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ABSTRACT

This paper reports on a case study that examined the development of two high school science student teachers. Teacher education programs are having difficulties helping preservice teachers develop the necessary skills required for the implementation of the contemporary vision of science instruction. Student teaching experience maintains the most important part of the teachers' preparation programs, although the student teachers are criticized for a lack of strong theoretical and conceptual framework. The understanding of preservice teachers' beliefs is an essential element in their education because of their effects on the prospective teacher's perception of classroom practice. This research investigates these questions: (1) What are the conceptions of teaching science held by participants?; (2) How do these conceptions change as participants progress through pre-student teaching and student teaching?; (3) What is the role of pre-student teaching and student teaching in the construction of these conceptions from the perspective of the participants?; and (4) In what ways did the pre-student teaching and student teaching experiences constrain or support the development of conceptual change pedagogy among participants? (YDS)

Changes in Prospective Science Teachers' Conceptions and Practices During Field Experiences

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Changes in Prospective Science Teachers' Conceptions and Practices During Field Experiences[1]

Introduction

There has been growing concern over the quality of science instruction offered in American schools, as evidenced by several reports issued by professional organizations which have called for change in school science (Aldridge, 1989; American Association for the Advancement of Science, 1989; National Research Council, 1996). At the core of contemporary reform visions are current theories about learning which hold that learning is an active process, and that the teacher's role is to structure course content and classroom environments which facilitate learning with conceptual understanding. In particular, a large body of research in science education has substantiated the notion that an appropriate conception of science instruction includes a view of learning as conceptual change (e.g., Hewson & Hewson, 1988; Hollon, Roth, & Anderson, 1991; Osborne & Freiberg, 1985; Stofflett, 1994).

Preparing prospective teachers who are able to implement contemporary visions of science instruction represents a challenge for science teacher educators, who are entrusted with the responsibility of helping prospective science teachers develop knowledge, skills, attitudes, and habits of mind that reflect change efforts. However, teacher preparation programs frequently fail to meet these goals (Clough & Berg, 1995). One of the most critical elements of the developmental process of learning to teach is the field-based component, particularly

[1] This article is a condensed version of a dissertation study. The complete report can be found in Bradford, 1997.

student teaching (Britzman, 1991; McIntyre, Byrd, & Foxx, 1996). Some of the knowledge about learning and teaching science is constructed during campus-based coursework, but a significant portion of the process of learning to teach science takes place during experiences in the field (Brickhouse & Bodner, 1992). Experiences in the schools are believed to shape a teacher's beliefs and understandings about teaching, learning and school contexts (Richardson, 1996). Therefore, examining the learning that takes place in the field is essential if we want to better understand prospective teachers' developing conceptions of teaching science, and how these are linked to their practice.

Guyton and McIntyre (1990) point out that school-based experiences are a legacy from medieval apprenticeship training models, with student teaching remaining as the most universally accepted segment of teacher education programs. Teachers consistently single field experiences as the most beneficial component of their teacher preparation, even though contextual variables--such as the bureaucratic nature of schools or poor mentoring by cooperating teachers--have been associated with negative influences on prospective teacher development. Despite their prevalence and centrality, though, field experiences are frequently criticized for lacking a strong theoretical and conceptual framework, for lacking consistent goals that are espoused by the teacher education program as a whole, and for not fulfilling their educational potential (Guyton & McIntyre, 1990; McIntyre, Byrd & Foxx, 1996). Furthermore, the teacher education literature indicates that, despite the interest generated by field experiences, there still is controversy about the role they play regarding a number of issues (e.g., McIntyre, Byrd, & Foxx, 1996; Zeichner & Gore, 1990).

This case study of the student teaching experience of prospective science teachers examined meanings and perceptions two high school science student teachers attributed to field experiences in their development as teachers of science. The relationship between a teacher's beliefs and practices is complex and not yet fully understood (Richardson, 1996). Beliefs can be described as a "proposition that is accepted as true by the individual holding the belief" (Richardson, 1996, p. 104). Beliefs held by teachers undoubtedly influence their perceptions and judgments, which, in turn, affect their classroom practices (Pajares, 1992). Conversely, researchers have also acknowledged that experiences coupled with reflection may lead to reformulation of previous beliefs. Further, although beliefs and practice have been linked through empirical research, one cannot assume that all changes in beliefs automatically translate into worthwhile practices; a teacher may simply not know how to develop a practice consistent with a new belief, or contextual variables may interfere with the enactment of beliefs into practice (Richardson, 1996). Therefore, a rich understanding of prospective teachers' beliefs structures is essential as we endeavor to improve their professional preparation (Pajares, 1992). More specifically, this paper reports on the ways in which participants' conceptions and practices of science pedagogy were influenced by practical work with learners, cooperating teachers and university supervisors. Because of the centrality of teaching for conceptual change in contemporary visions of appropriate science instruction, the data were analyzed against the backdrop of conceptual change teaching. Borrowing from Hewson and Hewson (1989), conceptions of science pedagogy were defined here as "the set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science, and the learners and learning which the teacher uses in making decisions about teaching, both in planning and execution" (p. 194).

Theoretical Underpinnings

This investigation was grounded in a constructivist view of learning, which holds that knowledge is constructed by individuals based on their interpretations of experiences and interactions with others (e.g., von Glasersfeld, 1993). An implication of this theoretical assumption is that teachers hold personalized, unique conceptions and beliefs about teaching and learning science which play important roles in their classroom decisions and practice (Brickhouse, 1991; Hewson & Hewson, 1987; Tobin, 1993). Consistent with this assumption, the principles of phenomenology were used as the theoretical framework for this study. Phenomenological inquiry examines "the perceptions of individuals and provides concrete examples of their experiences and the meanings they construct" (Pape, 1993, p.53). This approach is supported by recent trends in research on field experiences, for naturalistic approaches have purportedly yielded meaningful data on complex processes as student teaching (Guyton & McIntyre, 1990; Zeichner & Gore, 1990).

According to Patton, phenomenological inquiry asks the question: "What is the structure and essence of experience of this phenomenon for these people?" (1990, p. 69). People's thoughts, feelings, and perceptions are used to describe and understand their experiences (Eichelberger, 1989). A phenomenological study focuses on people's descriptions and constructions of their experiences so as to make sense of the world. The main assumptions underlying this approach are: (a) each person's reality is the result of the interpretation and meanings the person attributes to events; and (b) for every experience there are common elements that are shared by individuals. As a result, the researcher's role is to (a) attempt to understand the meaning of events from the participants' point of view, and (b) seek to uncover the essence of a phenomenon shared by a group of people by identifying the commonalities in those people's experiences (Bogdan & Bicklen, 1992; Patton, 1990). According to Eichelberger,

> a phenomenologist assumes a commonality in those human experiences and must use rigorously the method of bracketing to search for those commonalities. Results obtained from a phenomenological study can then be related to and integrated with those of other phenomenologists studying the same experience, or phenomenon. (1989, p.6)

Therefore, the subjective aspects of people's behaviors and interpretations of experiences underlie the phenomenological approach. It is based on the premise that understanding a phenomenon from the participants' point of view enables the researcher to bring the least amount of distortion possible into the description of the phenomenon under investigation (Bogdan & Bicklen, 1992). These assumptions about the nature of learning and principles of phenomenological inquiry underlie the design and procedures chosen for this investigation.

Design and Procedures

The following research questions guided the investigation: (1) What are the conceptions of teaching science held by participants? (2) How do these conceptions change as participants progress through pre-student teaching and student teaching? (3) What is the role of pre-student teaching and student teaching in the constructions of these conceptions, from the perspective of the participants? (4) In what ways did the pre-student teaching and student teaching experiences constrain or support the development of conceptual change pedagogy among participants?

Given the nature of the research questions and theoretical framework, this study was undertaken following an interpretive case study design. Gallagher (1991) believes that interpretive research provides science educators with a powerful tool for examining the work and thinking of science teachers at all levels, and for documenting the details of teaching against a rich contextual backdrop that renders depth and meaning to the events and thoughts under scrutiny. According to Merriam (1988),

> a case study is an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group. The bounded system, or case, might be selected because it is an instance of some concern, issue, or hypothesis. (p. 9)

Further, the purpose of a case study is not to be generalizable to an entire population, but to contribute to a richer understanding of the phenomenon under investigation by "setting the particular case within a larger theoretical . . . context" (Grossman, 1990, p. 150).

Data Collection

Primary sources of data were verbatim transcripts of an average of seven semi-structured, formal interviews with participants. Field notes from eight classroom observations, and documents such as journal entries and lesson plans were used as supporting data. Data were collected for 10 weeks during Fall 1995 and for 15 weeks during Spring 1996, as participants progressed through pre-student teaching and student teaching, respectively.

