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ABSTRACT

This paper describes the changes K-8 teachers made in their conceptions of science, teaching, and learning as they participated in a year-long professional development program. The program was based on principles reflected in the national science education reform initiatives, and focused on the role of teachers as decision makers in promoting scientific literacy for all students. The study concludes that: (1) teachers were accepting of examining and even embracing new conceptions of science, but clung to their prior conceptions of science when pressed with uncertainty in a teaching situation; (2) teachers understood the notion of knowledge construction but did not have a clear understanding of the process; and (3) teachers perceived the alignment of science curriculum to national standards to be a time-consuming and sometimes frustrating process. (Contains 34 references.) (WRM)

Science Curriculum Reform: What Teachers Are Saying

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RUNNING HEAD: Science Curriculum Reform

Science Curriculum Reform: What Teachers Are Saying

As teacher educators are searching for the very best models of instruction to facilitate teacher candidates' conceptions of what it is to teach effectively, they are reminded of the all too forgotten, *here today, gone tomorrow*, sentiment that followed the 1960's reform. 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. Given a teacher's central role in the classroom, it is reasonable to hypothesize that the classroom culture is a function of a teacher's conceptions of science and science teaching. Therefore, teachers are central to solutions and successes for current reform efforts. Unless we understand teachers' conceptions of science and teaching, why they hold them, and constraints in changing them, we will find it impossible to move from reformed curriculum to reformed practice. Therefore, teachers' conceptions must be examined as they reflect upon and apply the principles of reform. Furthermore, successful modes of achieving reformed practice must be examined.

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 schools search for the best models of instruction to help teachers become more effective teachers, they are incorporating the standards into their curriculum. 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 teachers. Specifically, 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).

It has been argued that teachers 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 teachers 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 instruction, teachers will have a new and better understanding of science and how science is taught. As teachers attempt to change their conceptions of what it is to teach effectively, they 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, teachers understand why they 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 K-8 teachers about science, teaching, and learning as they participate in a year long professional development program focused on the principles reflected in the national reform initiatives. The program focused on the role of teachers as decision makers in promoting scientific literacy for all students. The overall goal was to familiarize teachers with reform initiatives in science education, focusing particularly on their role as change agents in the reform. The overall goal was addressed through three phases where teachers learned to apply the principles reflected in the national reform initiatives in designing, implementing, and evaluating curriculum, instruction, and assessment.

Phase One: Confront and Challenge

The first phase of the program was designed to enhance teachers' knowledge and understanding of national reform initiatives in science education. Realizing that conceptions are difficult to change (Posner, Stike, Hewson, and Gertzong, 1982) the purpose of the first phase was to confront and challenge each teachers' conception of science in order to structure the following phases of the program.

With the recognition that the understanding of the nature of science is a global conception that frames teachers understanding of science teaching (Bohm & Peat, 1989), the first activity was designed to confront and challenge teachers' 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 teachers' 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 teachers to both traditional and alternative paradigms concerning the nature of science. Teachers debate and reach consensus in groups on their conceptions of the nature of science based on their dialogue and reflections.

The second activity was designed to explore the existence of world views held by teachers 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). 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 teachers not only present scientific concepts, but tacitly create a context in which scientific concepts are presented, a context influenced by teachers' world view. Therefore, teachers examined their world views to fully understand the cultural context created by the teacher within the classroom.

Teachers' 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.

Teachers also participated in developing a concept map of thirty words that describe their conception of the nature of science. The teachers 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 third activity was designed to expose teachers to the notion of conceptual change. Teachers 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. After watching the videotape, the teachers 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.

The fourth activity was to familiarize teachers with the content and pedagogy implied in the science reform initiatives. Teachers 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, teachers were asked to decide which scenario most adequately addressed the content and pedagogy implied in the science reform initiatives. Next sample model lessons were presented that highlighted 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, teachers worked in pairs to practice identifying central and related content and process benchmarks/standards specifically related to the lessons. The pairs compared their central and related benchmarks/standards with other pairs and discussed the differences between their listed benchmarks/standards.

Phase Two: Application

The second phase of the program was designed to have teachers apply the principles of the national reform initiatives in designing curriculum, instruction, and assessment. Teachers analyzed model lessons showing how effective science instruction establishes connections across grade levels and subject areas. Working in groups of two, teachers decided on a science theme for a specific grade level, wrote 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), identified the central and related content and process benchmarks/standards for each lesson in their unit that students should know by their selected grade level, explained how they will integrate the unit into other subject areas and identify any benchmarks/standards which will help them integrate, and developed authentic assessment measures for each lesson and the overall unit and described how they plan to assess competency for the entire unit.

Phase Three: Evaluation

Phase three of the program was designed for teachers to extend their learning by evaluating instructional resources and programs by applying the principles of in the national reform initiatives. In this phase, teachers analyzed and reviewed curriculum packages and materials to assess the match between the content and pedagogy of the materials with those of the benchmarks/standards.

