Why are we doing this? Preservice Science Teachers' Interpretations of the Role of Open Inquiry in Understanding Teaching

AHMAD QABLAN

The Hashemite University, Zarqa, Jordan

MARTIN BALINSKY, YAVUZ SAKA, SARAH CARUTHERS, MYOUNG-OK KIM, AND SHERRY SOUTHERLAND

Florida State University, Tallahassee, FL, USA

Submitted to the *Journal of Institutional Research* June 3, 2008, accepted September 2, 2008.

Abstract

Echoing the current emphasis on examining changes in teacher beliefs, combined with the central role of inquiry in reform, this article argues that science *education* research experiences should hold promise in shaping preservice teachers' beliefs about the role of inquiry in understanding classroom science teaching. The aim of this research was to explore the beliefs of preservice teachers that shaped their interpretations of and actions within open inquiry in science teaching. In this research three prominent beliefs emerged as central in shaping the participants' interpretations: division of research and teaching, disdain for ambiguity and primacy of the individual. In this research we came to understand that these beliefs played such a central role in shaping participants' interpretations of their experiences that the act of researching science teaching was not recognised nor valued, as they often left this experience asking, 'Why are we doing this?'

*Keywords***:** Preservice Science Teachers, Open Inquiry, Teaching Beliefs, Educational Reform

This study is about preservice science teachers' reactions to open-ended inquiry, and what these reactions reveal of their beliefs about science teaching and learning. We studied preservice science teachers engaged in a semester long open-ended inquiry project in an attempt to learn their reactions to the experience. Their answers, in turn, provided us with a window of insight into preservice science teachers' belief systems.

We subscribe to Alan Colburn's (2000) definition of open-ended inquiry, which he describes as going beyond simple guided inquiry (where students are given a problem, and devise and carry out procedures to investigate it) to include student-created questions for investigation. Colburn states that under open-ended inquiry, 'Students also formulate their own problem to investigate' (Colburn, 2000, p. 1). In our study, students selected, and studied their own issues of choice.

Correspondence to: Ahmad M. Qablan, The Hashemite University, PO Box 330206, Zarqa13133 JORDAN. E-mail ahmadgablan@hotmail.com

The teacher education literature is clear about the central role that teachers' beliefs play in the practice of reform (Woodbury & Gess-Newsome, 2002), and this realisation is echoed in research specific to science education (Andersen, Dragsted, Evans, & Sorensen, 2004; Lumpe, Haney, & Czerniak, 2000; Ritter, Boone, & Rubba, 2001). Educators now understand that teachers maintain deeply held beliefs about academic content, teaching, and learning that inform the decisions they make about teaching methods and strategies, as well as the information they share with children (Cochran-Smith, 2003). What teachers know and what teachers believe greatly influence how they interpret and enact curricula (Lumpe et al., 2000). However, it is important to recognise that teachers' beliefs shape their practice, and, in turn, teachers' practice can shape their beliefs (Cochran-Smith, 2003).

Given the emphasis that current research places on examining changes in teachers' beliefs and the central role that inquiry plays in current American and international science education reforms efforts (American Association for the Advancement of Science, 1989, 1993; National Research Council, 1996, 2000) many science educators have seen a need to include preservice teachers in science research experiences. In part, this is in the hope that such experiences and practices might shape not only their understanding of inquiry and its role in teaching but also shape their beliefs about the importance of inquiry (Chopin, 2002; Windschitl, 2002, 2004).

As an example of this call regarding inquiry experiences, Windschitl (2004) introduces a project in which 14 preservice science teachers were given the opportunity to create their own science inquiry projects. The intent of the study was to understand preservice teachers' levels of understanding of scientific inquiry What Windschitl found was that, for the most part, the preservice teachers did not have an understanding of how authentic science is done. Instead, they tended to have many misconceptions about scientific inquiry. With similar research objectives, another research study conducted by Windschitl (2002) illustrated that the only type of student who developed an in-depth understanding of the true nature of scientific inquiry during these experiences was one with prior experience in scientific investigation.

Mindful of Windschitl's (2004) work and the fundamental role inquiry has in national reforms, we sought to further explore preservice teachers' beliefs about inquiry with the understanding that inquiry is important in shaping preservice science teachers' practice. In our work, we sought to explore these beliefs in the context of inquiry in science education as opposed to in the context of inquiry in science.

In her review of the educational literature on the nature of preservice teachers' beliefs, Kagan (1992) explains that teachers' beliefs are stable and resistant to change, and that they reflect the nature of the instruction the teacher provides to students. She also argues that that preservice teachers' beliefs act as filters through which others' teaching performances are interpreted (Kagan, 1992). In contrast, in the science education literature some suggest that instruction is influenced by many factors other than beliefs, and thus there is no direct relationship between belief and classroom practice (Southerland, Gess-Newsome, & Johnston, 2003).