To facilitate and guide discussion, a questionnaire and an interview protocol were used in the first two interviews. Participants completed the Exercise on Teaching (Hewson & Hewson, 1987) during the first interview. This task was useful in helping draw a baseline about participants' initial conceptions of teaching science for conceptual change. The second interview was based on the Conceptions of Teaching Science (CTS), an interview protocol developed and established by Hewson and associates (e.g., Hewson & Hewson, 1989; Hewson et al., 1995; Lemberger, J., Hewson, P., & Park, H., 1994; Meyer, H., Hewson, P., Lemberger, J., Park, H., & Tabachnick, R., 1994; P. Hewson, personal communication, May 26, 1995). The CTS consists of a series of ten short written extracts containing instances and noninstances of science teaching and learning, with variations for biology, chemistry, and physics. Participants' answers during the first two interviews were used by the researchers in helping draw inferences about their initial conceptions of teaching science and generating questions for subsequent probing.

Additional interviews and other types of data yielded a broader and contextual range of participants' conceptions of teaching science than would be achieved by using those tools alone. In fact, Hewson and Hewson (1989) urged researchers to supplement the information gathered using the CTS with other sources of data, such as the observations and documents used in this study. Furthermore, subsequent interviews were less structured and more open-ended, incorporating discussions about events occurred during classroom observations, contents of documents, and participants' perspectives on their field experiences and conceptions of teaching science. Interviews built upon previous interviews, as the study aimed at examining possible changes in participants' thinking, as well as the processes involved in these changes. Whenever possible, participants were asked to elaborate on topics introduced in the previous meetings, or to address aspects that remained unclear to the researchers. Mid-point through student teaching, the investigators built conceptual webs synthesizing their understanding of individual participants' most salient conceptions up to that point; in a subsequent interview participants were presented with their respective webs and asked for their reactions to the researcher's diagram.

Data Analysis

Data were originally collected from four informants. Two of them, "Helen" and "Crawford", were selected for the in-depth analysis presented in the complete report of this study (see Bradford, 1997). Compatible with the type of data yielded by interpretive case studies, inductive analysis (Bogdan & Bicklen, 1992; Marshall & Rossman, 1989; Merriam, 1988) was the primary method for analyzing the data, at two levels of data analysis: in the first level the data for each individual participant were analyzed; in the second level, a cross-participant analysis was performed.

Data analysis consisted of repeatedly examining the data to uncover salient patterns, singularities, and themes associated with the research questions. Chunks of meaning or "*units* of information that . . . serve as the basis for defining categories" (Lincoln & Guba, 1985, p. 344) were identified. From this process, tentative categories were developed to be used as a coding system for sorting, organizing, and retrieving data. A separate coding system was developed for each participant. Because this investigation was concerned with the role of field experiences in the development of student teachers' conceptions, we did not find it appropriate to impose Hewson's (Hewson & Hewson, 1989) categorization scheme of teacher responses a priori. Rather, categories and themes emerged from the data, by using the inductive analysis process explained here.

Based on this process, a tentative coding system of 45 categories was devised for Helen. Her interview transcripts were then imported into QSR NUD.IST (1996), a qualitative data analysis software. Coding of Helen's interview transcripts according to the tentative category system devised was then performed using NUD.IST. In practice, this meant scrolling down each transcript on the computer screen; whenever a unit of information was identified that fit under any of the 45 categories previously developed, it was assigned to that category. The length of each unit of information varied from one sentence to several paragraphs, depending on the idea being conveyed. Also, a unit could belong to two or more categories. The software stored the units of information by category in the computer memory. During the actual coding of the transcripts, some of the tentative categories were modified, expanded, or deleted. Once the interviews were coded, a complete print-out by coding category for Helen was generated. This print-out provided quick reference to all units of information coded, which facilitated the subsequent analysis and write-up processes. Not all of the categories generated were used in the final report.

Emergent relationships and tentative assertions were then generated. According to Erickson (1986), in reviewing the data to generate and test assertions the researcher looks

> for key linkages among various items of data. A key linkage is key in that it is of central significance for the major assertions the researcher wants to make. The key linkage is linking in that it connects up many items of data as analogous instances of the same phenomenon. . . . In searching for key linkages the researcher is looking for patterns of generalization within the case at hand, rather than for generalization from one case or setting to another (p. 147-148).

Tentative assertions were tested for validity against the data, and reformulated as the analysis developed. That is, throughout the process, there was searching and testing of evidence that could potentially disconfirm the assertions made (Erickson, 1986). These assertions became the organizers for each participant individual case report . The entire analytical process was then performed a second time, in which the data for Crawford were analyzed. A total of 39 coding categories were generated for Crawford. Preliminary drafts of the participants' case reports were then verified by respective participants--member checks--so as to ensure that assertions were plausible from their perspective (Lincoln & Guba, 1985).

As analysis of each individual's data set proceeded, the investigators continuously searched for trends in the data that cut across participants' experiences. In a sense, the findings for Helen and Crawford became the data for the cross-participant analysis. According to Grossman, "each individual case becomes the first unit of analysis, as the researcher identifies patterns and themes within the individual case that can be useful in the cross-case analysis" (1990, p. 150). The cross-participant analysis then became a process of deconstructing the individual participant's cases and using evidence gathered this way to substantiate the overarching research assertion that emerged from this process. This article serves to highlight findings from the cross-participant analysis, as well as discuss commensurate implications for theory and practice in science teacher education, particularly the field experience components. The complete report, including the accounts for the individual participants' findings, can be found elsewhere (see Bradford, 1997).

Participants

Helen Smith was a 21 year-old who graduated from the University with a recommendation for a Chemistry teaching certificate and a 3.7/4.0 overall GPA. Helen had a history of academic success in high school. Upon high school graduation, she started college as an engineering major. Within a few weeks, though, she came to realize that teaching was her true calling and transferred into the secondary education program. She also held a part time job tutoring university freshmen and supervising peer tutors for the University learning support program. Helen appeared to have excellent organizational and time management skills, as indicated from her self-reported ability to juggle her assignments efficiently. She conveyed a "matter-of-fact" attitude about her tasks and academic experience--she did what she was expected to do in a focused, task-oriented fashion. Perhaps due to Helen's affable and reserved demeanor, combined with her task-oriented approach to things, her interview transcripts were comparatively shorter than those of the other three informants. A total of seven formal interviews and nine classroom observations were made with Helen.

Helen was placed with the same cooperating teacher for both the pre-student teaching and student teaching experiences, Ms. Naomi. She taught four sessions of Chemistry in the Community, a chemistry course for college bound students, but not necessarily in science-related fields. Classes met for six periods each week; there was one double period each week, intended for laboratory activities. The target population were students in the 11th and 12th grades.

By most accounts, Helen had what one could consider a successful student teaching experience, as reflected by her receiving an 'A' as a final letter grade. Helen was dedicated and thoughtful, genuinely concerned about her students' learning, and about bringing her beliefs into her practice. In addition, her task-oriented nature and good time management skills proved very instrumental, allowing her to adjust successfully to the great pressures and expectations involved in the experience. The relationship with the cooperating teacher evolved into a satisfactory one, despite some initial mismatch between them. The feedback offered by the supervisor was valuable to Helen, who was able to incorporate it into her teaching. Besides, Helen's affable demeanor and easy smile contributed to a pleasant classroom climate, with most students on task without major behavioral problems.

Crawford Eckhart was a 28 year-old returning adult student enrolled in the university scholars' program. He graduated with a B.S. in Secondary Education with Honors in Educational Theory and Policy and a recommendation for an Earth and Space Sciences teaching certificate. His overall GPA was 3.54/4.00. He was married to his wife of 9 years, and was the father of two young daughters at the time of this study. Crawford self-admittedly was never a top student in high school. Upon graduating from high school he opted for a career in the Navy, serving for eight years. During that period he obtained an Associate in Arts degree, through the Navy's Enlisted Education Advancement Program. Suddenly one day, while serving in a nuclear submarine, he was struck by a sudden realization which eventually led him back to college for a degree in Education: *"I figured there's a better way to spend my life than sitting around in a submarine waiting to launch missiles".*

Crawford was loquacious and presented evidence of being rather introspective and critical, not only of others but of himself. He had a tendency to stray off the topic and volunteering much information; he appeared to enjoy talking because he wished to share a wealth of ideas. These qualities proved to be important for the data collection process, for Crawford was the least available participant during the student teaching period. He always agreed to observations of his lessons during that period, but he contended that time constraints and amount of homework did not allow him to meet more often for formal interviews. (As per the research agreement that was negotiated with each participant, participants could choose to limit contacts with the interviewer at any point they wished.) His willingness to volunteer information and ability to articulate his reflective thinking yielded answers and interview transcripts that were longer in average than the other participants', which somewhat compensated for fewer meetings. A hint of sarcasm could be sensed at times, particularly during the latter two interviews, as the obstacles that Crawford perceived in the field became almost insurmountable. A total of five formal interviews and eight classroom observations were made with him.

For the five week long pre-student teaching experience during Fall 1995, Crawford was placed in Pleasantville Junior High School, where he taught General Science to 7th and 8th graders. For the Spring 1996 student teaching experience, Crawford was transferred to the Pleasantville High School. There he taught five periods of Earth and Space Sciences to 9th graders: *"Two college preparatory, two regular, one below average. [A total of] five classes per day plus lunch duty every day."* All classes met five days a week.

