

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Abstract

In this article, I describe a model for utilizing national science reform initiatives in an elementary science methods course. By focusing particularly on Project 2061 benchmarks, the reform movement initiated by the American Association for the Advancement of Science, teacher candidates were able to successfully analyze, integrate, and utilize both "content and "pedagogy" into the design of lessons and curriculum. This background provided the teacher candidates with the skills and knowledge to incorporate the benchmarks in the development and implementation of teaching 4th grade science. Teacher candidates were also invited to lead and facilitate an in-service program showing elementary teachers how to incorporate the benchmarks in their science classes. The teacher candidates' reflections revealed support for the use of this model in demonstrating the importance of the benchmarks in promoting scientific literacy for both students and teachers.

Teaching for Excellence in K-8 Science Education: Using Project 2061 Benchmarks for More Effective Science Instruction

As teacher educators, we are all searching for the very best models of instruction to facilitate teacher candidates' conceptions of what it is to teach effectively. Remembering the reform of the 1960's, educators are reminded of the all too forgotten, *here today, gone tomorrow*, sentiment that followed. As Gerry Wheeler (1996) states, *Systemic reform has a temporal character* (p. 308). Reform has been on the national agenda in science education for over a decade, and key leaders have offered their perspectives of progress to date (Rutherford, 1996; Strassenburg, 1996; Vos, 1996). There is little disagreement among science educators about the need for reform but the same cannot be said about the specific modes suggested to achieve this reform (Linn, 1992). Most educators agree that it is not enough to have great materials, very good summer programs for teachers, and an incorporation of educational philosophy concerning the very best in the practice of educational methods. A commonly agreed upon theme for reform in science education is the active involvement of learners in the teaching and learning process. As teacher educators strive to embed the principles of the science reform initiatives into their classrooms, they must involve teacher candidates every step of the way. In doing so, teacher educators will involve teacher candidates in the process of reform. As Robert Yager (1992) states, *teachers are central to any solutions and successes for current reform efforts* (Yager, 1992, p. 907). Most importantly, this includes teacher candidates.

Due to the importance of promoting systemic reform, professional associations in science such as the National Resource Council (NRC) and the American Association for the Advancement of Science (AAAS) have developed national science standards for grades K-12: the *National Science Education Standards* (1996) and *Project 2061 Benchmarks for Science Literacy* (1993), respectively. Both documents elaborate ideas emerging from Project 2061 (Rutherford & Ahlgren, 1990) and other efforts that have focused on the science knowledge and skills literate citizens should possess. Although developed by two separate groups, the projects share common goals and recommendations. Specifically, both aim to develop a nation of scientific literate citizens.

The national movement has trickled down to state and local boards of education with the development of state and local science curriculum standards. As a result of the new era of reform, Colleges of Education across the country are incorporating the curriculum standards into their science methods courses. As a science teacher educator, I am aware of how the science standards movement is affecting K-12 science education. However, the standards movement also has implications for the preparation of teacher candidates. Specifically related to teacher candidates, the standards provide a map for: teachers to develop curricula with improved content, teaching methods, and assessment and institutions of higher education to refine programs for learning science through inquiry (Close, Miller, Titterington, & Westwood, 1996).

Educational reform in science education is not only about what students should learn; how science should be taught is equally important (American Association for the Advancement of Science, 1993; National Research Council, 1996). There is an agreement that science instruction should facilitate the development or understanding of "science as a way of knowing" (American Association for the Advancement of Science, 1993; National Research Council, 1996; Rutherford & Ahlgren,1990). With the recognition that effective instruction helps students sort and distinguish among a multitude of ideas, the purpose of teaching becomes one of facilitating an environment that encourages students to actively engage in the process of lifelong learning. The national standards support the notion that learning is greatly influenced by how they are taught (National Research Council, 1996; Rutherford & Ahlgren, 1990). This does not imply that "good" teaching necessarily leads to understanding. Rather an environment that is conducive to promoting students own construction of understanding by conveying attitudes, habits of mind, and challenging students existing ideas empower their knowledge, abilities, and attitudes conducive to understanding. For teachers to orchestrate a classroom environment that models life long learning, they themselves need to reflect upon their implicit and explicit conceptions of science, learning, and teaching. Only in doing so will teachers be able to answer the call towards systemic educational reform where all students can learn science.

