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Culture Wars in the Classroom: Prospective Teachers Question Science

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Abstract: Does studying about the nature(s) of science contribute to a prospective teachers' effectiveness as a science teacher? This research grew out of a course created by a science educator and historian of science who believed prospective teachers needed more complex understandings of the cultural wars surrounding science. The research team consisted of five prospective teachers who participated in the course as well as the two instructors. This paper describes the experience of participating in the course from both perspectives. We argue that studying the cultural wars over science contributes to prospective teachers' professional growth as much because the course elicits tacit beliefs about school science as it introduces more complex understandings of science. We found that prospective teachers' tacit beliefs about school science were their greatest barrier to developing more complex understandings about the nature(s) of science. We contend that willingness to grapple with complexity and developing a professional identity by locating oneself in the conversations about the nature(s) of science are better criteria for determining the professional growth of prospective teachers than knowledge measures. Finally, we argue that prospective teachers should be viewed as professionals who are responsible for finding their own voice, making their own decisions, and considering the consequences of their beliefs on their practice. This study raises questions critical to teacher education programs for prospective teachers and teacher-educators alike.© 2000 John Wiley & Sons, Inc. J Res Sci Teach 37: 895–915, 2000

> *And if they are very vital questions, if they are truly relevant to our lives in 'the real world', then I would argue at the outset it is because of a very simple logic: the way we story our lives directly affects the way we understand ourselves; the way we understand ourselves directly affects the way we act; and the way we act directly affects the way the world is (Randall, 1995, p. 9)*

Research describing the effectiveness of courses about the nature(s) of science and the links between understanding the nature(s) of science and subsequent practice is conflicting. Some researchers argue that understanding the nature(s) of science is essential to being an effective science teacher, while others suggest there is little connection (see McComas, 1998, for recent

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discussion). Some argue prospective teachers are incapable of understanding the more complex debate (Abd-El-Khalick et al., 1997), while others contend exploring the history and philosophy of science is central to prospective teachers understanding the nature(s) of science (Mathews, 1994). The research literature describing the relationship between prospective teachers' beliefs about science and practice is also conflicting. While some suggest teachers' beliefs about science, including the nature(s) of science does influence their practice (e.g., Duschl, 1983, 1987; Lantz and Kass, 1987; Brickhouse, 1989; Cornett et al., 1990; Palmquist & Finley, 1997), others conclude there is little or no relationship (e.g., Rowell & Cawthorn, 1982; Mellado, 1997; Lederman & Zeidler, 1987; King, 1991). According to the latter group of researchers most beliefs or views prospective teachers hold about science get set aside by 'realities' of the classroom. Research also suggests that prospective teachers' conceptions of science are limited, often described as naive (e.g., Kruger, 1990; Fleury & Bentley, 1991; Gallagher, 1991; Pomeroy, 1993; Lakin & Wellington, 1994; Ginns & Watters, 1995).

We suspect that the confusion in the literature reflects researchers' own widely different understandings of the nature(s) of science, a sometimes inadequate appreciation of the complexity of the current debate over the nature of science, and their very different instruments and criteria for assessing teaching effectiveness. Our paper assumes from the outset that science teachers ought to be informed about this debate, that their teaching will benefit from their engagement with it, and that grappling with the debate offers an important context for professional growth. It focuses on a different problem, not addressed in the existing literature: how do prospective teachers react, cognitively and emotionally, to their first classroom-encounters with the nature-of-science debates? What prior experiences influence that response? What can their encounter tell us about opportunities for and resistence to cognitive change, and about how professional attitudes are shaped? Finally, we raise several issues suggesting a need to rethink the kinds of experiences teacher education programs provide prospective teachers of science.

This paper grows out of a collaboration among university educators and prospective teachers who participated in the course ED3512, Nature(s) of Science: Implications for Education, offered in the Education Faculty of the University of New Brunswick. Here we present our own experiences, our observations about those of our colleagues and some common perspectives on the relationship of those experiences to professional development. We hope that our experiences will encourage the development of similar such courses for prospective teachers, and prepare those who develop them for the highly contested and sometimes emotional nature of the experience those courses can offer.

The Problem: The Nature(s) of Science Debate

The reassessment of science to which ED3512 aimed to introduce students began at least thirty years ago. It began with the challenge to falsificationism that Lakatos and Kuhn launched in the 1960s. Building mainly on historical case studies, they denied that empirical appeal to nature through ''scientific method'' provides practitioners with a fully sufficient guide for resolving scientific controversies or making contested theoretical decisions. In one form or another, they contended, ultimate scientific decisions are programmatic ones, about the validity or rationality of which there can be no appeal beyond the judgement of the relevant specialist community. These influential arguments, far beyond what their originators intended, impugned the traditional status of science as a ''privileged'' form of knowledge, uniquely consensual due to its constant recourse to empirical validation. They cracked the door for relativist perspectives on scientific knowledge and sociological interpretations of scientific change.

In the ’70s and ’80s sociologists of science (or, as they preferred, sociologists of scientific knowledge (SSK)) kicked the door open. They turned from history to the empirical analysis of contemporary scientific controversies, including those over pseudo-sciences, to demonstrate the common inability of experimental appeals to nature to satisfactorily resolve disputes. In the so-called ‘‘Strong Programme,’’ they embraced relativism as a methodological, although usually not an epistemological, principle. If empirical recourse cannot resolve scientific disputes, the SSK concluded, then dispute-resolution can only be explained by appeal to the sociological dynamics of the relevant expert community. The SSK produced several variant approaches to the task of mobilizing ‘‘social factors’’ in explaining cognitive scientific change and its directions; these varied from consideration of the subtle microsociology of the expert community to the blunt instruments of class interest. All the versions, however, carried the epistemological ‘‘de-privileging’’ of scientific knowledge-claims much further than had Lakatos and Kuhn. They generated angry opposition from some scientists and philosophers of science that expressed itself in the ‘‘rationality debates’’ of the period (Kuklick, 1995; Roth et al., 1990; Hess, 1997; pp 81–111).