Context of the Study

Both participants were placed in the Pleasantville Area School District, located near a university community of 65,000 situated in a rural region of a northeastern state. Occupations and professions in the area relate largely to the university, agriculture, and the incipient local technological industry. The Pleasantville system comprised eleven elementary schools (K-5), two middle schools (6-8), one high school (9-12), and an alternative program (7-12), totaling approximately 7,100 students who consistently performed above average on nationally normed achievement tests. The district had an enviable budget, and schools were equipped with resources and facilities that reflected the largely middle-class community's expectations for quality education. Nearly 40 A.P. and advanced courses were offered at the high school. The high school profile of the class of 1996 indicated that enrollment for grades 9 through 12 was at 2115 students, with a total of 478 graduates. Verbal SAT scores for this group averaged 557, while math scores averaged 576. The majority of these students were academically oriented, with 81% of graduates indicating an intention to pursue degrees at four year colleges upon graduation.

At the time of this study, the secondary education major at the university was a typical four year undergraduate teacher education program, comprised of coursework in general education, subject area specialization, pedagogy, and field experiences. There were three official field components: early field experience, pre-student teaching experience, and student teaching experience. This study was concerned solely with the latter two components of the students' field experiences. Science teacher candidates at the University typically enroll in a sequence of two three-credit science methods courses with concurrent school-based work that is meant to be an orientation to the two subsequent field experiences, namely, pre-student teaching and student teaching. Pre-student teaching consisted of a five-week period, at the end of the Fall 1995 semester (after the conclusion of second methods course), during which prospective teachers spent a minimum of 12 weekly hours, from Monday through Thursday, in the cooperating teacher's classroom. Students were required to teach a minimum of 10 lessons during that period. On Fridays, students met on campus with their previous science methods instructor, who was also their field supervisor, for a two hour group seminar. The student teaching experience consisted of 14 weeks during Spring 1996, when student teachers were placed in one cooperating teacher's classroom. During that period, student teachers were to gradually take over the responsibilities of their respective cooperating teachers. They also attended a weekly evening seminar on campus. Student teachers' evaluations were based on ten performance areas: planning, implementation, learner evaluation, analysis of teaching, classroom management, organization of environment, communication skills, cooperation, dependability, and additional performance objectives based on individuals' situations (such as community/school wide activity). Major assignments consisted of lesson plans and the development of one unit of instruction spanning about three weeks. Throughout the experience, students were required to prepare detailed lesson plans for every lesson they taught, which were to be approved in advance by the cooperating teacher. Lesson plans were to follow the format prescribed by the supervisor. Students were observed teaching by the supervisor a minimum of five times. The student teaching supervisor did not have a science background.

The Proffered Nature of Field Experiences: The Pursuit of Technical Proficiency[2]

The individual accounts of Helen's and Crawford's field experiences brought to light the overt and dominant emphasis of their experiences on technical proficiency. Both participants self-admittedly did not recognize any major reconceptualizations in the ways they conceptualized science teaching and learning that resulted directly from their experiences in the field, particularly student teaching. Except for a few instances of subtle changes, both participants' conceptions of teaching science, as well as their dispositions towards inquiry, appeared to have remained rather stable throughout the field experiences, although for different reasons. Our research assertion based on this analysis was:

The nature of the field experiences for these participants may have (inadvertently) rewarded the pursuit of technical proficiency at the expense of both critical reflection and development on issues related to participants' conceptions of science pedagogy.

This begs the question: If we consider learning to teach science also a process of conceptual change, what does absence of conceptual change imply about these participants' learning about teaching science during the field experiences? The overall stability of participants' conceptions over time therefore seemed to indicate that little, if any, conceptual change, inquiry-oriented teacher education took place during their field experiences. The theoretical foundation and the reasoning steps that led to this assertion are discussed elsewhere (Bradford, 1997), and were grounded on the combined notions of conceptual change (e.g., Hewson et al., 1994) and inquiry-based teacher education (e.g., Zeichner, 1983).

[2] Findings were organized thematically, based on themes that emerged from the data sets. Answers to the research questions are embedded in those themes.

The most salient data that led to the aforementioned assertion are highlighted under the following organizers: (1) participants' dispositions towards introspection and inquiry; (2) participants' conceptions about teaching science; and (3) participants' conceptions about the nature of science. Although, technically, 'conceptions of the nature of science' are subsumed in Hewson's operational definition of 'conceptions of teaching science' (Hewson & Hewson, 1989), they were treated separately here for organizational purposes. Likewise, 'dispositions towards inquiry' is not an explicit part of Hewson's original definition, but since in this study participants' dispositions towards inquiry seemed to go hand in hand with their conceptions, analysis of these data seemed to be warranted.

Participants' dispositions towards introspection and inquiry

One of the single most salient contrasts between Helen and Crawford lied in the differing levels of introspection and inclination towards inquiry that each was able to attain during their experiences, which may help to explain some of the other findings of this study. For instance, the data support the assertion that Helen's reflections upon her experiences lied at the technical/practical level (Gore & Zeichner, 1991). As a case in point, according to Helen, at the end of the five week long pre-student teaching experience, planning and classroom management were the major areas of her development:

> *Planning enough for a full class time, as well as anticipating what students are going to ask or think about what you're doing. . . . [also] a lot has been done in our classes here, you know, reading books and talking about [classroom management], but we've never actually experienced it. So I think that the most important thing I learned was classroom management. (12/12/95, cat (23)).*

Therefore, it appears that at that point Helen's major focus was on the technical/performance aspect of her development as a teacher. Classroom management issues seemed to have remained as a major focal point for Helen throughout the study. About nine weeks into the student teaching experience, classroom management was again brought up as an important aspect in Helen's self-described development, as captured in the following dialogue:

> I: *Would you be able to identify a couple of ideas that you had about teaching science which changed as a result of the field experience?*
>
> H: *Most of my ideas that have changed have been involving things like classroom management, I mean, that is still part of teaching science but, the way I thought I would teach science hasn't really changed at all.*

In addition, she had expected more specific guidance about practical matters on the part of the supervisor:

> *[Dr. Supervisor] has given me a lot of things to think about as far as planning and implementation. She's helped out a lot there. I would prefer to have a lot of more specific feedback, I think that would have been a greater help for me just because, when I'm asked a question I think into it and then well, it could be this, it could be that . . . . I'm sure there are several different ways to do things, however, it's kind of hard for me as the beginning person to realize which one would be most helpful.*

Throughout the study Helen remained focused on technical issues of lesson planning and delivery, effective teaching, management techniques, and the like. She seemed to have passively accepted the requirements of the field experiences, assuming that those requirements were the logical way whereby her evaluators could track her progress and achievements towards becoming a science teacher. She never explicitly brought into question the adequacy of either the goals that she was expected to follow for her students, nor the direction to which the field experiences were leading her.

On the other hand, Crawford seemed prepared to tackle critical issues, not only by questioning his own experience as a student teacher, but also by examining the goals of science teaching, purpose of learning activities, and consequences of schooling:

> *Until last semester it was like all these ideas about here's what you can do to teach . . . and it seemed like it was this big, huge, here's the world of possibilities you can do as a teacher. . . When you start off you have this real small idea of what being a teacher is and what you can do and the different levels of understanding and then as you progress*

> *through the different semesters and different classes, that idea of what teaching is about expands bigger and bigger and also how to deal with students and what teaching is about and, even the meaning of life and how to shape children. It gets just larger and larger and then in these last two semesters instead of funneling out even more or letting me choose what I want to do . . . [it came] down to this is what you have to do and here's how [to do it]. And that's I guess why I seemed to become semi-hostile.*

Crawford and Helen evidently came into their field experiences with differing predispositions to pursue critical issues related to their practice and the institutional contexts in which they operated. It appears that the field experiences did little in the way of helping Helen develop a framework and a language that could assist her in making sense of her experiences at progressively deeper and more critical levels. On the other hand, Crawford, who was eager and more prepared to pursue critical issues related to his experience in the classrooms, felt as if he had been robbed of his chance to do so. For Crawford, the experience had a profound impact, but at a level different than the technical:

> *There's just so many different ways the whole experience has bothered me . . . . I found myself [suddenly focusing on] psychology . . . that's what I started focusing on because it's the easiest to deal with and write about. And in doing that I totally dropped out of the mind and soul and spirit aspects [that I had wanted to emphasize for the sake of addressing students' characters, as opposed to their behavior alone].*

In fact, Crawford's case can be used to challenge theories about prospective teacher development which contend that prospective teachers must acquire procedural skills before they can progress into addressing critical and conceptual issues related to their practice, and teaching and schooling in general (e.g., Kagan, 1992). Therefore, it seemed that the field experiences, and more specifically student teaching, failed to fulfill the promise for helping a prospective science teacher like Helen to move along an imaginary reflective continuum and become more critically inquisitive about her science-specific conceptions and practice.