It has been argued that teacher candidates need to gain an understanding of how science works (Bates & Culpepper, 1991; Ganem, 1993; Keeports & Morier, 1994; Rutherford & Ahlgren, 1990). This is especially true for elementary teacher candidates because of their limited science background. With the information explosion in science, teachers are confronted with tougher and tougher curricular choices of what topics to include and decisions about which models of instruction to emphasize to promote lifelong learning. Just as science is a dynamic process, so is teaching and learning. In reference to educating future science teachers, the national reform initiatives provide a framework that articulates the goal of supporting lifelong learning by addressing the conceptions teachers have about science, teaching, and learning (National Research Council, 1996; Rutherford & Ahlgren, 1990). By successfully infiltrating the science standards into science methods courses, teacher candidates will have a new and better understanding of science and how science is taught. As teacher candidates attempt to change their conceptions of what it is to teach effectively, teacher educators need to understand what their conceptions are, why they hold such conceptions, and what constraints they perceive in the course of changing their conceptions. Unless, teacher educators understand why teacher candidates hold such conceptions about science and teaching science effectively, it will be impossible to move from a reformed curriculum to a reformed practice (Bybee, 1993; Hurd, 1992).

Purpose

In this paper, I describe the conception changes of teacher candidates about science, teaching, and learning as they participate in a K-8 science methods course designed utilizing the principles reflected in the national reform initiatives at an Eastern Urban University. In an effort to incorporate the national reform initiatives into my science methods course, I followed the procedures outlined by Project 2061 of the American Association for the Advancement of Science. The course focus was on the role of teachers as decision makers in promoting scientific literacy for all students. The overall goal was to familiarize teacher candidates with reform initiatives in science education, focusing particularly on their role as change agents in the reform. The overall goal was addressed through four phases where teacher candidates learned to apply the principles reflected in the national reform initiatives in designing, implementing, and evaluating curriculum, instruction, and assessment. The purpose of this paper is to take a closer look at the four phases and to understand how incorporating the principles reflected in the national reform initiatives into a science methods course challenged teacher candidates' conceptions of science and what it means to teach science effectively.

The four phases deal with the following topics: (1) confronting and challenging teacher candidates' conceptions of science and science teaching; (2) applying the principles reflected in the national reform initiatives in developing science lessons; (3) evaluating science resources and instructional programs; and (4) sharing with teachers the process of reform.

Phase One: Confront and Challenge

The first phase of the course was designed to enhance teacher candidates' knowledge and understanding of national reform initiatives in science education. The objective was to confront each teacher candidates' conceptions of nature of science and science teaching. As Posner, Stike, Hewson, and Gertzong (1982) found *students tend to reject new information and even prevent new information from conflicting with existing conceptions.* Realizing that conceptions are difficult to change, the purpose of the first phase was to confront and challenge each teacher candidates' conception of science in order to structure the following phases of the course.

With the recognition that the understanding of the nature of science is a global conception that frames teacher candidates' understanding of science teaching (Bohm &

Peat, 1989), the first activity was designed to confront and challenge teacher candidates' conceptions of the nature of science. The nature of science can be characterized as accepting that events in nature are knowable and predictable; that events that occur in nature are the same over time and can be applied to all parts of the world; and that knowledge is stable but also subject to change upon further evidence (American Association for the Advancement of Science, 1993). In order to elicit teacher candidates' conceptions of the nature of science, they participated in a cooperative controversy exercise designed to engage students in a debate of opposing conceptions of the nature of science (Hammrich, in press). Briefly, this exercise exposes teacher candidates to both traditional and alternative paradigms concerning the nature of science. Teacher candidates were assigned to cooperative groups of four which then was further divided into pairs of two. Each of the pairs in the cooperative groups of four are given one of the two opposing passages that describe the nature of science. One of the passages describes the nature of science in a traditional manner where science is seen as knowable and predictable. The other passage describe the nature of science in an opposing fashion in that science is random and unpredictable. The pairs read their passage and plan how they will argue effectively for their position. Then each pair presents their position while the other pair takes notes and asks for clarification on anything they don't understand. Open discussion takes place where each pair argues forcefully and persuasively for their position, presenting as many facts as they can to support their point of view as stated in the passage. After the first debate takes place, there is a role reversal where the pairs in the cooperative groups argue the opposing pair's position. The goal is to elaborate on what already was said by the other pair. The final step is for the cooperative group of four to come a decision where all four members of the group can agree with. When a group decision is made the group organizes their arguments to present their decision to the entire class. The group is reminded that they must be able to defend the validity of their decision to the entire class. The results of this activity revealed that six of the nine groups took the position that the nature of science is predictable and knowable.