By 1980 ‘‘STS Studies’’ (‘‘Science, Technology, and Society Studies’’) was well-launched as a new, interdisciplinary venture. Its institutional success fed on growing anxiety about technology, its consequences and control, and on the growing literature showing that scientific change, including its theoretical and conceptual aspects, was deeply intertwined with ‘‘society.’’ But as STS gained strength, the SSK itself showed some signs of fragmentation and self-absorption. While something like its original programme and perspectives were transferred successfully to the sociological and historical analysis of technological change, other STS theorists took the analysis of science itself in different, sometimes inconsistent directions.

And deeper currents were stirring. Through the ’80s and ’90s the critical analysis of science became steadily less ‘‘sociological’’ and more ‘‘cultural.’’ Science was more and more interpreted as a repository of often-unconscious cultural assumptions about race, gender, and power, and as a set of structures for reproducing and perpetuating those cultural assumptions (Hess 1997, pp 111–156; Latour, 1992). Of course, this trend only reflected broad changes in academic discourse in the western world, but it is doubtful if the cultural critiques could have received the currency they possess today had they not built upon the epistemological de-privileging of science that had gone on previously at the hands of philosophers, historians, and sociologists.

These cultural interpretations have often been highly political, often strongly critical of present science, and intensely controversial. Earlier disputes over the nature of science and the status of its epistemological claims had been little followed outside the narrow academic circles frequented by philosophers, historians, and sociologists. But the emerging cultural critique of science has raised the stakes of the dispute, intensified the vehemence of the rhetoric, and brought it to much wider public attention, especially to the attention of scientists themselves. These disputes exploded into public consciousness with the publication of Gross and Levitt’s *Higher Superstition: The Academic Left and Its Quarrels with Science (1994)* and in the debates that followed it, and with physicist Alan Sokol’s 1996 hoax-article parodying ‘‘postmodernist’’ analysis of science in the journal *Social Text*. Today the ‘‘science wars’’ or the ‘‘culture wars’’ over science have become a familiar element in the cultural landscape.

The Course: ED3512

ED3512, the undergraduate course discussed in this paper, is entitled *Nature(s) of Science: Implications for Education*, and is one of the two introductory courses within the science

education portion of the teacher education program at the University of New Brunswick (see Sullenger & Turner, 1998, for a detailed description including readings). Prospective teachers who enter the program must have or be working on an undergraduate degree in a field of study; the bachelor of education is a second undergraduate degree. Participants come with varied academic backgrounds, including history, economics, mathematics, physical education, English literature, psychology, and science. That year, 15 of the 38 prospective teachers had or were working on science degrees and wanted to teach science. The rest were taking the course as part of a second concentration or, as in the case of four participants, an alternative introductory course. About one-third of the class members, those with backgrounds in social studies, language arts, and early childhood education, had little or no university science experience. Except for a few mature students who had held other jobs, the prospective teachers entered the education program directly from their first undergraduate degree program.

The two instructors who organized ED3512 were a science educator and a historian of science. We presented the course in three sections that successively raise with prospective teachers the questions scholars and others have about science and teaching science; introduce them through lectures and readings to the nature of science debate; and lastly, consider the leading science teaching approaches in light of these questions and debates. Readings, lectures, and/or outside assignments provide a basis for regular discussion. A ''question of the week'' is presented as the basis for a journal entry and Friday discussion groups. Besides the journal, prospective teachers are assigned a research paper exploring an issue concerning the nature(s) of science and teaching science they find interesting.

The section of the course dealing with the nature(s) of science debate combined a program of lectures, source readings, and discussions. Early lectures developed the familiar theme of science as ''unnatural'' knowledge—unnatural in the sense that scientific change has often required the ''re-education of common sense'' about nature and natural relationships, rather than only an accumulation of data and knowledge. Lectures introduced changing historical conceptions of scientific method, beginning with Baconian Inductivism and proceeding through the sophisticated falsificationism of Popper. The early focus was strongly historical; the Copernican Revolution was used extensively as the historical case study around which to introduce Kuhn and Lakatos and their early challenges to falsificationism. To accompany these discussions students read from Chalmers'(1976) venerable *What Is This Thing Called Science*? Students were introduced to the Sociology of Scientific Knowledge through Collins and Pinch's (1993) recent book, *Science the Golem: What Everybody Should Know about Science.* Lecture background introduced the Strong Program and elements of the rationality debates. The course made no attempt to introduce students to the more recent and esoteric turns in the SSK program, but it did briefly deal with the early literature on ''laboratory life.''

The discussion of the nature(s) of science also emphasized the problematic relationship between science and technology, the question of their historical interrelationship, and the nature of techno-scientific controversies today. Students read Weinberg's (1986) classic essay on the technological fix and selections from Toffler's (1986) futurology, and they were invited to analyse the texts for their attitudes toward technology and the tacit assumptions about the science–technology relationship that they embodied.

Other discussions of the nature(s) of science introduced students to the more radical claims made about the cultural presuppositions of western science: its alleged mechanistic and analytical biases, its implicit masculinist approach, and its supposed impetus to control and manipulation. The standard rejoinders to these critiques were also introduced and discussed. In order to communicate the bitterness of the controversies raised by these claims, students were asked to read sections of Gross and Levitt's polemical work, to thrash out their own position in

class discussions, and to weigh the implications of these disputes for science teaching. Although the course included teacher–student dialogue, the focus was on generating discussion among prospective teachers.