Just as science research experiences seem to hold promise in shaping students' understandings of the role of inquiry in the science classroom, it seems that science *education* research experiences and, as suggested by Dewey (1933), reflection on

those experiences, should hold promise in shaping students' understanding of the role of inquiry into their practice in those same classrooms. But what would inquiries into science teaching look like?

Echoing the importance of reflection in science education, if we look at the broader literature on teacher education, the notion of a reflective practitioner (Schon, 1987) resonates with many. As teachers/educators we are often compelled to help students develop a reflective stance toward their practice in order that they continually refine what they do in their professional lives. Reflection can be a critically important tool for preservice teachers to assist them to improve their practice (Caldwell, 2003). Roehrig and Luft (2004), as well as van Manen (1995) suggested that teachers should be reflective practitioners. The notion of reflective practitioner originated in Schon's (1983) work in the practical domain of teacher development (Feldman, 1997).

It has been theorised that novice science teachers need to reflect upon their practices in order to develop (Luft, Roehrig, & Patterson, 2003; Roehrig & Luft, 2006). In her early study on teacher development, Kagan (1992) reports that novice science teachers need opportunities to explore and examine their instructional and curricular decisions. Consequently, by exploring and examining their own decisions, they might be able to modify their beliefs and practices (Roehrig & Luft, 2006).

Classroom inquiries seem to be ideal vehicles for preservice science teachers, both for learning about inquiry as a process and for learning to reflect upon the classroom settings. Thus, this study intends to explore the beliefs of preservice science teachers that shape their interpretations and actions with open inquiries to learn how to teach science through inquiry.

Action research has gained increasing popularity in preservice and inservice teacher preparation programs (Adler, 2003), engendering reflective practice (Rock & Levin, 2002), promoting educational change (Lytle & Cochran-Smith, 1993), solving problems (Hendricks, 2004, Lohman, 2002), and allowing for the development of lifelong learning skills (Gieselman, Stark, & Farruggia, 2000). Given the difficulties of teaching science, in this research we investigated if: (1) collaborative action research experiences, in which preservice teachers worked with practitioners, could teach the preservice teachers the role of such inquiries in their future science teaching; and (2) Preservice science teachers would recognise this type of learning when they encountered it.

Methods

The settings

We conducted this research in the fall of 2003, in the context of a science teaching methods course at a large research university in the south-eastern United States. As this study involved preservice science teachers engaging in collaborative action research in classrooms, a significant portion of the context of the study was the K–12 school in which the preservice teachers worked toward their preservice field experiences. The school site involved in the research is a developmental research school associated with the university.

The school

The K-12 school has approximately 1600 students. Its student selection process is carefully crafted to represent a cross-section of the demographics of the community, including the use of selection factors such as parents' level of education, economic class, and ethnicity. The free and reduced lunch program[1] supports approximately 11% of the students, and approximately 30% of their high school students plan on completing a university education after graduation. At the time of the study, the student body was composed of 60% European-American, 25% African-American, 8% Hispanic, 4% Asian and 0.5% Native American students, a close reflection of the population of the local community.

Participants

Due to the collaborative nature of the research projects that form the context of this course, there were three different groups of participants in the research: preservice teachers and researchers (graduate students and the course instructor), and participating teachers. Preservice teachers were the focal point of our study as described in this article. The primary participants that shaped the entire research were twelve preservice teachers who were students in a methods course and who voluntarily participated in the research.

Preservice teachers

The twelve preservice teachers participating in the action research course in this study were enrolled as full-time students. Eleven were European-Americans and one was a native of Africa; there equal numbers of males and females in the study cohort. Most of the students were in their early twenties, and for 10 students the course was the last of three science methods courses required before beginning their student teaching. These 10 had completed a number of prior courses together and were quite familiar with one another as students within the two previous science teaching methods courses. The remaining two students took this course out of sequence, and this represented their first methods course. All of the preservice teachers were middle- or high-school teacher candidates from a variety of the science disciplines, and all were nearing completion of their science education coursework requirements.

Practicing teachers

The main role of the practicing teachers was to communicate with the preservice teachers and provide help and space for these preservice teachers' inquiries. The two practicing teachers who participated in this study were both veteran teachers who had taught a variety of high school science courses. Both were European-American, one was male, and one was female. The male teacher had been teaching for 26 years and specifically at that school for 13 years, while the female teacher had been teaching for 13 years and at the school for three years. The male teacher was the chairperson of the science department at the laboratory school. His areas of focus were alternative assessment and portfolio assessment. At the time of the study, he was teaching 10th grade chemistry.

[1] A school's program that offers free lunch for low economic status students.