The second activity was designed to explore the existence of world views held by teacher candidates and discuss the impact of how world views influence the understanding of science. According to Kearney (1984) *The world view of a people is their way of looking at reality. It consists of basic assumptions and images that provide a more or less coherent, through not necessarily accurate, way of thinking about the world* (p. 41). World views, generally speaking, are what people presuppose about their world and they accordingly drive people's actions. Given a teacher's central role in the classroom, it is reasonable to hypothesize that classroom culture is a function of a teacher's world view. In teaching science, elementary teacher not only present scientific concepts, but tacitly create a context in which scientific concepts are presented, a context influenced by teachers' world view. Therefore, teacher candidates examined their world views to fully understand the cultural context created by the teacher within the classroom.

Teacher candidates' world views were elicited by a questionnaire and concept map activity. The world view questionnaire was comprised of thirty-three items selected from and based on various empirical research studies (Cobern, 1993, 1995; Lawrenz and Gray, 1995; Ogunniyi et al., 1995) as well as numerous theoretical works (Cobern, 1991, 1995; Jones, 1972; Kearney, 1984).The thirty-three questions were related to the following world view universals as described by Kearney (1984): Causality, Relationship, Self, Nonself, Classification, and Time. The teacher candidates' responses were used to help delineate the theoretical sample as describe later in the methodology section.

Teacher candidates also participated in developing a concept map of thirty words that describe their conception of the nature of science. The teacher candidates were given thirty words to use in developing their concept map but they were also allowed to substitute other words not included in the list that they considered to be part of their conception of the nature of science. The teacher candidates were give one week to complete their concept maps. In the next class period, teacher candidates shared their concept maps with each other and compared the similarities and differences between their maps.

The third activity was designed to expose teacher candidates to the notion of conceptual change. Teacher candidates watched the video *A Private Universe* (Schneps, 1987).The videotape gives an introduction to student misconceptions in science and provides a brief introduction to conceptual change teaching. Teacher candidates read chapter 13 in Science For All Americans (Rutherford & Ahlgren, 1990) and chapter 15 in Project 2061 Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) as a prelude to the integration of the teaching philosophy and methodology promoted by the national reform initiatives. After watching the videotape, the teacher candidates answered questions that confronted their conceptions of what conceptual change is, how conceptual change occurs, where misconceptions come from, and how to challenge students misconceptions. After answering these questions individually, teacher candidates discussed with each other their conceptions.

The fourth activity was to familiarize teacher candidates with the content and pedagogy implied in the science reform initiatives. Teacher candidates were given scenarios of four different teachers teaching the same lesson. They were given content and pedagogy questions to answer as they read each scenario. After they read each scenario and answered the questions, teacher candidates were asked to decide which scenario most adequately addressed the content and pedagogy implied in the science reform initiatives. Next the instructor modeled lessons in class on topics that presented the content and pedagogical principles implied in the national reform initiatives. Sample lessons included: the causes for the seasons, where heat comes from, and photosynthesis. After the lessons were modeled, teacher candidates worked in pairs to practice identifying central and related content and process benchmarks specifically related to the lessons. The pairs compared their central and related benchmarks with other pairs and discussed the differences between their listed benchmarks.

Phase Two: Application

The second phase of the course was designed to have teacher candidates apply the principles of the national reform initiatives in designing curriculum, instruction, and assessment. Teacher candidates analyzed model lessons showing how effective science instruction establishes connections across grade levels and subject areas. These model lessons were related to four themes: Systems, Constancy and Change, Models, and Scale. Teacher candidates made curriculum and assessment decisions by drawing on knowledge and experiences from the earlier phase. The application phase allowed the teacher candidates to experience and share together in the shaping of their conceptions of science, teaching, and learning.

Working in groups of two or three, teacher candidates are asked to decide on a science theme for a specific grade level, write an overview or rationale concerning what the unit is about and what the students are to learn in each lesson and overall (specifically addressing how each lesson is related to the entire unit), identify the central and related content and process benchmarks for each lesson in their unit that students should know by their selected grade level, explain how they will integrate the unit into other subject areas and identify any benchmarks which will help them integrate, and develop authentic assessment measures for each lesson and the overall unit and describe how they plan to assess competency for the entire unit.