Both instructors and prospective teachers were surprised when prospective teachers' reactions and interactions were much more intense than we anticipated. On occasion the larger culture wars over science seemed to erupt in the ED3512 classroom. Students' reactions were very personal and sometimes emotional; their previous science experiences became a critical, almost central, part of the discussion and course dynamics. At the end of the course, participants (prospective teachers and instructors alike) realized that the experience they had gone through had been a wrenching one, and one that presented a microcosm of the larger social response to the culture wars over science.

The Inquiry

Towards the end of ED3512, we asked prospective teachers if anyone would be interested in writing a research paper with us about the experience of participating in the course. Only a few indicated any interest. However, it was not until the conclusion of the course, the two instructors became convinced that the mutual experience of Ed3512 could be important and valuable to other science educators. We contacted those participants who had indicated an interest in the next term, when they would be free of course requirements, and invited them to join us in a process of analysis and reflection, the ultimate goal of which would be writing a formal paper about our experience. Five prospective teachers accepted our invitation, although one later withdrew, observing that the experiences had been too unsettling to talk about and relive as was happening in our discussions. Two months later, the team decided the voice of the four prospective teachers preparing to teach in elementary school was a significant factor that none of the team members could provide adequately. Instead of just interviewing them, the team decided to invite the most outspoken member of the group to join the research process; she agreed. During the term, four of the prospective teachers were either completing their internship or finishing course work, the fifth prospective teacher graduated after the fall term. Every member of the team was working on the research project in addition to their other responsibilities and commitments; we received no outside funding.

As our inquiry process went forward that spring and throughout the summer, team members took responsibility for compiling answers to questions such as ''What went on in the course?'' ''Why did some people talk and others stop talking?'' ''What did we learn?'' We met collectively to discuss and probe for details. Members of the team had all been active discussants in the course, but we knew that others had been largely silent throughout. Team members set out to contact and talk with those who had been silent—to collect their stories. We were disconcerted that a few would not even talk about the course at all, but this led to new questions and raised the importance of other questions, such as the possible uneven benefits from the course. The science educator acted as research coordinator and often provided first drafts of research text for others' reactions; we worried about the implications of one voice being stronger than others. Even when one prospective teacher accepted a teaching position in another country and others began jobs or looked for teaching positions more locally, we shared and completed the research by email.

The inquiry process was shaped by Reason's (1988) notion of research as ''dialectical engagement with the world'' and Clandinin and Connelly's (1994; see also Connelly & Clandinin, 1990) personal experience methods. Personal experience methods suggest viewing inquiry as narrative in which one moves from field to field texts to research texts and through which a research group identifies their voice and signature. In narrative inquiry, experience is

seen as moving inwards and outwards and has a backwards and forwards. From our initial meeting, field texts were created in the forms of individual writings, including draft answers to questions, interviews, e-mail messages, notes from informal conversations (often carried out in places as unlikely as parking lots); and records of research team meetings. As we moved outwards toward the preparation of a formal text, we worried about the danger that one voice might become stronger than others. We addressed this concern by sharing the text in rough drafts and working on parts at a time. We were determined in our presentation to preserve for our readers the multiple voices of the research team's members. Although ''we'' in this paper expresses the collective consensus of the team, each participant-researcher brought a unique perspective to the inquiry and as such to the questions, stories, and narrative themes that emerged. Understanding each ''I'' and that person's perception of herself/himself provides the reader with further insight into the sense the group made of the experience.

> Hart: I played a number of roles in the class, but most prominently I was the one who disturbed the peace. I endeavoured to ask controversial questions and stem the tide of naive positivism and scientism. I was not a despiser of science, though I believe I was often thought of in that way.
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> Rick: I came to the Nature of Science class straight from a physics degree and had a lot of faith in science. Probably from my parents, I brought an open mind to the class and I tried to consider every argument before dismissing it. I wasn't afraid to speak to a group of people about what I think, so I became a member of the vocal minority from the beginning.
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> Cynthia: I was clearly a member of the vocal minority in this course. More often than not, when I spoke out I did so because I felt that I had to be either a defender of biology or a voice of practical reason. My role as the former was due to both the anti-biology sentiment amongst others on the vocal minority combined with the fact that most of my biology colleagues rarely, if ever, spoke. I suspect this was due to a variety of reasons, such as, a lack of interest in the discussions at hand, a feeling of frustration leading to a sense of apathy, and the inability to get a word in edgewise.
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> Joe: Coming into 3512 I was in a ''neutral'' position because I had enough science to feel accepted into the science crew, yet I could distance myself if I wanted because I was studying Physical Education. I came into the class believing that all of us put our faith or trust into something or someone, and that these issues of faith, belief, and trust are core issues people do not leave outside of the classroom. I wanted to keep reminding people, ''What does each one of us really believe or trust?'' and ''Why or why not?''
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> Beth: I entered 3512 with a Liberal Arts/Early Childhood background. At first, I was completely lost in the readings, lectures and discourse. I remember feeling anxious every time I would enter the discussion. The discussions were often so intense and bogged down with ''scientific jargon'' it was almost impossible to penetrate the discourse. As the course progressed, Karen made ''questioning'' and ''challenging'' and ''exploring'' the focal point. She opened up the conversations and debate to everyone. For me, this course was not about ''the nature of science,'' it was about being given the opportunity to participate in exploring, questioning and challenging beliefs.
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> Karen: I was the science educator. I carried the responsibility for assigning a grade, raising questions, listening to and balancing concerns, provoking thought, providing encouragement, limiting my involvement, not taking things personally, and remaining true to the beliefs that lead me to propose the course to Steve.