Likewise, it seemed that the program inhibited Crawford's self-directed development towards goals that he had originally anticipated.

Britzman (1991) has eloquently cautioned those involved in teacher preparation against the pitfalls of practicum experiences that do not facilitate student teacher development towards critical ways of thinking about their practice. She argued, echoing the voices of others (e.g., Calderhead, 1991), that "experience is not instructive in and of itself", and that the processes and forces that render experience either "meaningful, useless, or even mysterious" (p. 218) must not remain unexamined. She placed responsibility on those who oversee student teachers, for "[their] official and practical orientations . . . are significant in that they work to inform, position, and fashion student teachers and their 'teaching' in both practice and theory. They do this by valuing particular practices as desirable and necessary" (p. 219). As Crawford put it:

> *The experience itself would have been a total waste of time except for realizing that basically I was compromising myself in the end to get the grade, in order to be able to get a job and support my family or not have to retake the course again. And that's probably the best lesson that came out of it.*

Interestingly, even upon realizing that he had compromised his conceptions to the point of momentarily forgetting some of them, Crawford stood convinced that remaining pragmatic would be the only way out of the experience for him. Crawford came full circle in his conceptions, but not in the classroom implementation of those same conceptions for reasons previously discussed. Ironically, he became living proof of the dichotomy between theory and practice which he so much criticized in his own college education, but from his standpoint there were no viable alternatives.

Participants' conceptions of teaching science

In the interest of space, we elected to summarize below three areas of the findings yielded by the data analysis, namely, participants' rationale for instruction, conceptions of student learning, and favored instructional strategies.

Rationale for instruction: Helen's rationale for science instruction seemed strongly influenced by her implicit understanding of science as an academic discipline. From her collective data set we gleaned that her purposes for teaching science were chiefly to foster student appreciation of scientific phenomena, skills, and technological applications of scientific knowledge in their daily lives, and for students to achieve a degree of self-fulfillment from exposure to it. On the other hand, Crawford's conceptions had a different base:

> *A lot of these [requirements for the student teaching experience] have to do with cognitive development of students, whereas when I'm a teacher I think that one of my primary aspects as a teacher is to get not so much to develop the students' cognitive . . . . ability, but more to focus on their . . . moral . . . [development].*

For him, teaching was a mission whose ends lie beyond scientific literacy. His ultimate goals in teaching were more holistic than academic, as they entailed facilitating students' development to their fullest potential, helping them to become responsible citizens and better human beings. From his perspective, teaching science was just a means to facilitate reaching those ends, content matter becoming a backdrop to a larger goal. Therefore, he described himself being more a facilitator than a disseminator of scientific knowledge. In other words, while for Helen scientific content and skills seemed to be ends in themselves, for Crawford these were just means to farther reaching ends of societal improvement.

Perhaps due to her underlying rationale, Helen repeatedly expressed strong reservations against the textbook approach to content presentation. Although Helen underscored applications of the content as an essential pedagogical tool, she clearly favored an approach opposite to the one taken by ChemCom (American Chemical Society, 1988); she would rather give priority to the concepts, proceeding then into the content applications as we can glean from the excerpt below:

> *One of the problems I ran into was that the course I'm working with is not set up the way a* **normal** *[emphasis added] chemistry course is set up, where the concepts are what is taught. This is more the application . . . so you have to actually supplement with the concepts. If you would look at our book, the chapter I just got done working on was conserving chemical resources. And the chapter before that was water. So they're all based on applications and within that are the concepts like the periodic table, writing equations, balancing equations, that type of thing . . . . I definitely like them being exposed to a lot of applications but I don't like the way this book does it. . . . I think it's too hard* Her disagreement with the approach used in the textbook, in presenting chemistry content matter went unchallenged for the duration of the data collection period,: *for them [students] to understand. Like it was hard for me reading the book [ChemCom] what they were getting at. I am big on applications but I think that if you have the concepts and you supplement the concepts with applications instead of the way this book does it where they have the applications and they're supplementing with concepts, I think that would work a lot better because talking with the students, I don't think they get the point of what they're doing. . . This book, I think it just goes about it wrong. I agree with the intent of the book, I just don't agree with the way they do this." (12/12/95, cat (6)).*

She argued that, by prioritizing applications and societal issues, ChemCom failed to include an in-depth coverage of the concepts, requiring her to spend additional time preparing lessons that compensated for the lack of conceptual depth she perceived in the textbook. For Helen, delivering detailed factual and procedural information about the concepts being covered was an enrichment to the textbook material that she believed was indispensable for her lessons and the content to make sense to students. For Helen, a chemistry course that placed more emphasis on science-related societal issues and concept applications as opposed to academic concepts was at odds with her overriding concern of providing students with a strong conceptual background.

Helen's dissatisfaction with the textbook approach to presenting chemistry content matter went unchallenged for the duration of the data collection period. Helen explained her dislike for the textbook based on her perception of how a "normal" chemistry course is organized. Even though the rationale for the textbook approach is based on contemporary visions of scientific literacy for the general population (American Association for the Advancement of Science, 1989; National Science Teachers Association, 1990, 1991), Helen was not prepared to find it sensible.

Helen admitted that her own experience as a student was limited on practical applications of the conceptual information, even though her academic background was exemplary by all accounts. This made it difficult for her to bridge the gap between concepts and their respective everyday applications. It seemed as if she herself was the result of curricula which stressed academic aspects of science in detriment of its everyday applications and societal relevance. Because she realized the importance of applications, she focused significant instructional time and lesson planning on filling this gap in her own knowledge.

Student learning: Both participants' conceptions of learning were strongly related to the constructs of student motivation and interest, although in different ways. It appeared as though both had come in with expectations about students' interest and motivation to learn science that were not met by their experiences. At the outset of the field experiences both Helen and Crawford seemed somewhat surprised upon realizing that many students were not as eager to excel as they might have expected. The generalized lack of interest amongst her students puzzled her:

> *Most of them are happy with passing. We gave out grades the last day of the marking period before their report cards were issued and all I heard was, 'yes, I passed.' It wasn't 'oh, I've got an A or B.' It was 'I passed' . . . . I don't know if it's just a bad batch of kids. That's all they're motivated for, is passing.*

Helen accounted for that as a "bad batch of kids", and she tended to rely on the notion that students' interest could be regulated by the types of teaching strategies and activities chosen by the teacher. On the other hand, Crawford discussed the emotional and conceptual development of students, as well as the schooling process itself, as reasons for students' low expectations for their own achievement. The following excerpt addresses some of his thoughts on this issue:

> *I think the idea of a scientific concept is new [for these 7th graders] for the fact that all the way from kindergarten through 6th grade everything's been . . . fact or a procedure, . . . and I don't think they've really been required to have a lot of abstract thought about scientific processes. (12/15/95, cat (6))*

Crawford reasoned that, when students are so used to facts and procedures that they seldom practice reasoning skills entailed in comprehending scientific concepts in breadth and depth, they become overwhelmed by the abstract nature of scientific concepts, which in turn can easily result in disruptive behavior on their part.

Crawford pondered that his teacher-centered, fact-oriented way of teaching during the student-teaching experience was not engaging enough to keep students interested in the subject. Because many students were naturally turned off to the excitement of scientific discoveries and learning in general, they needed additional reasons to feel motivated to learn science:

> *I think that with the role you're playing, this being a fact and procedure type of person, that's automatically the role you're going to fall into, a baby-sitter, because you know that's what the kids are used to. Without doing these other things . . . [like] challenging their understanding and trying to get them to want to understand things at a higher level, without doing that the students aren't going to be interested in learning or understanding or anything like that. So then they go back to doing what they want to do and that's basically . . . [socializing] or whatever. That's where you end up being a baby-sitter, and that's a role I [frequently] found myself in.*

Therefore, Crawford believed, schooling itself, in many instances, contributed to students' discipline problems.

Both Helen and Crawford struggled, although at different levels, to make sense of constructivism and conceptual change teaching in a manner that would make them functional in their classroom practices. Helen's understanding of the notion of constructivism seemed to be somewhat limited to an awareness of the need to address students' preconception; she reported that throughout her experiences in the classroom this had hardly been an issue, thus she did not explicitly think of constructivism as a framework when planning instruction for conceptual understanding:

> *If I run into a lot more people that I see are coming up with their own conceptions about things, I think I would change a lot to incorporate that idea more, constructivism. But in all this stuff that I've done, it hasn't been such a problem to me to make me think that it's a priority right now.*

At points, Helen did seem to picture constructivism and teaching for conceptual change as two intertwined concepts. However plausible these notions may have been for her, though, she did not feel compelled to explicitly incorporate them as part of her teaching philosophy because of the limited usefulness that they had had in her teaching experiences. Other items, such as the teacher's content knowledge and ability to explain, students doing group work, and including applications of content, ranked much higher than constructivism in her views about good science teaching. It is possible that these items were more tangible and readily applicable to Helen's teaching practice at the time.