During one class period, teacher candidates explored various science themes, what the themes mean, and possible ideas for topics relating to each theme. At first, they had a hard time distinguishing between a theme and a topic. The entire class spent considerable time discussing the differences between them. They finally came to the conclusion that a theme is a global framework that interconnects topics to a main focus. Teacher candidates were asked to first decide upon a theme that would structure their unit. They were given until the next class period to decide upon a theme. The themes that the teacher candidates came up with included: Cycles, Relationships, Change, Constancy, Scale, Structure, Systems, Models, and Interactions. The next step was for the teacher candidates develop a rationale for their unit. The rationale was to include a discussion of how the topics of the lessons are interconnected and related to the overall theme. Teacher candidates spent the next two weeks deciding upon the central and related benchmarks that related to each lesson and the entire unit for their specific grade level. On average each teacher candidate came up with at least one content and one process benchmark for each lesson. After they had decided upon their benchmarks, they exchanged their papers with another classmate. The teacher candidates evaluated the benchmarks chosen by their peers and made comments and suggestions for refinement. In each lesson, teacher candidates were to develop an authentic assessment measure for each lesson. The curriculum designs that the teacher candidates developed were quite similar. The one opposing contrast was that many of the teacher candidates had difficulty deciding upon the correct process benchmarks.

Phase Three: Evaluation

Phase three of the course was designed for teacher candidates to extend their learning by evaluating instructional resources and programs by applying the principles of in the national reform initiatives. In this phase, teacher candidates analyzed and reviewed curriculum packages and materials to assess the match between the content and pedagogy of the materials with those of the benchmarks. All curriculum packages and materials were provided and previously evaluated by the instructor.

As recommended by Project 2061 of the American Association for the Advancement of Science this activity included five steps. In the first step teacher candidates identify benchmarks that appear to be covered by the curriculum material. After browsing through the curriculum material and looking briefly through the relevant sections of the *Benchmarks*, the teacher candidates developed a list of possible benchmarks that upon closer examination may be found in the curriculum material. Next, teacher candidates spent a great amount of time going through the actual curriculum material page by page to locate instances where the possible benchmarks they listed before are addressed. Many of the teacher candidates developed a matrix of benchmarks with coinciding page number instances. In step two, teacher candidates studied the benchmarks to clarify their meaning. They selected one benchmark from their list and examined the relevant sections in *Science for All Americans* and *Benchmarks*. In step three, teacher candidates analyzed the curriculum material to determine the extent to which the activities actually addressed the actual content of the benchmarks. They evaluated whether or not the activities are appropriate for the intended grade level content and whether the whole benchmark of only part of the benchmarks is addressed. In step four, teacher candidates analyzed how the curriculum addresses the pedagogy of the benchmarks. They considered whether or not the activities provide concrete experiences for the students with opportunities to reflect and explore concepts in varied contexts. In the last step, teacher candidates suggested ways to adapt and supplement the activities in the curriculum material.

After the teacher candidates practiced the evaluation procedure, they were given the curriculum module *Nuffield Primary Science: Living Things in Their Environment* to evaluate. Teacher candidates were given four weeks to complete their evaluation. Each week during the four weeks class time was spent and deadlines were given for teacher candidates to compare and discuss their evaluation steps with the entire class.

Phase Four: Sharing

In phase four, teacher candidates taught lessons they designed utilizing the recommended principles reflected in the national reform initiatives. They spent four weeks, one class period a week, teaching lessons to 4th grade students in two Philadelphia elementary schools. Teacher candidates met with the classroom teachers before they presented their lessons and discussed with the teachers which content and process benchmarks they identified for the lesson. The teacher candidates worked in pairs to present their lessons while four other teacher candidates were in each classroom during the lesson to work with each group of students throughout the lesson. The instructor was also in each classroom during the lessons.

In addition to teaching the lessons to 4th grade students, teacher candidates also provided in-service instruction for a Suburban School District. Fifteen of the thirty-five teacher candidates spent one day presenting their lessons to twenty-five K-8 teachers. After presenting the lessons, teacher candidates discussed how they decided upon the content and process benchmarks, how their assessment matched the instruction presented in the lesson. Two of the teacher candidates are still working with the School District. They developed an after-school program where they spend one afternoon a week presenting science lessons to elementary students. The two teacher candidates work closely with one of the teachers at the school. Since the in-service program, the School District has been working on reforming their K-8 science curriculum to address the content and pedagogy implied in Science for All Americans and the Benchmarks.

Procedure

Sample

This newly designed course took place during Spring semester 1996, with thirty-five teacher candidates enrolled in *Science Education 150: Teaching K-8 Science* at an Eastern Urban University. The researcher was the instructor of this course. Fifteen of the teacher candidates participated in the interviews. Purposeful sampling was utilized for the initial study while a theoretical sample was used to select the fifteen students to be used as comparative case studies based on the recommendations of Strauss. According to Strauss (1987) *theoretical sampling is a means whereby the analyst decides an analytic grounds what data to collect next and where to find them.* (p. 38). The basic question in theoretical sampling is: *What groups or subgroups of populations, events, activities (to find varying dimensions, strategies, etc.) does one turn to next in data collection. And for what theoreticalpurpose?* Consequently, this portion of the data collection is directed by emerging ideas and theories. There were thirty-five teacher candidates in the initial purposeful sample. Twenty nine were female and six were male. Age ranged from twenty to thirty-one. All of the students were American citizens. There were eight African-Americans females, three Asian-American females, and eighteen Europe-American females. There were three African-American and three Europe-American males.