The female teacher graduated with a Bachelor of Science degree in education and later received a Master of Science Degree in computer education. In 1983, she created an electronic bulletin board system for a school where she taught. At the time of the study, she was teaching a 9th grade earth a space science course.

Researchers

Working in collaborative groups with these 12 undergraduate students were five of the authors of this study, all graduate students who were enrolled in a doctoral level 'Research in Current Issues in Science Education' course. The main objective of this course was to help graduate students to analyse problems in the practice of science teaching. These graduate students were a diverse international and ethnic mix of two females and three males. Of the two females, one is Korean with 17 years teaching experience, the other African-American with 35 years of teaching and leadership experience. Of the three males, one is Jordanian with seven years of teaching experience, one is Turkish with three years of teaching experience, and one is a European-American with five years teaching experience.

Each doctoral student was assigned to be a team member of one of the five undergraduate student groups, and conducted research with them as co-participants. At the same time, the doctoral students conducted research on the thoughts and actions of the undergraduate students.

The final author of this study was one of the two instructors for the course. She is European-American with 10 years of teaching as a science educator, but at the time of the study, with only one year at this particular institution. She was largely responsible for the design of the methods course and assumed primary responsibility for supporting the students' research efforts.

The primary role of the graduate students in each research team was to cooperate with preservice teachers in finding the best resources to address the issues they identified as salient. Their participation in group work was rather limited and did not extend beyond facilitating effective inquiries of preservice teachers.

The course

Being the last of the required series of three science method courses, the goal of this capstone course was to provide an opportunity for preservice teachers to participate in open inquiry into some aspect of science teaching. In these inquiry experiences, the preservice teachers were to grapple with the types of issues that local science education practitioners have found to be particularly difficult. This method course was structured to allow for the inquiry teams to find a systematic approach to understand a real-life problem identified by veteran science teachers. This would involve using the dual lens of the classroom teacher and the relevant research literature to explore the issue, and, perhaps, to suggest possible resolutions to the problem for the practicing teachers.

These open inquiries into science teaching were intended to help the preservice science teachers to become familiar with issues in science teaching, as well as to explore resources available to science education as possible sources of solutions for the issues. In addition to the scholarly literature, sources could potentially include

consultation with local, national, and international experts, previously developed curriculum, and Internet sources. In addition to gaining skills in researching problems in the practice of teaching science, another goal was for students to reflect on these experiences in order to shape what they knew about science teaching and learning. Finally, this course was designed to allow preservice teachers the opportunity to develop professional behaviours and expectations that optimise meanings made in cooperative groups of colleagues.

Throughout this course, the major course texts were *National Science Education standards* (National Research Council, 1996), and *Inquiry and National Science Education Standards* (National Research Council, 2000). Besides these two major texts, the preservice teachers were assigned to read a variety of articles relating to reform and classroom culture (i.e., Davis, 2003). Electronic discussion boards were established for students to discuss the articles. Topics of study were selected according to needs professed by the participating teachers. Attempts were made to match the assignments to the preservice teachers' professed interests. As was previously mentioned, one graduate student researcher was assigned to each group. Thus, the inquiry groups were composed of two to three preservice teachers and a graduate student.

Students were told that they were to interact with each other to design and pursue the inquiry. Student groups arranged their own meetings, planning and doing their work together. They either divided up their work, or worked together as groups. Some of their activities included: reviewing literature; distributing, collecting, and analysing surveys; talking to state education officials; reviewing and testing curriculum; observing classes; meeting with the practitioners; arranging meetings with the course instructors to discuss their projects; and meeting as groups to work on their PowerPoint® presentations and papers. Groups also had the option of meeting by appointment with instructors, and most of them took advantage of this at one point or another.

The following is a brief summary of the group projects, as is also shown in Table 1.

Table 1
Research Groups in the Class

Group	Main Focus
Assessment	State-wide achievement tests and their impact on teaching
Motivation	Student motivation and excitement for learning
Resources	Ways to contend with resource shortages
Social Factors	Students' emotional problems and child abuse issues
Technology	Ways to incorporate more technology into the science classroom

Motivation group. This group focused on lack of student motivation toward learning science. The group sought to determine the relationship between students' and the practitioner's point of views on lack of student motivation in science class. The group reviewed relevant literature and developed a student motivation survey. To triangulate assertions they were constructing as a result of their inquiry, they conducted a focus group interview with some of the students, and also interviewed

one of the host practitioners to understand the teachers' views on lack of student motivation toward learning science**.**

Assessment group. This group sought to explore to what extent the state achievement test corresponded to state science standards and to determine the types of learning the assessment was designed to assess. To pursue their research, the group reviewed the relevant literature on assessment and interviewed professionals in school testing field**.**

***Technology group*.** This group aimed to understand the effects of technology use in science teaching, to investigate how it could be employed in the teaching of chemistry, the kinds of learning engendered through such technology, and whether or not students were engaged by such technology. Group members carried out a literature review, a student survey, a review of available technology for science education curriculum, conducted classroom observations, and explored the technology resources available at the school**.**

***Social factors group*:** This group focused on social factors that affect students, looking specifically at the way childhood abuse impacts students and their classroom learning, and exploring options available to teachers for helping such students. The group reviewed the relevant literature and, based on this review, developed a survey that they gave to teachers and counsellors throughout the city. They then interviewed state education officials regarding legal responsibilities of schools and teachers towards students who have experienced abuse.