> Steve: As an historian of science and long observer of the so-called 'science wars', I saw my role as that of resource person: one who introduced the class to the issues in the contemporary literature of Science Studies and who then hovered about the fringes of the class proceedings to assist individual students, to clarify issues when needed, and on occasion to nudge the discussion in constructive directions. My problem was how to avoid being cast in the role of expert, and how to assist the discussion in the course while keeping a low profile.

Shifting from the collection of field texts to creating research texts was complicated. The cultural wars we experienced were not always polite or considerate; we believe the reader needed access to the juxtaposition of discourse and silence among participants. Capturing the experiences entailed reliving them as we retold the stories of our involvement. The process of moving from reliving our separate experiences to describing experiences to writing about the significance of these experiences involved several cycles of generating texts; searching for patterns, narrative threads, and themes; and reexamining interpretations. Eventually, we began speaking about experiences instead of our experience, about the consequences of such experiences for prospective teachers and instructors of science rather than the consequences for ourselves. While we initially had difficulty naming the themes which emerged from the analysis, we finally recognized them as tensions, threads of discomfort embedded in the fabric of the experience. Tensions that defined the landscape of the classroom cultural wars.

As we undertook writing the research text, it became clear that the narratives of the instructor-researchers were significantly different than those of the prospective teacher-researchers. It was untenable to blur the two together; we wanted a way around what Shulman (1991) described as the silence of the respondent or participant and Goodson's (1996) caution about storytelling as deprivileging and isolating the voice of teachers. We were encouraged by Eisner's (1991) admonition to push the boundaries of accepted research narrative.

As a solution, we developed co-lateral texts—the prospective teacher-researchers and the instructor-researchers' writing separate narratives. The left-hand narrative is written by the prospective teacher-researchers while the instructor-researchers' narrative is on the right. We believed formatting the research text this way works in that the voices and signatures of the researchers emerged as part of the research findings. Both the prospective teacher- and instructor-researchers generally used italics to denote first-person reflections or anecdotes taken from the field texts and selected because they best capture the sense of what happened. We recognize we are inconsistent in places, but decisions about story-telling, such as clarity, transition, and pace, prevailed over consistency. The research narratives were joined once each group was finished writing although drafts were shared and compared as each group strove to articulate and support interpretive statements. Comparing the narratives, including deciding how and what parts of the texts to juxtapose, was part of the research process.

The prospective teacher-researchers describe their experience in the course as unconventional and sometimes overwhelming. Our research narrative portraying the experience is also unconventional and may be overwhelming at times. However, we see such a depiction of the experience as important for others who may undertake a similar course.

Voices from the Cultural Wars in the ED3512 Classroom

Cultural wars are a way of describing the strongly held, often opposing, perspectives that make up the landscape of ideas about a phenomenon. Perspectives and their concomitant experiences can be so different that, as some suggest (e.g., Rorty, 1979; Shulman, 1988) they

may be incommensurable. This research narrative depicts the tensions that arose from the differing perspectives of the prospective teachers as well as the instructors. As you will see in the co-lateral text that follows, the tensions created by differing perspectives can make reasoned discussion a challenge and resolution improbable.

Questioning Beliefs, Confronting Faith

In ED3512, many of the discussions contained questions connected to beliefs, including religious beliefs. For each person, the issues varied across a wide spectrum of views, values, and disbeliefs. There were also some who either did not know what they believed, or simply were not interested in the debate. Regardless, the many dynamic discussions regarding the nature of science and all the heated debates that came with it triggered something deep for many. Our foundations were proverbially shaken as if we were living on a fault line. Why, we wondered separately, were we affected so deeply? It was, after all, only a university course, and we had experienced many years of schooling. Perhaps there was something more at stake than just grades. Perhaps it became a question of faith.

One day after class I went to see Karen to ask her point blank if my assumptions about what she was trying to do were correct. I asked her "do you know that the questions you are trying to get us to ask, and the way we are to question science boil down to what we believe and what is "truth." Karen simply responded, "Yes."

Faith is not only what we believe in the existence of (''head knowledge''). Faith also asks what do we put our trust in? We can believe many things but they might leave us unchanged; however, putting our trust into something in a deeper, more than intellectual way can have a profound impact on our lives. It was these decisions that were being processed in the course, and that is why the stakes were high and discussion so dynamic, not to mention the hours outside of class spent debating among one another and individual contemplation. I think at some junctures in the course people had decided that it was better to leave things alone and believe what they believed, because they were not willing (or ready) to dig deep to find the answers.

In the context of the future and surveillance technology, I remember one class member stating that he was uncomfortable with the prospect of being constantly watched. I asked him, "If you are not going to put your faith in technological

Participation—Emerging Voices

Participation begins heatedly with hostile proclamations stating science is religion and unrightly privileged knowledge. These claims are met with equally heated claims that science is truth or the most certain form of knowledge, especially, physics. Participation begins slowly with stunned faces and long silences. The few offer ideas during the first class; a few more join in the second.

Week Three: A student stopped me in the hall today and asked whether I shouldn't do something to get more people talking. He felt more people should take responsibility for contributing ideas. I had just spoken with two others who asked me whether I shouldn't control the arguing and outbursts. They didn't feel like talking in class when people were speaking so emotionally.

As the kinds of ideas presented become more challenging of science, at least more challenging of the view of science many of the students had constructed from their experiences, they became less willing to participate. We thought the readings and Steve's lectures would provide a context for discussion, e.g. I liked this point, I did not understand this idea, these ideas seem contradictory. Using highlighted and underlined sections of readings as an indicator, most people read the papers. Even so, few seem experienced in talking about science or had experience defending their ideas or having their ideas challenged.