Likewise, Crawford agreed with the need for addressing students' preconceptions; however, he thought that constructivism was limited as a framework for instructional planning due to its focus on academic learning, which is not what he wanted to emphasize:

> *[I agree that constructivism is] a useful tool for teachers in a way, but I don't want my students to be motivated and feel that their cues are coming from that kind of mindset. I want them to realize that I think that they have a soul, [that] there is innate good in people . . . . I think it does [provide] a better explanation [of learning than behaviorism] in a way. . . . But to have that as your core philosophy. . . . It's not for me and I don't think it should be really for any teacher.*

Yet, because he felt unable to effectively incorporate his conceptions into his practice, he reasoned that he basically did not have enough impetus or feedback that would have prompted him to rethink or refine any of them. Crawford's experience, particularly the student teaching segment, was a continuous struggle against the constraints which he perceived forced him to teach in ways that went against his espoused conceptions of teaching and learning science in order to succeed in the eyes of his evaluators. However, the resistance and disagreements that he encountered did not cause him to question or abandon his earlier conceptions. Rather, he held onto them while dismissing both the supervisor's and the cooperating teacher's demands as too strict and unreasonable or pedagogically inappropriate.

Instructional strategies: Helen and Crawford differed in their underlying images of science pedagogy. Helen emphasized the need for group activities to foster understanding and applications of chemistry concepts while minimizing misbehavior by keeping students involved in the task at hand. Because she thought that the structure of typical chemistry courses could be too arid for students, she tried to break free of the traditional mold by minimizing lectures, varying activities, and assigning tasks that involved students in creative designs and forms of self-expression. On the other hand, Crawford placed emphasis on activities that could highlight the historical development of scientific knowledge and the connections of this knowledge to other realms and disciplines. In addition, such activities, he wished, would help students to see the value of this knowledge for their lives in that they could not only better understand the natural and technological world around them but also the human activities that impact, and in turn are impacted by, the natural world. He also wished to relinquish some control of the classroom to the students.

Helen perceived her classroom practice as largely consistent with the conceptions she espoused, although the interviews highlighted some inconsistencies that she dismissed at the time. As a result, Helen seemed to have acquired progressively more sophisticated teaching and managerial skills, experimenting with a variety of instructional strategies, and positively succeeding in the eyes of her evaluators. Other than that, she admitted that most of her conceptions about learning and teaching science remained stable, only she became more proficient at implementing them.

Conversely, lessons which Crawford delivered and criticized as not pedagogically appropriate received high marks from his evaluators; the constraints imposed on him, real or perceived, forced him into a role which he thought was not in tune with his underlying philosophy. He preferred to search for ways in which he could touch the students at such profound levels that resulted in them becoming naturally interested to learn science. In summary, while Helen's conceptions of pedagogy were based on the notion of learning as activity-driven, Crawford pictured learning as soul-driven, resulting in contrasting approaches to their respective classroom roles: she was a disseminator of scientific knowledge, whereas he was a facilitator of students' holistic development.

It appeared that the participants' experience lacked the outside challenges and support that might have prompted them into rethinking and re-evaluating their pedagogical conceptions and practices. Grossman's study (1990) comparing the development of English student teachers both with and without formal teacher preparation highlighted the issue of new teachers' implicit assumptions about students' learning. She argued that:

> Without help, teachers may learn to blame the students for not learning . . . rather than to rethink their own assumptions about [teaching and learning]. . . . This potential mismatch between teachers' implicit assumptions about students and the realities of their own students' abilities and interests may lead . . . to instances of mislearning (p. 142).

While both Helen and Crawford evidently had formal teacher preparation, it is interesting that in their minds each appeared to come to terms with the issue of student learning with different outcomes. This highlights the need for consistently challenging encouragement so preservice teachers can clarify previous assumptions about students' learning and desirable practices.

Participants' conceptions about the nature of science

Helen never explicitly brought up during the interviews her conceptions on the nature of science. The data set for Helen was virtually void of references to how she either perceived science or wanted to portray it to her students. Her apparent lack of concern with intentionally providing students with a well informed stance on the nature of scientific knowledge seemed to indicate that she understood science as both an uncontroversial body of knowledge and a set of scientific reasoning skills and processes used to gather that knowledge. Crawford, on the other hand, went further:

> *It's the Carl Sagan quote I like so much . . . something along the lines that science is not a body of knowledge but a way of thinking, and the fact that you might know something now as far as accepted by science, but in year it might change.*

He held a view of science as a human enterprise, with virtues and limitations, as one set of lenses through which humans can attempt to understand, and interact with, the natural world. He showed an awareness of the ever-changing nature of scientific knowledge, as well as a less-than-idealistic stance on the nature of scientific activity vis-à-vis societal issues and needs.

Teachers' naiveté about issues related to the nature of science can lead to the perpetuation of pervasive misconceptions on this topic amongst school students. Scientific knowledge in many domains consists of formal constructs and the relationships proposed to exist between them, which are validated by the scientific community (Driver et al., 1994). Science teachers need to be aware that standard science textbook accounts are but the result of negotiation of meaning within the scientific community and that school science can not be equated with providing "unproblematical access to 'the way things really are'" (Millar, 1989, p. 43). Russell and Munby (1989) argue that science teachers should be sensitive to the fluid nature of scientific knowledge for it is characterized by human "attempts to capture the essence of phenomena with available language [and constructs]" (p. 114). They caution against the pitfalls of coursework implying that science "provides the correct way to organize our perceptions of the world. . . . [as opposed to viable] constructions of the world" (p. 109). According to these authors, it is essential for science teachers to give students the opportunity to witness and participate in the intellectual effort that gives origin to particular scientific constructions--or viable explanations--about natural phenomena. For instance, when a science teacher wants to assist students in moving from observations to conclusions about a natural phenomenon, such process should be based not on assertions that may have no logical conceptual basis for students, but on legitimate scientific arguments. Legitimate scientific arguments are those which provide warrants that allow students to see the relationships between a scientific construct and observational data. Such warrants allow students to, for example, "understand how a category system is built and then legitimated by its usefulness as a conceptual tool" (p. 111).

> It is important in science education to appreciate that scientific knowledge is both symbolic in nature and also socially negotiated. The objects of science are not the phenomena of nature but constructs that are advanced by the scientific community to interpret nature. (Driver et al., 1994, p. 5)

Indeed, the National Science Education Standards (National Research Council, 1996) call for science teachers who can help students develop a sophisticated understanding of science as a human activity, of the nature of scientific knowledge, and how the historical development of ideas in science can be influenced by the values, ideas, and resources available in the society at large at any given time.

It appears that little was accomplished during the field experiences that might have encouraged Helen to re-examine and perhaps broaden her understanding of the nature of science--a process which, one can argue, is essential throughout the preparation of a science teacher. Brickhouse (1990) has convincingly documented how science teachers' conceptions of the nature of science can, both explicitly and implicitly, shape the way in which they frame their curriculum and instruction. Thus, it is probably safe to assume that in Helen's case her limited perspective on the nature of science strongly influenced other domains of her conceptions, e.g., her conceptions on the purpose of teaching secondary science, her rationale for instruction, and the way in which she implicitly portrayed science to her students. Crawford, on the other hand, although bound by the constraints which he perceived in his situation, frequently brought up during interviews remarks related to his attempts to convey to students a well-rounded perspective on the nature of science.

Discussion

Driver, Asoko, Leach, Mortimer, & Scott (1994) challenge the "non problematic portrayal of the knowledge to be acquired" (p. 11) in science classrooms. They argue that science teachers should endeavor to foster

> a critical perspective on scientific culture among students. To develop such a perspective, students will need to be aware of the varied purposes of scientific knowledge, its limitations, and the bases on which its claims are made. A crucial challenge for classroom life is therefore to make these epistemological features an explicit focus of discourse and hence to socialize learners into a critical perspective on science as a way of knowing. (p. 11)

Their concern finds echoes in the broader teacher education literature. Britzman (1991) pointed to the pitfalls of teacher education programs where prospective teachers are led to treat curriculum knowledge as a given, rather than as problematic. Knowledge that is taken up as given is limited because of its presentation

> as unencumbered by the problem of construction, interpretation, or subjectivity. In counter distinction, knowledge as problematical posits a tentative view of knowledge as socially constructed, subject to political, economic, social, and cultural forces, and contingent upon communities of discourse, relations of power, and social change. (p. 48)

When how to teach conceals the more difficult questions of what to teach and why certain strategies are suitable, prospective teachers may lack opportunities for identifying and examining connections among pedagogy, content, and social interactions (Britzman, 1991). According to Driver et al. (1994),

> the view of scientific knowledge as socially constructed and validated has important implications for science education. It means that learning science involves being initiated into scientific ways of knowing. Scientific entities and ideas, which are constructed,

> validated, and communicated through the cultural institutions of science, are unlikely to be discovered by individuals through their own empirical inquiry; learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level. (p. 6)

Grossman (1990) argued that classroom experience alone is unlikely to help prospective teachers rethink their subject matter from a more pedagogical perspective. According to Grossman, this task is not an automatic one, for prospective and beginning teachers may not be prepared to reconceptualize on their own their purposes for teaching their subjects. "While prospective teachers can learn much from their field experiences, they do not seem to develop new conceptions of teaching their subject matter from classroom experience alone" (p. 143). Teacher educators who are aware of this difficulty should thus attempt to explicitly provide learning opportunities that might facilitate this transition, and conceptual change approaches have potential for success in this task (Hewson et al., 1994).