Resources group. This group investigated viable options for chemistry teachers faced with limited laboratory space and equipment. They used classroom observations, interviews with one of the host practitioners and other classroom teachers, as well as a college chemistry professor. These interviews were augmented with a search of relevant literature and online sources.

There was some collaboration between groups, but most worked independently.

Data sources

To understand the preservice teachers' experiences in the course, we collected several forms of data: our own participant observation journals, preservice teachers' reflective journals, exit surveys (see Appendix A for this survey), and semi-structured interviews conducted with all participating preservice teachers in the semester following the course (see Appendix B for this interview protocol). Through capturing reflections of both the research team and the preservice teachers, participant observation journals and preservice teachers' reflective journals helped find either negative or positive instances solidifying the generated themes. Semi-structured interviews provided opportunities for the research team to capture broad understandings about these preservice teachers' experiences in this activity. Exit survey interviews, by contrast, aimed to glean information from each individual preservice teacher serving to identify their feelings about the nature of this activity.

As described by McDiarmid (1992), it is important to triangulate findings from direct and indirect measures in order to increase the faithfulness of the descriptions generated. The use of direct measures alone can be misleading, as they

can often trigger socially acceptable responses and fail to elicit participants' true conceptions. Better reflections are gained by sitting and talking with individuals, eliciting their responses in a face-to-face conversational manner, which is why we used exit interviews in this study. The intention of the exit interviews and interviews was not to directly ask the students about their impressions of the usefulness of the project to them as future teachers. We felt that we would hear more genuine answers if we asked them questions that stimulated their discussion of the course and its research projects.

Data analysis methods

Analysis began with open-coded grounded analysis of exit surveys (Strauss & Corbin, 1998), continued with theme comparison and selective coding and secondary interviews, and concluded with another round of coding, according to the methods of Strauss and Corbin (1998). We ensured rigour in the analysis through the use of multiple data sources including surveys, interviews, participant observations, negative case analysis, and researcher journals, as well as the use of multiple readers for each data set.

Additionally, the use of multiple data collection including both qualitative and quantitative methods such as surveys, questionnaires, interviews, participant observation, and the collection of mediating artefacts enhanced the validity of this study through the triangulation process.

Strauss and Corbin (1990) recommend close examination of data that contradicts previous developing patterns during the triangulation of data analysis. When it is the case, Gall, Borg and Gall (1996) suggest that the researcher should ask participants to clarify the inconsistencies. Guba and Lincoln (1989) identified this process as 'member checking'. The process of member checking has been recognised as one of the most crucial techniques for establishing credibility of the research (Guba & Lincoln, 1989). To fulfil the credibility criterion, the research team constantly checked their emerging findings through conversations with the participants during and after data collection. In addition, we checked our reports for accuracy and completeness by allowing the participants to read case analyses and written discussions of our research. The participants were aware that they had full access to the transcripts of their own interviews as well as the full document.

Another test for the quality of case studies is reliability. Yin (2003) indicates that the objective of testing the reliability is to be sure that if a later researcher followed the same procedures as described by an earlier researcher and conducted the same case study again, the later researcher should have the same findings and conclusions. The goal of reliability appears to minimise the errors and biases in a study. To ensure the reliability of the research, Yin (2003) suggests that '[T]he general way of approaching the reliability problem is to make as many steps as operational as possible and to conduct research as if someone were always looking over your shoulder' (p. 38). As discussed earlier, throughout the research period the research team engaged in reviewing the transcripts of all data analysis and met periodically to discuss emerging themes and interpretations.

Data Analysis and Findings

As we analysed the data, three themes emerged. These themes were: division of research and teaching, disdain of ambiguity/lack of structure, and primacy of the individual as opposed to the collective. There were other themes that emerged in the exit interviews, such as those involving technology, but these did not occur with sufficient frequency to be considered robust.

In the following section, we will explore each of these themes. But first, we need to mention how our study changed. When we began the conceptualisation of this research, our intention was to explore how the 'fresh eyes' of preservice teachers gave insights useful to practitioners. Our reasoning was that, given their position as novices, the preservice teachers would be able to give us an 'outsider's perspective' on the workings of science classrooms. In other words, we posited that the preservice teachers' novelty would be a strength in analysis of teaching.