Interestingly, two of the most talkative students, often said they did not do the readings or could not get through the reading because they found them too off the wall or offensive to their ideas. I wondered if their reaction to the papers was as visceral as mine the first time I read Gross and Leavitt (1994); I never experienced a physical reaction, much less such nausea, to reading something.

Friday participation was very different. Each participant read from their journal entry and as the term progressed it seemed from the voices and intensity of discussions in the groups, that more students participated beyond reading their journal

solutions, then what are you going to put your faith in?" He responded, "I don't have time to discuss it right now." The class chuckled knowingly; they knew he had ducked the question.

The search for faith can also be cast in a less formally religious way, as the notion of "world view." A world view is the lens we look through to try and make sense of the world. So, once again, through the readings and discussions about the nature of science, we had to continually ask ourselves, Who are we? Where are we? What is the nature of the reality in which we find ourselves? What is our task as human beings? Not only were we asked to answer these questions for ourselves, but we also had to explore the ways these questions were answered in the past.

Not surprisingly given the above discussions of faith, religion, and beliefs, emotions played a very important role in the course. They are, after all, what drives our responses. Interestingly, there was a lack of response by the majority of the students in the class. One reason for the lack of response could be intimidation.

Early in the semester, there was open hostility in the classroom, emanating mainly from students with science backgrounds. Initially, this hostility arose because of the following challenge issued to students during the first class: Why teach Science? Students scrambled and stammered for reasons that they came to realize were ultimately inadequate. All the while Karen hammered at their beliefs about the infallibility of science.

One of the most memorable points in the class occurred when one student, who felt under attack for his allegiance to science, responded to the following query:
Student x: Well, Karen is a scientist. Why don't you ask her?
Student y (face bright red): KAREN DOESN'T EVEN KNOW WHAT THE FUCK ENTROPY IS!

Each day new challenges were presented and eventually questions were left unanswered or answered unsatisfactorily. This lead to an uncertainty in position, which was a source of frustration for many students. What once was certain and unchallenged was being questioned and doubted. One student described the incident in the entry. There were some though whose silence suggested they limited even this involvement.

Some groups of students interacted throughout the course within their own microcosms. They whispered to one another and wrote notes. These clandestine exchanges seemed to act as an outlet and create a context with which they were comfortable responding to the ideas that seemed more centre stage. I was told later these comments and notes were often in opposition to those spoken within the group—e.g. regardless of the side the speakers were taking they were just too argumentative and loud and emotional. Other comments were inside jokes or rebuttals to arguments. From this group three eventually became more outspoken in the class. I wondered whether the notes and whispers and security of knowing others agreed with their perspective gave them the confidence to venture their ideas to the larger group.

Fitting In/Feeling Listened To

P.T.: Please let me in the course. I only need one more course to graduate and this is the only science course that fits my schedule. I'm in the early childhood program and I need one science methods course.
Inst.: This isn't a 'What do I do on Monday?' kind of course. It is about 'big ideas' and issues in science. Are you sure this is the kind of course you want?
P.T.: Yes, I know I can do it.

Four weeks later, this same prospective teacher asked me if I thought she would do okay in the course, the conversations were over her head. Slowly, she began to speak out more and more often. The hesitancy in her language, in her tone diminished as she became the voice of student awareness. When others talked about the consequences of some issue for science or teaching, she proposed consequences for students. There were five early childhood prospective teachers in the course. Each of them became more outspoken during the third part of the course. Only one seemed unable to overcome being intimidated. Prospective teachers raised concerns over the lack of respect people had for other perspectives. They pointed out

following way: "At first I was arguing from atop a solid box, only to have the box replaced by a bowling ball. It was all I could do to maintain my position, let alone defend it!"

Challenging One Another, Questioning Authority

One of the greatest divides in ED3512 was between students of the so-called "hard sciences" (chemistry and physics, especially the latter) and the "soft sciences" (biology, botany, and environmental sciences). There was clearly a sense in the room that those who had backgrounds in chemistry or physics were not only "smarter" than those with biology backgrounds, but that they necessarily had a deeper understanding of the "true" nature of science. This stemmed from two sources. First, of the dominant members of the class, there was an over-representation of students with undergraduate physics and chemistry degrees. As a result, there was a relentless shift in discussions to matters of physics and math, in some sort of search for a deeper meaning of the nature of science. Had most of these dominant class members been graduates of biology, geology, or even ecology undergraduate programs, I suspect that our discussions would have touched upon more inclusive scientific issues, like evolution, genetic testing, and the role of science in environmental issues. These topics seem more germane to people's daily lives and potentially could have encouraged and included many more participants. Instead, we were often caught up in convoluted, highly specific examples of physics and math that left many people confused, most people bored, and almost all excluded. Here is an example of the same exchange interpreted by two different students:

When we were discussing the hierarchy of sciences in class, I endeavoured to spark one of the women in environmental sciences, whose discipline was being denigrated by those in the "hard sciences," with the following question: "Do you think that walking around a forest categorizing plants and animals is science?" Nothing. Silence. Did people take me seriously? I figured that someone would respond by knocking me into the dirt. No response.

One student asked, "Do you biology people really think that looking around in the jungle for new species makes you scientists?" It should be noted that this particular person did not have a science background. Not only was this comment full of that when comments were made by one person the points or ideas were often ignored by the next. Each speaker took the discussion in a different direction. Moreover, speakers were often interpreted. For some the change of focus was considered a rejection of their idea or, at best, disrespect. In one instance, a person came to me concerned that others had ridiculed a peer for a response, but also challenged the person's silence. The person was distraught not only that the ideas presented were dismissed, but that she felt unable to defend herself with what she saw as a group of people who were willing to escalate the emotional and volume level of the debate way past her comfort level.