The students who participated in the case study interviews did so on a voluntary basis and were randomly selected from four groups determined from the initial instruments and activities completed by all thirty-five students. Pseudonyms were used and results were provided to participants. A biography of each of the fifteen students was prepared to summarize background information and information obtained while interacting with students both in and out of school.

Data Gathering Instruments

To gather data to complete descriptive and comparison case studies, fifteen students were randomly chosen to be interviewed. Interviews were semi-structured and open-ended. Interviews were conducted based on suggestions of Kvale (1987), Lythcott & Duschl (1990), and Roth (1989). The main questions that guided these interviews were concerning the conceptions of science, knowledge construction, and the principles implied in the national reform initiatives. In order to encourage student reflection and discussion of their conceptions these questions merely served as a starting point. While the probing questions may have differed for each interviewee, the main questions remained the same. The interviews were designed to elucidate students beliefs concerning science and how science should be taught. Each interview lasted approximately one hour and was recorded and later transcribed verbatim. The second interview was conducted approximately two weeks after the initial interview upon preliminary coding and analysis of the first interview.

Methodology

The overall conception of the whole study is that of a micro-ethnography (Bogden & Biklin, 1982). As such, it was an emergent case study of a small part of a larger organization. The sample of teacher candidates that participated in the interviews were part of the larger micro-ethnography study. The use and analysis of all the data combines what Tesch (1990) has described as ethnographic content analysis and ethnoscience or cognitive anthropology. The larger study focused on teacher candidates as they interacted in the classroom but it also considered their life setting, their culture, and what they do and do not believe. This particular part of the study attempted to describe the context of teacher candidates' conceptions of science and science teaching and to describe the interactions of their conceptions as they learned and applied the principles of the national standards.

The background demographic instrument was developed in order to determine the personal context, understanding, and other information that would illuminate the formation of teacher candidates' conceptions of science and the teaching of science. A questionnaire was given with the demographic instrument that aided in the delineation of differing conceptions of science and science teaching. These open-ended questions were used to show how students understood or viewed science and science teaching. The responses to these two instruments were analyzed to determine teacher candidates' conceptions. Using the whole class as a case study aided in grouping students based on the initial instruments and activities and demographic instrument on science and science teaching. Based on analysis, teacher candidates were grouped into similar conceptions of science and science teaching.

A complete description of each of these instruments and the analysis of them is beyond the scope of this paper. Instead, the focus will be on the students selected for the interviews based on the groups identified from the two instruments described above. Each of the four groups identified contained teacher candidates with differing conceptions of science and science teaching. The open-ended interviews specifically explored teacher candidates' conceptions of science and science teaching in relation to their interactions with the national reform initiatives. One teacher candidates were chosen from group one, and three. Four teacher candidates were chosen from group two, and nine students were chosen from group four. According to Cohen and Manion (1989) this type of quota sampling attempts to *obtain representatives of the various elements of the total population in the proportions in which they occur* (p. 103). Students in group two viewed science as school based and their views of teaching and learning science rest heavily on what they had been taught in school. Therefore, it was hypothesized that students in this group may possess conceptions that may hinder the understanding or acceptance of the principles implied in the national reform initiatives; while those students in group four would possess conceptions that would accommodate the principles implied in the national reform initiatives. Students in group four view science as a practice or process of understanding and believed that teaching and learning occurred through construction. Students in group one and three had diverse conceptions that made it difficult to hypothesize how they understand science and science teaching.

Analysis

Grounded theory was used as the method of analysis for this study. Grounded theory seeks to develop a theory without commitment to specific types of data collection or theoretical interests (Strauss, 1987). It utilizes the constant comparative method and coding paradigms that aid in the uncovering and development of themes, assertions, and constructs. It seeks to generate a theory based on data that the theory is grounded in. Ideas emerge from organization, sorting, coding, and categorization of the data. Cases were examined individually and as a whole for themes and patterns. Commonalties and differences between cases were noted. From these, preliminary assertions were made and data from these cases were highlighted as to possible warrants to support these assertions. Upon reviewing the preliminary assertions, several themes emerged that were based on science and teaching, as well as groups of the assertions, within these areas four final assertions were made. The data were re-examined to report warrants that confirmed or disconfirmed the final assertions. *Warrants are those things which allow one to move from data to conclusions in a defensible fashion* (Lythcott and Duschl, 1990, p. 451). In other words, warrants are how one gets from data to assertions or premises. These warrants and assertions were cross checked by interviewing students a second time in order to confirm or disconfirm data collected initially. The coding of notes and analysis of data included both inter-rater and intra-rater reliability as well as several other provisions for trustworthiness that included member checking and an instructors log. Intra-rater reliability was achieved by the researcher checking codes three two times and achieving a 92% agreement. Inter-rater reliability was achieved by using an outside researcher not involved with the study to cross check the coding and assertions and examples or warrants used to confirm or disconfirm the data. A 87% percent agreement was achieved.