As the semester continued, and we came to understand what the preservice teachers' perceptions of the research project were, we realised that some more intriguing themes were emerging. We saw their lack of valuing of the research, and failure to connect it to their future professions. We realised the potential applicability of these findings to the understanding of the preservice teacher experience in science education, so we decided to focus on these 'disconnects'.

Later, when analysing the interview data, we discovered two other themes. We saw the preservice teachers' disdain for the ambiguity inherent in such self-directed projects. And, finally, we saw their preference for individual work versus group collaboration.

What is important to note at the outset is that the nature of the groups' work, particularly in terms of the products of these inquiries (the papers and presentations), exceeded both instructors' expectations — both in terms of rigour of research design and quality of presentations. Indeed, at the end of the course, the instructors felt that the inquiries had been a success. So quality was not an issue.

Yet participant observations and review of the preservice teachers' reflective journals suggested that the preservice teachers were not 'connecting' their activities with their understandings of science teaching or learning. Although the preservice teachers recognised that they were honing research skills and simultaneously learning to systematically understand the difficult realities of the classroom, they perceived little change or development in their understanding of science content or science teaching. Intrigued by this seeming contradiction, as a research team we further concentrated our efforts on understanding the beliefs of preservice teachers that shape their interpretations their research experiences.

Division of Research and Teaching

Our expectation was that by examining, constructing an understanding, and perhaps attempting to solve the issues that practicing teachers were facing, the preservice teachers would learn skills and gain experiences that would allow them to reflect on their practice as they transitioned into teaching. Instead, however, we found

that the preservice teachers tightly compartmentalised the act of research and the act of teaching.

Indeed, to most of these preservice teachers, researching science teaching was something quite separate from practicing science teaching. They saw their research as an 'academic' endeavour and, as such, not something that could inform a practicing teacher. As one student stated, 'I don't know how many opportunities you will have to go out and research like we did … I don't know that I could directly apply it to teaching. It would be a little bit of a stretch' (Preservice Teacher D Interview, p.1). This quote suggests that these preservice teachers felt it is not beneficial to learn how to do research, because teachers would never have opportunities to conduct such activities.

The majority of the preservice teachers did not connect research with their teacher preparation, but instead reserved a notion of research as something that occurs only in libraries or laboratories. They understood it to be, 'a search for information using the media'(Student B, Interview, p.2), or 'spending lots of hours at the library. Looking things up, finding current information about a particular topic' (Preservice Teacher C Interview, p. 2). Clearly, these students did not view research as an activity useful in making meaning of the complexities of the classroom, or of making a difference, or of being applied to the teaching situation. The authors of this paper, by contrast, saw the research activity as potentially quite useful in terms of their own teaching practice.

While some of the preservice teachers did see some value in research in the classroom, they saw it as only a way to instruct their students in good research, not as a tool a teacher could employ to refine her/his teaching, as suggested by this quote: 'Is there anyway to combine research and teaching? If you feel research is beneficial to teach, you can teach (your students) how to research' (Preservice Teacher B Interview, p. 2). This preservice teacher saw research as something that could be taught to their future students, but not something that they could use themselves.

Thus, our data demonstrate that the preservice teachers had distinct definitions of teaching and researching. Because of this, when asked what they learned in the class, the students generally reported that their learning was limited. Indeed, when queried directly or as noted in their own personal journal reflections, the preservice teachers did not describe any significant development of their knowledge of science teaching or learning, but instead recognised their learning to be confined to the most obvious findings from their projects, as was described by a student in the technology group:

> My group did [the statewide assessment test]. And, as far as [the statewide assessment test] went, we learned a little bit about [the statewide assessment test]. Maybe not as much as we had hoped. I think all of us agreed that the test was valid as long as you were using it for the right reasons. So I think we got that out of it. We also learned that you are not always going to get along with your cooperating teachers. [In terms of my learning] those are all that come into my mind at this moment. (Preservice Teacher D interview, p. 1)

While there appeared to be a recognition that some learning had occurred, the preservice teachers did not recognise the role of research in reflecting on teaching nor in developing as a teacher.

Perhaps fuelling this compartmentalisation of research and teaching, several of the preservice teachers reported feeling relegated to the status of large research institution 'lab rats' themselves, a feeling that may have stemmed from their long-term immersion in the culture of a research university. Because they saw research as an activity distinct from teaching and refining one's teaching, they saw this experience as yet another example of the way in which research has co-opted aspects of their own education, circumventing the time and place for 'real learning'. There were several times when students reported that they felt this was more of an academic-type exercise that was more appropriate for graduate students: 'I think it seemed to me … now I haven't had any graduate classes. But it seemed to me [to be] more of a graduate style class (Preservice Teacher D Interview, p. 4)'. '(The) instructors, were trying to get us realise to different parts of research that were important in academia (Preservice Teacher Interview, p. 8)'.