Teaching based on a conceptual change approach recognizes that learning does not happen by merely adding new knowledge to what the learner already knows; learning depends upon the nature of the interactions between old and new knowledge, and the outcomes of the learning process hinges upon the nature of the interactions (Hewson et al., 1992). A key element in this process is the notion of status of a conception. According to Hewson (1996), "status is a measure of a learner's acceptance of, or preference for, an idea, new or old" (p. 132). Hewson's model suggests that conceptual change happens when the status of inappropriate conceptions is lowered, while the status of more appropriate ones is raised. To facilitate this process, teaching must deliberately target learners' pre-existing conceptions by first promoting dissatisfaction with current conceptions (thus lowering their status), and then fostering the exchange of these conceptions by new ones which are intelligible (learner understands what it means), plausible (learner believes it to be true), and fruitful (learner finds it more useful to solve problems than previous conception) (Hewson, 1996; Posner, Strike, Hewson, & Gertzog, 1982).

Clearly, the participants of this study were learners of teaching science. In considering a conceptual change model to explain their development during their field experiences, one can note that the conceptual change learning cycle for the participants was not satisfactorily completed in a number of crucial instances. For example, with respect to the notion of using constructivism as a framework for their practice, it seemed like both participants' appeared to understand what constructivism meant, they found it plausible, but both had grounds not to find it fruitful. Likewise, Helen might have been helped to raise the status of alternative conceptions on textbook appropriateness, and as a result she might have come to see the approach taken by the textbook as a fruitful one. The experience with the textbook was dissonant, but not enough to cause her to reconsider her conceptions.

This study has reinforced previous research findings which indicate that practice alone doesn't necessarily lead to development towards enhanced understandings amongst prospective teachers (Britzman, 1991; McIntyre et al., 1996). If a science teacher education program is interested in preparing future teachers not to adapt to current school cultures, but to challenge traditional practices and work for educational reform, then the critical aspects should not be separated from the technical and practical, for "teacher education must help prospective teachers see the interdependence of management and educational goals" (Grossman, 1992, p. 175). Grossman pointed to recent developments in cognitive psychology which challenge prevailing "hierarchical models of learning in which skills instruction must precede higher order thinking" (p. 175). By addressing the critical, teacher educators are not "necessarily violating alleged 'laws' of student teacher development" (Gore & Zeichner, 1991, p.124).

Grossman (1992) challenged models of teacher development, such as Kagan's (1992), that overrate mastery of procedural routines at the expense of theoretical knowledge, because such models presume that preservice teachers are not developmentally ready for critical reflection. Grossman argued that overemphasis on management might reduce novices' thinking to the level where management choices dictate the academic environment, rather than vice versa. Likewise, Britzman (1991) argued that when a teacher preparation program focuses on how to teach as opposed to what and why to teach a given subject, one finds that student teachers tend "to look to teaching methods as the source rather than the effect of pedagogy" (p. 227). This "methods as ends" approach to teacher preparation, she argued, "reduces the complexity of pedagogical activity to a technical solution and 'forgets' that methods are a means for larger educational purposes" (p. 47).

Munby and Russell (1994) also addressed the tension between practical and theoretical knowledge in teacher education. Like Kagan (1992), they found disenchantment with foundations courses and a desire for more specific practical knowledge among education students. Munby and Russell claimed that universities have traditionally undervalued the legitimacy of practical knowledge as opposed to theoretical knowledge. As a consequence, teaching practice typically comes after theory and methods courses. They argue that the old notion of practica as putting theory into practice has outlived its usefulness and needs to be reexamined. According to Munby and Russell, rather than putting theory into practice, using practice as a means to better reflect upon theory might be more instrumental--"what preservice candidates lack is direct experience of teaching and appropriate frames for thinking about that experience" (p. 4). Schön (1987), from whom Munby and Russell derived their views, argues that the framing of practicum settings solely as the application of theory previously learned causes a dichotomy that is artificial and arbitrary, for it leaves little room for practice-based research. Schön talks about the notion of a reflective practicum, which in a school of education should encourage prospective teachers to

> think of their teaching as a process of reflective experimentation in which they try to make sense of the sometimes puzzling things children say and do, asking themselves, as it were, 'How must the kids be thinking about this thing in order to ask the questions, or give the answers, they do?' (p. 323).

An assumption upon which the present discussion was premised is that "development of teacher thinking requires more than mastery of certain teacher behaviors associated with student achievement. It requires involvement of student teachers in critical, reflective thinking about their work" (Bolin, 1988, p. 48), along the lines of an inquiry orientation to teacher education. Additionally, it is assumed that prospective teachers should move towards a view of teaching science for conceptual change, as this has been proposed as a highly desirable view of teaching science (Gunstone & Northfield, 1992; Hewson & Hewson, 1988; Hollon et al., 1991). This assumption is compatible with the inquiry orientation previously described, for "the purpose of conceptual change teaching is . . . to help students [or learners in general] form the habit of challenging one idea with another, to help students develop appropriate strategies for having alternative conceptions compete with one another for acceptance" (Hewson, Zeichner, Tabachnick, Blomker, & Toolin, 1992, p. 4).

A significant implication from this study suggests that science student teachers require special support and time to be able to clarify and enact their conceptions of teaching science. According to Brickhouse (1990),

> teacher education will make little impact on practice if beginning teachers are unable to implement instruction consistent with their beliefs about science. If the environment places constraints on teachers' knowledge and thereby plays a role in its development, we must influence this environment so that it allows teachers to be powerful practitioner of their professions (p. 60).

This kind of support involves intensive classroom inquiry and a mentoring process tailored to the future teacher's needs. Student teachers would likely benefit from opportunities to explore dilemmas that constrain the achievement of current visions of good science education.

Implications and Recommendations for Practice in STE

It is reasonable to assume that one of the goals of field experiences is to facilitate prospective science teachers' moving towards more complete understandings of science teaching and learning, in particular of the types of goals that are espoused in contemporary visions of science education. In that sense, field experiences could provide an ideal context for encouraging prospective science teachers to re-examine their conceptions of teaching science from a pedagogical perspective. This could help them further develop their conceptions of what it means to teach their subject to school students, as well as to explore the consequences of different conceptions and their connections with larger educational issues (Grossman, 1990).

Focusing field experiences on the mastery of predetermined behavioral goals may pose barriers to the preparation of reform-minded science teachers. Instead, field experiences ought to be an extension and reinforcement of what the teacher education program advocates in terms of teacher change towards constructivist approaches. To accomplish this, it is essential that prospective science teachers be treated as learners and be taught according to the best available knowledge on teacher learning. Involving them continuously in challenging their own understandings in light of new ones while providing encouragement and collegial support lies at the heart of conceptual change pedagogy.

True, it has become such a commonplace to suggest that learning to teach science for conceptual change is itself a conceptual change process that it masks the complexity of the change process (Hollon et al., 1991). Borrowing from Nichols, Dana, & Briscoe (1992) and Hollon et al. (1991), we propose here five guiding principles that might be useful for science teacher educators in designing teacher education programs that take this process into account:

(1) The program should effectively address prospective teachers' previous beliefs about teaching and learning science, including their conceptions of the nature of science and of the purposes for secondary science instruction. For instance:

(a) coursework and associated field experiences should emphasize a view of learning science as a resolution of dissatisfaction caused by inconsistencies between old and new knowledge. Consistently, from this perspective knowledge is seen as internal to the learner as opposed to an entity that exists outside of the learner and can therefore be transmitted intact;

(b) the program should frame science teacher learning as a process in which previous knowledge of science pedagogy is deconstructed and replaced with viable alternatives whenever necessary. Consistently, field experiences should be orchestrated around opportunities for deconstructing prior knowledge and building new understandings through testing and reformulation of old and new ideas about science teaching and learning;

(c) coursework and field placements alike should shed the notion of science as a body of knowledge to be transmitted, replacing it for an approach to teaching science as offering opportunities for students to make sense of scientific ideas and consider the applications and implications of the newly constructed knowledge in their lives.

(2) The program should consistently strive to stimulate and model an inquiry-orientation among prospective teachers.

(3) The program should strive for congruence between the pedagogies it advocates and the strategies used to teach those pedagogies; in other words, the program should be organized around a conceptually coherent framework that well dovetails means and ends. Constructivism and conceptual change should be included in this framework.