Outcomes

Discussion of Assertions

<u>Assertion # 1: While the teacher candidates participating in the interviews had varying conceptions of science, the majority revealed that their conception of effective science instruction is directly influenced by their conception of science. However, while teacher candidates are accepting of examining and even embracing new conceptions of science, they still cling to their prior conception of science when pressed with uncertainty in a teaching situation.</u>

By the time teacher candidates enter science they have already developed a conception of teaching and learning (Perry, 1990). Quite often they have not reflected on their conception of science and how their conception of science influences their conception of effective science instruction. As this study shows while teacher candidates are accepting of examining and even embracing new conceptions of science, they still cling to their prior conception of science when pressed with uncertainty in a teaching situation. This maybe due to lack of practical experience, reflection, or lack of specific knowledge. *KA* is a good example of a teacher candidate that reflected the willingness to examine different ways of conceptualizing science but still relied heavily on her initial conception of science when posed with teaching something unfamiliar.

Interviewer: What is your conception of science?

KA: Before I participated in the cooperative controversy activity, I was not real sure what my conception was of science. Granted I have taken all the necessary science courses during my college career but I have never really been asked to reflect or debate my conception of science. I guess what after participating in this activity and then actually analyzing curriculum, developing and presenting science lessons I would have to say that science is a conquest of ideas and discovery.

Interviewer: At the beginning of this course, what was your conception of science?

KA: Well I wasn't sure...I guess I thought science was what I learned in school...you know facts and theories, finding out the right answers.

Interviewer: Why did you change your conception?

KA: I guess just reflecting about my conception, learning about the national reform movement, and constantly re-examining my conception in class.

Interviewer: Is science ever about knowing facts, laws, or theories?

KA: Oh, sure...when I was teaching lessons to the fourth grade students I found myself trying to follow the principals of the national reform initiatives...while trying to focus on the process of discovery in science...but I found that students would ask me questions I didn't not have an answer too and I would immediately show them the facts...I felt insecure.

This same sentiment is expressed by *BS*. On the one hand she appears to acknowledge that science is a process of theory building through personal discovery but on the other hand she personally does not feel comfortable using the discovery approach all the time.

BS : While I like the conception of viewing science as a process, I still feel more comfortable relying on just the facts...I guess I feel this way because I don't feel I have enough of a science background to help facilitate students in their discovery...what if I make a mistake.

While many of the teacher candidates expressed similar conceptions of science as *KA* and *BS* there were four teacher candidates that expressed the conception that even if they don't understand a science process they will work with their students and learn together. This common conception held by these four teacher candidates is expressed in the following statement:

NH: Science is just that...the process of exploration and formulating ideas. My view of science as a practice of discovery was strengthened by confronting areas that I didn't understand in science or in learning with the fourth grade students I taught. My conception was only strengthened as I discovered new understandings for myself or helping students construct their own understanding.

In summary, there does not appear to be a pattern based on the assigned groupings of the teacher candidates. All of the teacher candidates in the four groups, with the exception of *NH, LA, DH,* and *FS*, conceptualized science as the practice of discovery regardless of the situation. *LC*, from group two, expressed that science is to philosophical to understand while *JS*, from group three, stated that science is a process that is imbedded in facts, terminology, and known knowledge. In general, while many of the teacher candidates expressed their conception of science as a practice of discovery, they readily fell back on the conception of science as fact based when they were teaching a topic in science they unsure of the answer. Basically, teacher candidates were more readily accepting of the notion of the process of discovery involved in science if they understood the topic.

<u>Assertion #2: Teacher candidates articulated an intellectual understanding of the process of constructing knowledge but they expressed a difference in how to facilitate knowledge construction. Some teacher candidates expressed that individuals construct their own understanding while others expressed that teachers are responsible for an individuals construction of knowledge.</u>

It was not surprising that while teacher candidates understood the process of knowledge construction, they interpreted their understanding differently. While they acknowledge the pedagogical process implied in the national reform, many of them commented on their frustration in trying to facilitate instruction to help students sort and create new conceptions. This sentiment is expressed by *MB*:

Interviewer: What is conceptual change?