Disdain of Ambiguity

It was clear from the outset of the course that many students felt unease with the ambiguity and lack of structure in a self-directed research project. Indeed, coming from the sciences, the students were used to being told what assignments to do and how and when to do them. For most of these students, this was the first time they had been in a course that was so heavily based on self-directed research. Through their prior college years they were used to classroom settings where the information was delivered to them, requiring little organisation on their parts. They generally were not comfortable with the lack of direction in this course, and would have preferred to have been given clear directions for the various steps of the process, as is exemplified in these quotes: '[The project] is a lot of work, and it is very hard, and we were very frustrated at first week—we could not figure out where to start' (Preservice Teacher A interview, p. 1). 'I would have liked a little bit more structure. I like to have a little bit more direction as to what is expected of me … it's hard to know if you've gone too far, [or] if you haven't gone far enough' (Preservice Teacher D interview, pp. 2–3).

The comments are insightful, considering that that the structure of the early weeks in the course allowed for weekly formal feedback from the course instructors and, later on, informal feedback from the instructors as groups were preparing for their weekly presentations. This feedback was provided to aid the groups in refining both their questions and the methods they were to employ to understand their question. However, the responsibility for the planning work of the class — describing how to conceptualise the inquiries and search for methods — did reside with the preservice teachers. The intentional lack of direction used in open inquiry was new to these preservice teachers, as it is very unlike their past research experiences in science and was often unwelcome to them.

Tied to this sense of unease about the seeming ambiguous nature of the inquiries, many of the students were also uneasy about the idea that their grades were being tied to their own self-motivation, self-reliance, and self-discipline, as is exemplified in these quotes:

> I think I prefer like — a structured class, because with a structured class, I feel like I have control over — I guess my grade … with the structured class I feel a little bit more confident that I'm going to do what it takes to get an A, whereas with an unstructured class there's a lot of questions involved in "Did I do what was required of me?" (Preservice Teacher G interview, pp. 3–4)

> I have (a) self-motivating problem a lot in college . . . it would not hurt to have a little bit more encouragement, like "you have to do this, you know". (Preservice Teacher B interview, p. 3)

They sought familiar parameters for grades, and for the work required to achieve those grades.

There was one interviewed student who reported enjoyment of the freedom and the responsibility inherent in an open-inquiry.

> I really enjoyed the independence of it. I think that upset some of the students because they may have had heavy course work but I really like the independence and we got as much as we put into it and handle it in your own way and come up with your own project. (Preservice Teacher B Interview, p. 1)

This preservice teacher went on to note that her positive reactions were not shared by other students, something she ascribes to the rigour of their heavy workloads. This suggests that open inquiries, although not prescribed and not scripted out, did require more work that more than a traditional coursework.

As was noted above, some saw such an open-ended class as being more appropriate for graduate students than themselves. This strengthens the 'division of research and teaching' theme, in that they saw the research as being useful only to researchers, and not to themselves as future practicing teachers. At no time during the journal entries, the surveys, or the interviews did we identify recognition on the part of the preservice teachers that the act of teaching continually requires the understanding and analysis of complex problems.

Primacy of Individual versus Collective

The third belief that emerged from our data analysis was the primacy of the individual. In general, the preservice teachers wanted to be self-reliant, preferring to not have to worry about whether or not their group members were going to complete the task, nor to have their grade tied to other group members' efforts. It was difficult for them to learn about working with other students, particularly when they knew they had to rely on others for their own grades. This is exemplified in the following quotes:

> It's really hard to trust people to pull their load. (Preservice Teacher D interview, p. 5)

> Relying on other people has blown up in my face too many times. When you have to rely on people to advance you own work you get frustrated — especially when they are not reliable … it would have been better to work on my own. (Preservice Teacher A interview, p. 7)

> If someone in your group is a slacker, then more responsibility falls on your shoulders. (Preservice Teacher C interview, p. 3)

Relinquishing control of parts of the project appeared to be particularly distasteful for students. The following quote highlights this complaint:

> When I work with a group I need to feel assured that everybody in my group is dedicated to the assignment as I am. When I'm working alone, I know that I have complete control over what is being done, so that I know that the final product is going to meet standards that I feel the products should meet. I know that the research will be thorough, and the methodology will be thorough. Whereas when I work with other people, there are other things I have to question. (Preservice Teacher G Interview, p. 6)