I asked some students why they felt strongly about their ideas when they talked to me but did not bring them up in class. In some cases the reluctance was the emotional response bordering on what they interpreted as an attack that could follow. These students asked why I didn't stop what they called the pointless arguing and outbursts of certain students. Wasn't it the responsibility of the teacher to control the conversation?

Others said they did not feel comfortable discussing ideas in class when there were so many new ideas they had not thought about before being introduced. They needed more time to think about them; they weren't comfortable responding impromptu so to speak. I felt conflicted and disheartened reading the weekly-question journals at the end of the course. Such insightful comments and excellent points that never arose, were never voiced in class. When did these ideas emerge? What was lost because they were not shared?

We questioned ourselves throughout the course. What are the consequences of allowing participants to work through their ideas, to take risks articulating and defending their ideas? Especially, when challenging, testing ideas puts participants in uncharted territory.

One person whose outburst was shocking to many students, said he was passionate about his ideas, in particular ideas that are central to his areas of interest, his life work. Where some prospective teachers tended to become defensive when their ideas were challenged, others became reflective, and still others withdrew. One withdrew from the course.

sarcasm and insult, it was clearly made in ignorance of the detailed, in depth work required to determine and confirm a new species. It not only served to demean the biologists in the class, but it sent a message to the rest of the class that biology deals merely with the "touchy feely" branch of science, and is not very scientific at all.

Secondly, given that biology is the least abstract of the three principle school sciences, there existed an attitude that biologists were somehow less respectable as scientists than physicists and, to a lesser degree, chemists. My interpretation of this perception is that many believe that a greater quantity, not a different sort, of intelligence is integral in the ''ability'' to do physics, as if anyone who could do it, would. This implied to a number of biology graduates in the class that they are less scientific as a result of the subjects, phenomena, or processes they study and the methods and instruments they employ.

I remember in my second year when I entered my first 'real' physics course, the professor came in and we began to discuss what physics was. He told us "Physics is everything, everything is physics. Biology is the physics of organisms and living systems, geology is the physics of the earth, it's rocks and it's systems, and chemistry is the physics of molecules, chemicals and reactions.

Some prospective teachers didn't see the big deal, too much controversy over nothing. They argued the ideas had nothing to do with teaching. The curriculum determined what they were to teach, wasn't that what they were expected to follow? When Karen asked whether teachers should have a voice in determining what should be taught about science, everyone agreed on the one hand, but critical questions began another debate.

Jobs are hard to get. You mean you're not going to do what they tell you? You'll be fired. What good is a job if all my years studying don't count? Why am I studying all this if they just want someone to follow the curriculum blindly?
What makes you think you know more than the people who developed the curriculum? It was good enough to get us here?
Yes, but just yesterday people were saying they got through science by memorizing. They do not understand science even now. Is that good enough?

It was also a voyeuristic experience for me and one that I learned from—different kinds of students from my own, a wildly different academic and disciplinary perspective and scholarly literature, and a radically unfamiliar pedagogical approach. My own teaching style is much more structured, much more information-oriented, much more addressed to articulating definite alternatives over issues.

Because of that, I always felt myself an outsider and tried to turn my outsider-status to the benefit of the class, by occupying the middle of the road, coming unobtrusively to the defence of the currently-losing faction, harmonizing disputes etc. As an outsider I was very aware of the power-relationships in the class. The milieu of the class demands emotional openness and it rewards acceptance of or at least tolerance of sceptical and critical attitudes about science; "power" in the course (particularly in that edition) was clearly on the cultural-critique side, not the Gross-Levitt side. Standing against it required courage and self-confidence; those who didn't have it but didn't want to go along resorted to silence or guerilla tactics. I had much sympathy for the disgruntled, even though intellectually I wasn't in their camp.

Complexity and Ambiguity

My style of teaching makes some prospective teachers uncomfortable. To complement the traditional introductory methods course, I wanted to create a course that provided prospective teachers with an opportunity to consider larger questions and issues within science education. I hoped two things could happen from such an opportunity. One, prospective teachers would begin to envision science education as more than delivering a curriculum and, two, they would recognize that their beliefs about science influenced their decisions as teachers. The challenge always was to design the course to allow discussion, not just teacher-prospective teacher dialogue.

Refusing to be the voice of authority generated ambiguity by removing the cues on which these academically successful prospective teachers relied to construct a web of ''what's important to know in this class'' information. Creating assignments that

Silence

As in any classroom situation, silence was an important and inescapable feature of ED3512. Silence is typically imagined as empty space, the opposite of language, signifying nothing. To understand any conversation silence must be considered as integral. One writer has adeptly suggested that "(l)anguage can only deal meaningfully with a special, restricted segment of reality. The rest, and it is presumably the much larger part, is silence."

For me, whenever I was silent it occurred for a few reasons. First, I couldn't get a word in. Secondly, the conversation was so far off on a tangent I was completely uninterested in the conversation. Thirdly, I was too mentally exhausted to get into it. Lastly, there was no point, none of the class members seemed to care about what I had to say anyway.

Mental Memos to those who keeps talking about Heisenberg, Schrodinger, and quantum mechanics:
(1) shut up!
(2) I can't get a word in edge wise
(3) finally, someone standing up for us, for science
(4) this debate sounds really difficult. I can't enter this debate.
(5) who cares! I'm not interested in science.

Though silence may be a legitimate lack of voice, it also may be understood in a variety of ways: ignorance, intimidation, nervousness, anger, indifference, disconnectedness, dissension, thought, and complacency to name a few. The question remains, "what did the silence mean in the context of this particular debate?"