MB: Conceptual change is the process of constructing an environment that allows students to construct their own understanding...this is the part that I have trouble with...I mean what if students construct the wrong understanding...does that mean I failed as a teacher?

Interviewer: Why do you feel this way?

MB: Well...while I agree with the pedagogical approach of the national standards, I have a hard time understanding how it will lead to scientific literacy for all...I feel everyone will construct their own conceptions and nothing will be constant...meaning no one will have the same conception.

Interviewer: How do you view your role in this situation?

MG: Well, I guess that I have a professional responsibility to make sure all students understand the same things in science as in other subjects...I see my role as not so much as a facilitator but as a guide to understanding.

Interviewer: What do you mean to guide?

MG: To guide means to show students the correct understanding...

Many other teacher candidates felt this same way about how students come to understand. There confusion came in making sure all students understood the same information in the same way. Perhaps *DH* summarized this conception the best.

DH: While I consider the reform movement to be a progressive approach toward scientific literacy...I find the pedagogical approach to be a bit vague...There is no guarantee that all students will learn...When I was teaching my lesson in the fourth grade classroom I had so many students at different levels of understanding that I didn't know where to begin...I mean what is a teacher to do when all students understand differently...there isn't enough time to help everyone individually.

MK had this same confusion when it came to helping students understand.

MK: I am so confused...I feel that all my students are not understanding the same things...I want to be a good teacher but how do I ensure that everyone will learn everything...We learned in class that everyone develops there own conception...I guess this is were I get confused...if everyone develops their own conception based on their own experiences how do teacher insure that all students have the same experiences...I think the most important thing I have learned from the national reform is that we are all accountable.

There were also teacher candidates who had an entirely different interpretation on the facilitation of knowledge construction. These teacher candidates felt that if you provide enough experiences for students that challenge or confront what they understand then they will change their conception when they are ready. These teacher candidates saw learning as more fluid and not time or grade dependent.

Interviewer: What is conceptual change?

FS: Conceptual change is the process of confronting what you already know, discovering that it is wrong, and changing your conception...I feel that we all do this all the time not just in science...Learning is a personal endeavor where you are involved in experiences and gain knowledge through these experiences that help you change your conception.

Interviewer: What is the teachers role in this process?

FS: I think that learning is not just taking place in school...but...in the school environment teachers are responsible for creating an environment that promotes students to confront what they already know...actively having students participate...also modeling the learning process to students...ultimately, through, students are responsible for their own learning...teachers are just facilitating their understanding by providing experiences.

In summary, it was apparent that teacher candidates have not had enough practical experience to adequately resolve their understanding of facilitating the construction of knowledge. However, it was enlightening to discover that teacher candidates were beginning to confront their own conceptions of teaching constructively. While teacher candidates understood the notion of knowledge construction, they did not have a clear understanding of the process.

Assertion #3: The principles reflected in the national reform initiatives are viewed by teacher candidates as being beneficial but very time consuming. Teacher candidates indicated that while they recognize the necessity of aligning curriculum to match the content and pedagogy implied by the national reform initiatives, they feel that the time needed to conduct such a process may out weigh the benefits.

Although teacher candidates acknowledged that they gained an overwhelming amount of experience and knowledge from learning about and applying the principles reflected in the national reform initiatives; they were frustrated by the commitment and lack of time in the classroom to actually carrying out the lessons. Many of the teacher candidates stated that they never finished their lessons. This could be due in part to the time constraints of their visits or to their lack of understanding in how long it takes to actually conduct a single lesson. *MK* expressed the sentiment that many of the teacher candidates expressed.

Interviewer: What was your experience in implementing the principles reflected in the national reform initiatives?

MK: The curriculum analysis process was extremely helpful up to a point. It was a good way to become more familiar with both the curriculum and the benchmarks, however. the pedagogical analysis section seemed superfluous. I suggest, instead of a critique of the pedagogy for each benchmark, there should be a single pedagogical analysis which requires specific citations of appropriate benchmarks addressed by each category. This would appear to be more beneficial to those analyzing and using the analysis.

Interviewer: What about your experience teaching the lessons?

MK: I feel like that biggest obstacle in teaching lessons that address the intent of the benchmarks is the time factor. It seems like I never am able to finish an activity that I have designed. I find myself spending way too much time finding out what students know and listening to their questions. I know that finding out what students know is important but I only which it took less time.