This situation is not unique to our classroom. Setting up collaborative groups will always present such challenges (Speck, 2003). Despite clear directions on the collaborative nature of the task (intended to enhance the meaning students would take away from the experience), most of the preservice teachers tried to approach the inquiries cooperatively, attempting to 'parcel out' the required work, as is shown in this quote:

> You focus on your part; other people focus on their part, another on theirs, so you get a more choppy knowledge rather than a complete in-depth knowledge. (Preservice Teacher D interview, p. 5)

Such a cooperative approach to the assignment indicates that the preservice teachers saw scant benefit from 'talking through' their findings, but participated in such events as the course design required. This cooperative approach has been described for other science and engineering students (Kittleson & Southerland, 2004; Linn & Burbules, 1993) and often indicates that the participants do not recognise the need to negotiate meaning of research or data. Instead, they understand that the data should 'speak for themselves', as if explanations are there to be uncovered, instead of explanations needing to be constructed.

Likewise, we were surprised to find that students generally learned little from each other's projects. Despite three meetings where each group made presentations and fielded questions and comments from the others in the class, the preservice teachers internalised little of the work of other groups. Perhaps they were too engrossed in their own demanding projects, as this preservice teacher notes:

> And I never did read the final product of the other groups. I mean, you pick up things here and there, but it's more like a fog. (Preservice Teacher D interview, p. 5)

We understand the students' approach to valuing individual knowledge to further indicate their emphasis on the division of research and teaching. The meanings constructed through other groups' inquiries were not perceived as being applicable to their own teaching practices. There was one instance, however, where this pattern was contradicted:

> I did [learn from other groups]. I think it was really good to learn about all the different things everyone did. One was about motivation—that was pretty cool—and, thoughts on [the state-wide assessment]. So yeah, I think that was beneficial to get to hear their point of view and get to hear their solutions to the topics. (Preservice Teacher C interview, p. 3)

Although the students felt uneasy about the collective nature of the work as it related to their grade, several of them did indicate that they understood its value. This is exemplified in the following quotes:

> This gave us a good opportunity to practice that professional teamwork that we are going to be expected to show out in the field. So I think we learned a little about that. (Preservice Teacher D Interview, p. 1)

> The most important part of the class, I guess, was how to work with other people. I guess being able to be flexible with times and, so that was the most important part, I guess, working with other people. (Preservice Teacher A Interview, p. 1)

> I definitely learned how to work—work with other students. (Preservice Teacher C Interview, p. 1)

So, despite not enjoying the collective nature of the work, we were encouraged to see that the preservice teachers did learn how to work with other students, and appeared to recognise the value of this learning. As they continue on into their future teaching jobs, teachers will need to cooperate with other teachers to assist and improve their practice, to gain ideas for lesson plans and resources, and to learn the skills necessary to be a successful professional educator. Possibly, with increased abilities to research and think through problems and issues, they may be better able to enact reform in their classrooms.

Discussion

Considering several from the American Association for the Advancement of Science (1989, 1993) and the National Research Council (1996, 2000) to include inquiry in science teaching and learning, it has been recommended that preservice science education programs need to prepare their graduates to promote science inquiry. It has been argued that this preparation should include participation in inquiry and research experiences similar to those the novice teachers will eventually provide for their own students.

Research indicates that involving preservice teachers in inquiry experiences in the sciences, however, may not be enough to develop their conceptions of inquiry or their disposition to use it in the classroom. Windschitl (2002, 2004) found that the experience refined the inquiry conceptions predominantly in those participants who already had more sophisticated understanding of scientific investigations. Participants with limited experiences in inquiry did not appear to progress beyond naïve notions of inquiry during their research experience.

But what about their understanding of science *teaching* as informed through inquiry? We wanted to understand how preservice teachers made sense of, and learned from, open-ended inquiry into science education. After completing this study, we feel that the same limited notions of teaching and its relationship to inquiry are present in preservice teachers as well (Windschitl, 2002). We attribute these limitations to the persistence of their preconceived beliefs about the role of research. They saw it as limited to theoretical situations and not to their own practice.

As the title of this article suggests, it is our interpretation that the open-ended inquiries into the practice of science teaching were not a tremendous success for our preservice teachers. By this we mean that in the recursive relationship between beliefs and practice (Cochran-Smith, 2003); as teachers; we often seek instances in which the practices we provide for our students actually shape their beliefs, or more frequently allow them to construct new knowledge that may eventually impact their beliefs. However, in this research we understand that these three aspects of preservice teachers' beliefs played such a central role in shaping their interpretation of their experiences, that the practice of doing research on teaching was not recognised nor valued, as they often left the classroom asking, 'Why are we doing this?'

At the beginning of the course, our participants had experienced initial difficulty conceptualising appropriate problems for inquiry, but they did eventually devise and conduct interesting studies. This initial discomfort is to be expected from students who have never gone through a similar experience. Roth (1999) found that his study's participants had considerable trouble creating research questions when he asked them to conduct independent inquiry on an ecology topic.