As recommended by Project 2061 of the American Association for the Advancement of Science this activity included five steps. In the first step teachers identify benchmarks/standards that appear to be covered by the curriculum material. Next, teachers spent a great amount of time going through the actual curriculum material page by page to locate instances where the possible benchmark/standards they listed before are addressed. In step two, teachers studied the benchmarks/standards to clarify their meaning. They selected one benchmark/standard from their list and examined the relevant sections in *Science for All Americans* and *Benchmarks*. In step three, teachers analyzed the curriculum material to determine the extent to which the activities actually addressed the actual content of the benchmarks/standards. In step four, teachers analyzed how the curriculum addresses the pedagogy of the benchmarks/standards. In the last step, teachers suggested ways to adapt and supplement the activities in the curriculum material.

Procedure

Sample

This professional development program took place during the 1996-1997 academic year, with twenty-five teachers participating. The researcher was the instructor of this program. Ten of the teachers participated in the interviews. Purposeful sampling was utilized for the initial study while a theoretical sample was used to select the ten teachers to be used as comparative case studies based on the recommendations of Strauss (1987). There were twenty-five teachers in the initial purposeful sample. Twenty were female and five were male. Age ranged from twenty-three to thirty-nine. All of the teachers were American citizens. There were ten African-Americans females, two Asian-American females, and eight Europe-American females. There was one African-American and four Europe-American males.

The teachers who participated in the case study interviews did so on a voluntary basis and were randomly selected from their responses on the initial instruments and activities completed by all twenty-five teachers. Pseudonyms were used and results were provided to participants. A biography of each of the ten teachers was prepared to summarize background information and information obtained while interacting with teachers both in and out of the program.

Data Gathering Instruments

To gather data to complete descriptive and comparison case studies, ten teachers 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 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. 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 teachers 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. The larger study focused on teachers 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 teachers' 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 teachers' 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 teachers understood or viewed science and science teaching. The responses to these two instruments were analyzed to determine teacher candidates' conceptions. Using the whole group 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, teachers were grouped into similar conceptions of science and science teaching.

Analysis

Grounded theory was used as the method of analysis for this study (Strauss, 1987). 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 three final assertions were made. The data were re-examined to report warrants that confirmed or disconfirmed the final assertions. The warrants and assertions were cross checked by interviewing teachers a second time in order to confirm or disconfirm data collected initially. The coding of notes and analysis of data included both inter-rater (90%) and intra-rater reliability (86%) as well as several other provisions for trustworthiness that included member checking and an instructors log.

Outcomes

Discussion of Assertions

Assertion # 1: Although the teachers participating in the interviews had varying conceptions of science, their comments revealed that their conception of science directly influenced their conception of effective science instruction. They were accepting of examining and even embracing new conceptions of science, but they clung to their prior conception of science when pressed with uncertainty in a teaching situation.

By the time teachers enter the teaching field 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 teachers 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. *AT* is a good example of a teacher 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?

AT: 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 the program, what was your conception of science?

AT: 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?

AT: 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?

AT: Oh, sure...when I was teaching lessons to my 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.

While many of the teachers expressed similar conceptions of science as *AT* there were four teachers 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 teachers is expressed in the following statement:

HN: 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 my students. My conception was only strengthened as I discovered new understandings for myself or helping students construct their own understanding.

In summary, while many of the teachers 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.

Assertion #2: Teachers articulated an intellectual understanding of the process of constructing knowledge, but expressed a difference in how to facilitate knowledge construction. Some said that individuals construct their own understanding while others stated that teachers are responsible for an individual's construction of knowledge.

It was not surprising that while teachers 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 *BN*:

Interviewer: What is conceptual change?

BN: 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?

BN: 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?

BN: 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?

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

Many of the teachers 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 *HD* summarized this conception the best.

HD: 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 am teaching my lessons in my fourth grade classroom I have so many students at different levels of understanding that I don'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.

There were also teachers who had an entirely different interpretation on the facilitation of knowledge construction. These teachers 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 teachers saw learning as more fluid and not time or grade dependent.

Interviewer: What is conceptual change?

SL: 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?

SL: 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 teachers have not had enough practical experience to adequately resolve their understanding of facilitating the construction of knowledge. However, it was enlightening to discover that teachers were beginning to confront their own conceptions of teaching constructively. While teachers 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 as being beneficial but very time consuming. Teacher indicated that although 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 teachers 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 teachers stated that they never finished their lessons. This could be due in part to their lack of understanding in how long it takes to actually conduct a single lesson. *KM* expressed the sentiment that many of the teachers expressed.

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

KM: 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?

KM: 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 teachers understood the importance of focusing on the process of students thinking skills as opposed to the end product.

WT: As I am teaching more and more science lessons...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.

In summary, many of the teachers 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 *A K.*

AK: 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.

Summary

The call for systemic reform presents a great challenge in facilitating teachers' conceptions of science and what it means to teach science effectively. Teachers' conceptions of teaching science are guided by their conceptions of science. In order for teachers 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, teachers 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, teachers 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 teachers gain a new and better understanding of science and effective science instruction.

As schools strive to embed the recommendations of the science reform initiatives into their curriculum they must actively involve teachers in the process of reform. The Implementation of the science reform initiatives has to have a reciprocal relationship with teachers conceptions and actions, because teachers are the agents of reform in the classrooms. How reform should be implemented into a classroom must be informed by teachers conceptions of science and science teaching. Likewise, teachers need to be informed by the reform recommendations.

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