Some of the teacher candidates understood the importance of focusing on the process of students thinking skills as opposed to the end product.

TW: As I am teaching more and more lessons to the fourth graders...I am realizing that it is not about getting to the end of the lesson just to finish it....but that it is more important to focus on the process of understanding through exploration and discovery. This realization for me did not come easy but I a happy it did...I think I have finally conceptualized my own understanding of science and the teaching of science.

Other teacher candidates felt the analysis procedure was time consuming but found it beneficial.

DH: Although I think the curriculum analysis procedure is very time consuming...I now know that I can take a lesson and describe whether or not it is designed to match the intent of the benchmarks both process and content.

AD expressed a similar sentiment:

AD: I felt the analysis project was beneficial in that we worked in groups and could help each other by bringing different conceptions and points of view to the project. I also felt the analysis procedure itself was beneficial because it gave me an idea of what should be included in a science curriculum as far as content and pedagogy. I thought that having the benchmarks and very specific questions to compare them too was also beneficial.

In summary, many of the teacher candidates expressed the sentiment that by understanding and utilizing the recommendations of the national reform initiatives, they were becoming more aware of the overall picture of teaching. This overall sentiment is best expressed by *KA*..

KA: I never realized that their was so much preparation and design in entire curriculum. This model of designing curriculum and assessment really made me question as to why I am teaching this unit, what is it that I want students to understand, and where are students coming from as far as understanding and where are they going. I guess I never gave much consideration as to what the grade before or after the one I was teaching was covering. This process has helped me see the big picture of understanding science and how conceptual learning is built upon prior knowledge. I also realized that teaching is not just simply telling but it is more of facilitating students own learning experiences.

Limitations of the Study

There are several limitations inherent in the sampling of this study. The students who participated where primarily women. However, there is a large percentage of women teachers at the K-8 school level. In addition, all of the students participating in the study were enrolled in an Eastern Urban University. Sampling teacher candidates who are enrolled in suburban universities in other regions of the country may yield different findings. Of the thirty-five teacher candidates, only fifteen participated in the in-depth interviews. Interviewing more students with this method may uncover further assertions. The teacher candidates only participated in the course for one semester. Perhaps conducting a more longitudinal intervention may provide more insight and differing outcomes. The participants were teacher candidates with little teaching experience. Having experienced teachers participate in a similar intervention may uncover differing assertions and conclusions.

Summary

The call for systemic reform presents a great challenge to teacher educators in facilitating teacher candidates' conceptions of science and what it means to teach science effectively. Teacher candidates' conceptions of teaching science are guided by their conceptions of science. In order for teacher candidates to model practices of teaching and learning as outlined by the national reform initiatives, they need to participate in activities that cause reflection and they need to apply the standards to lessons that they can or will use. First, teacher candidates need to confront their conceptions of science and scientific thinking. Secondly, they need to be familiar with the pedagogical philosophy addressed in the standards that reflects current research in science education. Third, they must be familiar with the content of the standards. Finally, teacher candidates need the opportunity to work with the standards either through analysis of existing curricula or development of their own lessons and curriculum. Only in doing so will teacher candidates gain a new and better understanding of science and effective science instruction.

As teacher educators strive to embed the recommendations of the science reform initiatives into their methods courses they must actively involve teacher candidates in the process of reform. The implementation of the science reform initiatives has to have a reciprocal relationship with teacher candidates conceptions and actions, because teacher candidates will be the future agents of reform in the classrooms of tomorrow. How reform should be implemented into a methods course must be informed by teacher candidates conceptions of science and science teaching. Likewise, teacher candidates need to be informed by the reform recommendations.

The teachers candidate's reflections revealed support for the use of incorporating the principles reflected in the national reform initiatives in an K-8 science methods course. Their reflections have implications for the science education of teachers. If we hope to reform science teaching at the school level, we need to reform teacher education first. Unless prospective teachers experience reformed science teaching, it is unrealistic to expect change; that is to expect them to teach in a way that they have not experienced. Just telling teachers what pedagogical changes are desired is unlikely to have any effect. If students are to be taught in a way that helps them construct their own knowledge, then teachers need to learn science in the same manner. We cannot continue to teach undergraduate science by lecture and cookbook laboratory experiments and by providing brief, unrelated exposure to pedagogy in a methods course, and expect prospective teachers to teach differently. The study points out that science courses for prospective teachers need reforming before effective, long-term changes in classroom teaching are systemic. After incorporating the philosophy and intent of the national reform initiatives into my course, I am convinced that using the framework of the national reform initiatives is both necessary and essential in demonstrating the importance of promoting scientific literacy for both our students and teachers.

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