However, the results of the papers and presentations indicated that the students learned the inquiry skills well and that their inquiries themselves were productive experiences. Thus, the difficulty and novelty of the experience, although they may have contributed to the students' failure to see the connection between inquiry and teaching, allow us to understand only a part of the overall picture.

We believe that the rest of the picture is explained by preservice teachers' naïve ideas about teaching, as well as similarly novice ideas about research, as described in our results. Indeed, as Lortie (1975) argues, many think that they know about K-12 teaching merely by having gone through school themselves, only to find out differently when they begin teaching. Spector (1989) argues that preservice teachers are at the 'fantasy' stage of learning. It is only when they reach the beginning teacher stage that they will enter the 'survival stage', where they will need to learn to deal with the realities of the classroom. Veenman (1984) refers to this realisation as 'reality shock'. Some may suggest that these ideas about teaching also reflect the preservice teachers' epistemological beliefs. Epistemology focuses on the 'grounds on which we base our decisions about the acceptance or rejection of scientific knowledge claims' (Duschl, 2000, p. 188). Researchers argue that epistemological understandings enable thinking critically (King & Kitchener, 1994), solving ill-structured problems (King & Kitchener, 2002), and making judgments about knowledge claims (Kuhn & Weinstock, 2002). It seems that the preservice teachers in this study had naïve epistemologies, and the open inquiries failed to develop these epistemologies.

Given our findings, several questions that continue to haunt us as teacher educators are: if preservice teachers are not able to understand the role inquiries can play in their teaching practice, will they be able to appreciate them when they become teachers? Will then learning become recursive? Will further experience in the classroom allow classroom teachers to use such classroom inquiry experiences as a site of reflection, allowing them to shape their understandings of teaching?

As we ponder the results from this study, we end where we began. Given the strong role inquiry plays in national reform movements, how can we best support

preservice science teachers to more deeply understand inquiry? This research represents, at one level, another attempt to craft situations to shape the beliefs and knowledge of preservice teachers. But, echoing earlier efforts, our work emphasises the need to better understand the constellation of beliefs influencing the novices' understanding of open-ended inquiry if we are to design more robust instructional experiences. If we are to support preservice teachers in their understanding of open-ended inquiry, we need to better understand preservice teachers, their beliefs, their conceptions, and their motivations. We recommend further research into preservice science teachers' beliefs. We also recommend inclusion of belief assessment in science teacher preparation programs.

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Appendix A: Exit Interview Questions

Have you ever had a course that is centred around a research project before?
Do you feel that you learned a lot from this process?
Did the non-traditional nature of the class make you feel uncomfortable in any way?
Did you feel that you were sufficiently self-motivated to meet your deadlines, or did the reminders help?
Did you think that enough time/too little time/about the right amount of time was spent in formulating the question?
Did you feel that the role of the graduate students in the course was helpful?
Did you feel that the size of the group was helpful? If not, should it have been larger or smaller?
Did you feel that you worked well with the other group members?
Did you feel as if work was evenly distributed?
Did you feel that it was easy to divide the tasks, or did you find that there was significant duplication?
Did you feel better served by the learning in this course than a traditional course?
As a prospective teacher, were you glad to have had a course of this nature?
Did you feel challenged by this project?
Did you feel that you were able to contribute your individual ideas to this project?
In what ways could this process be improved?

Appendix B: Interview Protocol

(Themes are identified in parentheses, although they were not openly identified as such to interviewees)

(Questions relating to Theme One: Division of research and teaching)

What did you learn from this class?
What was the most important part of this class to you?
Do you see any application of this to your future teaching?
How do you define teaching?
How do you define research?
What you would do if you were one of the teachers you worked with, and were faced with the problems that they were?
Did this course help you to think about what to do when you start teaching and having similar problems to those of the practitioners you studied? If so, how?

(Questions related to Theme Two: Disdain of ambiguity/lack of structure)

Do you prefer a structured class or an unstructured one? Why?
What was the role of the instructors in this class?
What was the role of the graduate students in your group?
Did you use the class website in this course? If so, how did you use it, and did it help?
Did this course require more self-motivation than other courses?
Did you find that you had problems self-motivating?
Do you think that more structure would have helped you?
If you had a choice to take this kind of research-based class again, would you? Why or why not?

(Questions related to Theme Three: Primacy of individual versus collective)

Did you learn from the other groups in the class?
Do you feel that you work better independently or collectively?
Do you prefer collective work or individual work? Why? Why not?
What do you see as the strengths and weaknesses of doing group work?
Did you feel ownership of your group's entire project, or just your contribution?
What unforeseen challenges/problems did you face in this group setting?