I read every god damn article in this class not because I am afraid of the consequences for not reading them, but because I feel that my responsibility to myself (to learn) and to the class (to participate) is at the heart of my intellectual and academic life. Have people read these things? Do people care? The things we are talking about in class are huge issues. Reading Kuhn is more than mere scientific. This class is about power and society and who get to decide what for whom. How can people not be interested in this? Why won't people speak up and defend themselves.

In speaking with some of the silent students months after the end of class, we can better flesh out for required they become voices of authority was equally new to most of them. I refused to give examples of what I was looking for or what students had done in the past. I did offer to read papers and give feedback, discuss ideas, and offer suggestions. Despite what I saw as providing an opportunity to assume leadership roles and practice being voices of authority, prospective teachers complained of a lack of guidance and uncertainty of what I wanted from them. This was just a course after all and they had four or five others with assignments too.

My own participation in the course was and is an ambiguous and ambivalent one. On the one hand I was there as the outside expert on the "nature of science" and its literature—the only lecturer, the ostensible source of definitive answers, if any were to be produced. But I also wanted to be participant, friend-of-the-court, advisor, helper etc. I had to both play the expert and resist it, in part so as not to compete with Karen for moral authority or to take the course off in directions different from those she wanted to explore. (Neither were serious problems, since I think there was a pretty wide range of common agreement about the directions to be explored.)

The final assignment was voluntary. A position paper describing what should count as an understanding of science and what steps would you take to implement your beliefs, was only completed by students who were concerned about the quality of their other assignments, with one exception. Three of the prospective teachers in the early childhood program wrote a collaborative response. They seemed unable to put aside the course without some closure.

Challenges to Beliefs and Understandings

Some students thought the points and arguments, the challenges to science were blown out of proportion. Sure there were some problems with science, but overall science was good and the best way of solving problems and finding truths. How were we going to continue progressing without science? These students separated science from the scientists.

I felt the milieu of the course got too radically polarized between "science is good and true" and

what the silence in the class stood. One woman suggested that early in the course people were afraid to attend, that the material was "over her head." So, early in the course, it would not be unreasonable to suggest that the silence was largely the result of nervousness and apprehension. Many, if not all, in the course were taken aback by the tone of the discussion. As one ex-student said, ED3512 was not really an education course. Although, as she rethought her response, she recanted that perhaps it was the ultimate education course: it "blew the top off our own myths." This myth destroying function of the class possibly had a relation to the silence. Words do flow freely when one's core assumptions are being challenged, or, even more distressingly, attacked. Perhaps, the silence initially was a function of students' nervousness, but later became a function of their defensiveness.

After the Course

Joe: After the course, conversations with peers and friends challenged me to rethink my beliefs. I attended lectures on Christianity in a post-modern world and read things like *Why Should I Believe Anything at All*? and *The Truth Sounds a Little Stranger than It Used To*. I became more critical of what I read, heard, and saw in the media.

Beth: I felt empowered and was given a voice. I successfully participated in "science". As Coordinator of a Family Resource Centre, I work with over 300 families. ED3512 reinforced my belief in life-long learning and having a voice. I bring these beliefs to my life and work everyday.
Hart: While I was not assigned to teach science during my practicum, taking the expanded critical base from which I was able to work. The intellectual investigations that began in ED3512, remained a central theme in my graduate work.
Cynthia: I was in turmoil; teachers in school were saying what I was 'told' in university was wrong. Finally, I was able to develop my own unit which students liked more than my co-operating teacher did. Even as a biology teacher, there is little time to include ideas about the nature of science.

Rick: Teaching physics offers no opportunity to implement or even discuss ideas from ED3512. The curriculum is content and test driven; we are pressured to produce ever greater performances on provincial assessments. Teaching the nature of science is a secondary goal. The first goal is ineffectual, the second is never considered.

"science is bad and false", and implicitly gave up its opportunity to explore constructive middle-grounds. I felt that "science" was always getting lost, as the logic of the course carried it straight onto the grounds of cultural politics over and over.

At one point I asked, if you had the choice, would you go to a medieval Galenist or modern doctor if you were sick? Would you depend on twelfth century understanding of human physiology or twentieth century? Questions like this served to refuel debates that became one-sided and at the same time opened ways for new ideas. Often, they opened opportunities for new speakers to enter the conversations. More often though, the conversations such questions sparked were squelched by those who returned to old rhetoric in defence of their positions.

I asked if they were teachers who were interested in science or scientists who were interested in teaching. Most of the prospective teachers with science backgrounds indicated the latter.

Who can call themselves a scientist? Once, I invited a member of the science faculty to participate in a class discussion. Towards the end of the discussion I asked him if students who completed a Bachelor of Science degree were members of the science community. He said, "No". I quoted him in class. Students who had worked with research teams as part of their program were angry and argued they were treated as equal members of the team. They were members of the science community.

The number of prospective teachers with strong negative and positive reactions to the experience grew throughout the course. Few were neutral; even the silence of those who refused to talk to the prospective teacher-researchers months later about their experience spoke volumes.

My own experience suggested, despite this experience, most prospective teachers continued to adopt the kind of science teaching they experienced as students and saw modelled in schools during their internship. Many prospective teachers argue teacher education programs are a way of extracting money from them and esoteric to the real task of teaching, which they know well from their years as a student.

How did you, the reader, read this text? Did you go down each side or across and back or skip and catch? Is your blood pressure a little higher? Are you disturbed or bored or angered or intrigued? Do you wish you were there or glad you missed this opportunity? Would you hire the instructors or support their dismissal? Are the stories and experiences familiar or foreign? Would you condone the practices of these prospective teachers in your program? Questions like this, we believe, are raised by our attempt to create a research text that captures the dynamics of an experience and that speaks with the multiple voices of that original experience.