(4) Individual differences and developmental needs among prospective teachers should be acknowledged, and supervisory and mentoring activities should take those into account;

(5) Preservice teachers work environment must encourage conceptual change and inquiry-oriented teaching through modeling and guided practice. Institutional and collegial support are critical in bringing about risk-taking behavior and the learning that generally ensues from taking risks.

In essence, prospective science teachers need opportunities to confront their beliefs, to render problematic otherwise taken for granted assumptions about aspects of schooling, and to visualize and accomplish new images of science instruction that are consistent with pedagogies that take a "learning approach to teaching" (Lambert, Collay, Dietz, Kent, & Richert, 1996, p. 168).

To ensure that student teachers are challenged to develop habits of introspection while close supervision and support are available, Bolin (1988) suggested that supervisors and cooperating teachers model inquiry oriented ways of thinking to assist student teachers in dealing with the most complex issues. One such way that has been advocated over the past four decades is action-research. More than problem-solving, action research can be understood as a problem-posing approach to teaching in that teachers are encouraged to identify and pursue problems in their own practices and situations and to systematically use the information gathered to inform and improve their practices and, it is hoped, the institutional contexts in which they operate. Action research is less a method of research than it is a view of teaching as a way of inquiry and experimentation (Hewson et al., 1992). It does not merely entail thinking and processing of ideas, but it implies teachers taking actions in the classroom and subsequently examining the consequences of those actions (Tabachnick & Zeichner, 1994).

A number of teacher educators have recognized the need for establishing such habits of self-monitoring amongst prospective teachers, thus enabling them to carry on the dispositions and skills that can help them to continuously learn from experience and improve their practice as a result (Gore & Zeichner, 1991). To help student teachers increasingly broaden the scope of the issues they consider in their deliberations, Gore and Zeichner introduced action research in the student teaching curriculum at the University of Wisconsin-Madison. There, the final practicum experience was framed as "an investigation of teaching and its social conditions" (p. 126), and action-research projects were presented as a way for prospective teachers to research and improve their own practice and contexts. Results were not as dramatic as Gore and Zeichner had hoped for, which they attributed in part to students' mostly "unpoliticized view of teaching and schools" (p. 126). Yet, in general, action research seemed to have at least raised students teachers' awareness of their own practices and the gaps between their beliefs and practices. Gore and Zeichner thus urged teacher educators to assist student teachers in bringing to the foreground their tacit assumptions and to challenge them to become increasingly analytical about their situations.

Action research projects have been introduced at the University of Wisconsin-Madison also in an attempt to help prospective science teachers move towards a conceptual change approach to teaching science (Tabachnick & Zeichner, 1994). The authors remind us that "the continual challenge and monitoring of teaching-learning and its consequences [characteristic of action research] are analogous to a conceptual change model of teaching science" (p. 4). Student teachers in their case study developed a greater awareness of the need for understanding their students' thinking and of the limitations of written assessments of student knowledge. Yet, this newly gained awareness did not induce corresponding changes in the student teachers' practices; their practices seemed oriented by a view of teaching science that remained, in most cases, one of imparting a body of knowledge to their students. Like Hollon et al. (1991), Tabachnick and Zeichner found that the translation of conceptions into practice hinges upon a number of contextual variables.

Tabachnick and Zeichner (1994) speculated about the factors that might have undermined their efforts. They admitted that student teachers held onto non constructivist views of learning despite concerted efforts of the staff to model conceptual change approaches during the methods courses. In addition, student teachers seemed to lack an in-depth and cohesive conceptual understanding of the subject matter, possibly due to the fact that subject matter courses are typically taught in ways not compatible with a constructivist orientation. Another obstacle to student teachers' use of conceptual change teaching might have been the fact that conceptual change teaching strategies were not consistently modeled by cooperating teachers during the field experiences. Further, in the settings where their experiences took place there was pressure for swift coverage of the prescribed curriculum. Therefore, to facilitate student teachers' incorporating conceptual change approaches into their teaching, Tabachnick and Zeichner urged science teacher education programs to address the nature of the subject matter courses as well as the lack of modeling of conceptual change approaches in school placements.

Another related example is the case study of an experienced science teacher carried over a four-year time span, during which the teacher began to gradually and deliberately reconstruct his conceptions and practice upon consistently challenging self-inquiry as part of an action research team (Tobin, Tippins, & Hook, 1992). The length of time involved in this process suggested that consistency and collegial support over an extended period of time are desirable in helping the reconceptualization process take place.

In considering specific recommendations to guide the design of science teacher education programs and associated field experiences, it may be helpful to think in terms of two main organizers, namely, the ends of science teacher education, and the means science teacher educators might use to accomplish those ends. If a science teacher education program wants prospective teachers not only to learn teaching strategies and procedures, but also to entertain new modes of thinking about teaching, to be self-directed problem-solvers and critical thinkers, and to develop an inquiry-orientation towards their own teaching, then the means chosen by the program must be compatible with these ends.

If we assume that science teachers' classroom decisions and actions are guided by their conceptions of learning and teaching science, then one desirable aim (end) for science teacher education is to have prospective science teachers develop towards constructivist views of learning. Therefore, prospective teachers should be engaged in activities (means) which assist them in developing such conceptions. To guide the design of such activities it is useful to consider a constructivist, conceptual change view of learning (Hewson, 1996). Specific ways that a hypothetical science teacher education program might consider in incorporating the aforementioned guiding principles while dovetailing ends and means are suggested below.

a) Organizing field experiences around a conceptually coherent framework

In this hypothetical program, the faculty involved in the clinical components of the teacher education program works collaboratively in planning, implementing, and assessing a sequence of activities and assignments, building upon a conceptually coherent framework that includes constructivism and teaching for conceptual change, as well as an inquiry orientation. As suggested by Dr. Russell Yeany during his presentation at the 1993 meeting of the National Association for Research in Science Teaching, there ought to be a "seamless connection" between university coursework and field experiences. That is, there is no visible delineations or boundaries between universities and schools were the field experiences take place. For instance, at the beginning of the program, each teacher candidate is assigned to work with a mentor teacher or professor, who follows his or her development through completion of the program, field experiences included (e.g., Hollon et al., 1991).

Supervisors and cooperating teachers not only advocate conceptual change strategies, but also model them in their own teaching. Supervisory/mentoring strategies are based on the premise that the kinds of questions a teacher asks of his or her own work "shape the nature and meaning of what is seen" (Carter & Doyle, 1996, p. 124). Activities and assignments encourage prospective teachers to deconstruct prior knowledge and images of teaching and learning and to consider conceptions that are based on a constructivist framework (Nichols et al., 1992). Prospective teachers are also continuously challenged in their conceptions of their purpose for teaching secondary science; as Grossman (1990) pointed out, prospective teachers must learn to "rethink their disciplinary assumptions about subject matter, as they consider the goals and purposes of secondary school subjects" (p. 16). An inquiry disposition permeates activities and assignments carried out during clinical experiences.

Strategies like the "critical incident technique" (Brookfield, 1995) seem to hold potential for successfully facilitating this type of development among prospective teachers. Brookfield has used several variations of his critical incident technique to foster reflective thinking and collegial relationships in his college classes. The technique consists, essentially, of either questionnaires or group work that are designed with the purpose of getting respondents/participants to focus on the meaning, assumptions, and personal and pedagogical implications of concrete events that occur in classroom environments.

Other viable strategies include, but are not limited to: revisiting prospective teachers' views of the nature of science; designing, conducting and analyzing clinical interviews; action research projects amongst student teachers (Hewson et al., 1992; McDiarmid, 1990; Trumbull & Slack, 1991); learning a content area topic through a conceptual change strategy (Stofflett, 1994); observing and deconstructing non-traditional classrooms (McDiarmid, 1990); designing, implementing and assessing a thematic curriculum unit (Goodman, 1991); engaging prospective teachers in writing up their own case studies of educational events (Richert, 1991); intensive journaling; and professors modeling of risk-taking behaviors (Gunstone & Northfield, 1992).

Teacher candidates are required to develop an ongoing professional portfolio, which they start upon entering this hypothetical teacher education program. It has been argued that the process of compiling a portfolio affords learners a vehicle for synthesis of theory and practice, reflection, and self-assessment (Barton & Collins, 1993; Richert, 1992). The introspection required in the process can help prospective teachers to confront their own self-images as learners and teachers. Through reflection, they also become more aware of their strengths and weaknesses.

As they progress through the program, prospective science teachers develop their professional portfolio to provide ongoing evidence of certain skills, knowledge, and dispositions required by the program. From time to time, they share their developing portfolios with their peers for input and support, building up a collegial environment. In addition to presenting evidence required by the program, teacher candidates design a personal learning plan, with input from their mentor, wherein they define and pursue problems and goals of their own. This attribute of the portfolio requirement is particularly compatible with the program orientation towards inquiry. Teacher candidates turn in the portfolio at pre-established checkpoints during the program, so that the faculty can monitor their progress towards the goals of the program and provide timely feedback and interventions whenever necessary.

b) Optimizing the structure of field experiences

The structure of field experiences in this hypothetical program is reworked so that they can better fulfill their educational potential. Prospective teachers are provided, from the time of acceptance into the program, with opportunities for continuous involvement in closely supervised teaching experiences in optimal school settings. Field work is less intensive and spans over a longer period, freeing up more time for planning and reflection and therefore making experiences less overwhelming (Bullough & Gitlin, 1991) and more meaningful in the prospective teacher's overall development. Earlier field work is carried out concurrently with science methods and general pedagogy courses, allowing for better integration of theory with practice (Yager & Penick, 1990) and for earlier development of the procedural skills so essential for prospective teachers (Kagan, 1992). Scheduling and sites are designed so as to encourage the development of collegial relationships amongst those connected to the field placements.

To be consistent with the program inquiry orientation, supervision of prospective teachers in the field is no longer merely evaluation driven, but centered around reflective coaching principles and goals. Assessment of field work is no longer based solely on pre-established performance criteria, as this tends to foster conformism and intellectual passivity (Bullough & Gitlin, 1991) given student teachers' vulnerable position.

Since the cooperating teacher's role and supervisory training have been strongly associated with the quality of field experiences (Glickman & Bey, 1990; McIntyre et al., 1996), the university recruits and rewards cooperating teachers who can be good role models, who work towards promoting reform oriented goals in their science classrooms, and who are knowledgeable about, or willing to be trained in, clinical supervision skills. Given student teachers' different developmental needs, they may benefit from clinical supervision based on a developmental approach (Glickman, 1990; Kagan & Warren, 1992).

To ensure that student teachers are challenged to develop habits of introspection while close supervision and support are available, university supervisors and cooperating teachers model more mature ways of thinking to assist students in dealing with the most complex issues (Bolin, 1988; Erickson & MacKinnon, 1991). As an illustration, Cavallo and Tice (1993) reported some encouraging findings as a result of a systematic problem-solving approach to supervision with science student teachers. Student teachers had the primary responsibility for identifying a problem area to be pursued, proposing viable solutions, implementing them, collecting and analyzing data on the effectiveness of solutions attempted, and reporting conclusions. Supervisors acted as guide and facilitators, so that student teachers gained experience in addressing concerns and pursuing solutions on their own. Indeed, this type of assignment resembles action research projects, which have been advocated by Hewson et al. (1992), Bullough and Gitlin (1991), Noffke and Brennan (1991) and others, to bridge the gap between theory/research and practice and promote reflection and conceptual change among prospective teachers. Action research can also be an empowering tool as it helps future teachers see themselves not only as consumers but also producers of educational research (Noffke & Brennan, 1991). Interactive journaling between student teacher and supervisor or cooperating teacher can also provide a vehicle for encouraging critical reflection (Bolin, 1988). Kagan (1992) herself found that presence of role models engaging in reflection, and opportunity to experience cognitive dissonance mediated changes and prospective teacher development. Again, Crawford's relationship with his thesis advisor (detailed in Bradford, 1997) stands as an example of the feasibility of such processes.

Implications and Recommendations for Research in Learning to Teach Science

This case study of two participants' experiences makes a strong argument for the implementation of a student teaching mentoring process that is predicated on sound principles of clinical supervision. Such process would likely facilitate student teachers' development towards current reform-oriented visions of learning and teaching science by providing a supportive atmosphere for teacher reflective thinking and growth. Further research that examines the potential of a reflective coaching process in the context of field experiences of prospective science teachers might be fruitful in this regard. Reflective coaching is a clinical supervision model whereby teachers' understandings of their own teaching are explored, in a collegial, non-evaluative setting, for the purpose of nurturing reflection, enhancing practice, and facilitating student learning (Nolan & Hillkirk, 1991). Based on the premise that instructional supervision should enhance teachers' own ability to modify themselves, this supervisory strategy is more concerned with expanding teachers' understanding of practice than with their mastery of instructional behaviors alone (Pajak, 1993).

Both supervisor and cooperating teachers might have wished to tailor their mentoring styles to the participants' unique backgrounds and personal traits. While Crawford was not yet a practicing teacher, he had the motivation and potential to continuously improve his classroom practice through critical reflection on his actions. As a result of a reflective coaching process he would likely gain valuable insights about his own thinking and teaching, possibly leading to the resolution of the seeming inconsistencies in his conceptions and practice. Indeed, the relationship between Crawford and his honor's thesis advisor (described in Bradford, 1997) stands as a good example of the potential of a mentoring process analogous to reflective coaching in bringing about student teacher reflection and growth.

Likewise, Helen might have benefited from a supervisory/mentoring process that would have helped her to question her own assumptions about teaching and learning science, as well as explore some of the gaps in her understandings and the inconsistencies in her thinking. For example, with appropriate coaching she might have come to develop a more useful understanding of constructivism as a unifying learning theory, one which might have helped her better integrate the notions of inductive models, conceptual understanding, and content applications. Or, by examining her views on the nature of science, technology, and their repercussions within society she might have been able to come to a more satisfying resolution to the conflict posed by the style of the textbook. She seemed ready for such a mentoring process, in which she would re-examine her beliefs and their implications for her practice.

Furthermore, reflective coaching can presumably lead teachers into a process of role metaphor exploration (Grimmett & Crehan, 1990), which in turn is a likely catalyst for teacher reflective thinking and growth (Tobin & LaMaster, 1995). Reflective coaching enables those engaged in the process to examine issues associated with teaching and learning while focusing on the science teacher's metaphorical understandings in an atmosphere that is not critical but supportive of the teacher's efforts to enhance practice (Grimmett & Crehan, 1990). Much of a teachers' pedagogical knowledge is based on tacit assumptions and taken for granted practices; therefore, teachers tend to assign meanings to events and behaviors in an effort to make sense out of their daily classroom experiences (Briscoe, 1991). In this regard, teachers' role metaphors have been a fruitful area of research. As Briscoe pointed out, "metaphorical language is an extraordinarily powerful linguistic tool through which a teacher can express more fully the meaning of what it is to be a teacher (1991, p. 186). A number of studies (e.g., Briscoe, 1991; Carter, 1990; Munby & Russell, 1990; Tobin & LaMaster, 1995) have indicated that both practicing teachers and student teachers can benefit from the use of role metaphors as catalysts to reconceptualize their teaching roles and as impetus for change. Indeed, although the participants' role metaphors was not the focus of this study, addressing those provided valuable insights into participants' conceptions and experiences. Further exploration of prospective science teachers' developing role metaphors and how they support or constrain their emerging practice might provide useful information in this regard.

Further research in which a discipline-specific supervisor plays the role of reflective coach/mentor in an action research context might also be enlightening. One might argue that, everything else being equal, a college supervisor with specific preparation in current visions of science education might have been able to discern and facilitate clarification of the rather subtle inconsistencies and nuances in participants' conceptions about teaching and learning science and, in turn, helped them develop further towards becoming exemplary science teachers.

This case study also highlighted the issue of prospective teachers' individual differences in their understandings of the nature of science and how these understandings can influence their practices. This is an issue which has been previously identified by previous empirical research (Coble & Koballa, 1996). For instance, MacDonald (1996) identified a gap in novice teachers' preparation, who seem generally unprepared to teach in ways that explicitly address the nature of science as an integral part of science instruction. Future researchers might wish to explore the potential of integrating coursework explicitly designed to address prospective science teachers' understandings of the nature of science and how these understandings either hinder or advance prospective science teachers' development towards constructivist-based pedagogies.

Time pressure on the part of participants during field experiences also was a factor in this study, which corroborated previous research findings (e.g., Bullough & Gitlin, 1991). Therefore, future researcher might wish to explore the feasibility of well-conceived and well-supervised field experiences that are spread over a more extensive period of time. For example, fifth -year science teacher education programs might free up additional time for early field work and for student teaching that spans over an entire year, conceivably facilitating student teacher development and growth over time.

Previous research comparing traditional and non-traditional teacher candidates--non-traditional being those students whose formal education for teaching presented a gap, either from pursuing another career or homemaking--found that these two groups differ considerably in their entering conceptions of teaching and how these develop (Richardson, 1996). This study seems to corroborate those findings. One can argue that tailoring programs and field experiences solely for the needs of traditional teacher candidates may shortchange non-traditional groups of students which are becoming increasingly represented amongst teacher candidates. Therefore, future researchers might wish to pursue the feasibility of programs that take into account group differences in the conceptual and developmental levels of teacher candidates that belong to different groups, such as Helen and Crawford.

Concluding Remarks

This case study indicated that a reconceptualization of the purposes and structure of field experiences of prospective science teachers like the ones reported here is in order. If we want these experiences to facilitate prospective teachers' development towards worthwhile ends, then content and structure ought to dovetail better with the goals of the teacher education program. While many obstacles exist, we remain optimistic that science teacher education programs can provide those "enabling conditions" (Erickson & MacKinnon, 1991, p. 34) that might facilitate the development of future science teachers towards conceptions and practices consistent with current visions of science pedagogy.

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