Since writing the text was creating the experience for nonparticipants, the challenge was to capture what we thought were important aspects of our experience. Just as we wanted prospective teachers to be actively, not passively, engaged, we wanted the same for readers. However, such a text raises questions about what are data and how should data be conveyed to readers. For example, is the experience of reading this text data? What is the researcher's responsibility in conveying data; should a research text reduce or induce complexity?

Discussion: What did We Learn?

We found studying the cultural wars over science offers a valuable context for learning to teach science despite the difficulties prospective teachers had grappling with the complex debates. We also found that the structure of the course and intensity of the interaction about the nature(s) of science was traumatic for some, a nonevent for many, and a welcomed experience for others. More specifically, we learned prospective teachers' school-university science experiences and prior beliefs were the greatest barriers to their developing more complex understandings of the nature(s) of science. Finally, we found the intellectual commitment to grapple with complex notions about the nature(s) of science and teaching science suggested that we need to rethink what we expect of prospective teachers of science. We examine these findings in more detail.

Whatever the issues about the nature(s) of science raised in the readings or lectures, prospective teachers' comments most often shifted the discussions to debates about their own differing school-university science experiences or membership in conflicting pedagogical cultures within the teacher education program. While the cultural wars emanating from the history, philosophy, and sociology of science debates about science were new to almost all the prospective teachers, conflicts over school science were nothing new. The science cultural wars were just a new dimension of the tacit culture surrounding school science to which they had been exposed and within which they have formed alliances, taken positions, assumed roles, and constructed beliefs. Moreover, participation in such a culture results in beliefs about science that are tacit as well. ED3512 challenged students to recognize and articulate these tacit beliefs.

One group of prospective teachers in ED3512 represent those whose academic background lay in science; these individuals usually identified closely with their success in science. Often, the accolades and recognition they received from family, teachers, community, and peers through their success in science are strongly connected with their sense of self-worth. The privileged status of science in the general culture becomes a source of personal status. Part of these prospective teachers' difficulties in coming to terms with the cultural wars about science is differentiating criticism of science from criticism about themselves. One prospective teacher-researcher admitted at the end of the course that he had always been aware of the tentativeness of knowledge in other areas; he always thought science was the one sure source of knowledge. It was devastating to acknowledge that serious discussion could exist about the methodological underpinnings of science knowledge itself.

Another group of prospective teachers in ED3512 represent a significant number of individuals who had not pursued science in school or university, and who had been silenced by their school science experiences. These individuals usually choose to concentrate on teaching primary and elementary level students. At least initially, they tended to cope with class discussions by avoiding the exercise, sitting silently through each class with eyes down cast at the floor or their papers. They had located themselves within the school science culture as not smart enough or, if good at memorizing, not interested enough. The door to science closed on them long ago, they had no confidence that opening it again would be any different than before, and they regarded the kinds of issues discussed in ED3512 as an extension of those that had created anxiety in other kinds of science classes in the past. Only slowly did some of these prospective teachers begin to find in ED3512 an avenue for reflecting on their science-related experiences of the past, speaking out about those experiences, and gaining some new sense of confidence and empowerment through this new venue for intellectual engagement with science-matters.

A third group of prospective teachers in ED3512 represent those who distrust science or who bring attitudes of hostility to their discussions of science. Some of these prospective teachers find their ideas and beliefs negated or critically undermined by science. Some repeatedly invoked the on-going contest on university campuses between arts and sciences (see the Leavis–Snow debate described by Stinner, 1989). Prospective teachers from arts programs are aware and sometimes resentful of what they consider unfair allocation of the university resources and space on campuses to science, and of the greater prestige sometimes accorded to those studying in the sciences. Some prospective teachers with strong religious beliefs must struggle to reconcile scientific teachings with their religious beliefs. These prospective teachers find allegiance to science difficult. This subgroup of ED3512 found critical theorists active in the nature(s)-of-science debate with whom they agreed and who helped them to articulate their own feelings of distrust and resentment, but they were often dismayed by unexpected reactions of hostility from other participants in the course.

Recognizing the very different backgrounds and professional aims of students in the course helps to explain why establishing and sustaining class discussion was one of the most difficult parts of ED3512. Clearly, the novelty of the issues being raised, and the refusal of the instructors to voice their own beliefs, were factors that contributed, at least initially, to the difficulties in maintaining discussion. But the challenge of listening to others, particularly those who speak from different and not-immediately-identifiable perspectives was also a significant problem. Prospective teachers have limited views about learners, including other prospective teachers, who are different from themselves (McDiarmid & Ball, 1987; Paine, 1990). Moreover, they have little tolerance for learning environments that are unfamiliar. Bird (1992) found prospective teachers were disconcerted and revolted when their conceptions of a course collided with the instructors' perceptions, and ED3512 clearly violated many of the prospective teachers' conceptions of teaching and learning as the transmission and reproduction of fixed knowledge. This egocentric view may account for the kinds of experience and discourse prospective teachers valued and challenged in the course as well. For example, debates over who is doing science, what counts as an understanding of science, and the role of the science cultural wars in curriculum, are instrumental for prospective teachers to recognize their own dissonant experiences and beliefs. While the resulting discussions raised hostilities and animosities among participants, we think those animosities are unavoidable and probably necessary to a full, responsible discussion.

Lastly, the disparate academic backgrounds and teaching interests prospective teachers bring to the course make initiating discussion particularly difficult. Aside from most of the

prospective teachers not knowing or interacting with one another before, they came with diverse, often tacit, political, ethical, and epistemological assumptions about science and teaching. Some were unaware of the issues of power that are inevitably associated with participating in a conversation, or the confusion and dissonance created by shifting from one conversation (or discourse community) to another. The science students, for example, were frequently accused of using their own language of expertise as a strategy to intimidate or impress. While ''talking physics'' had been a way to demonstrate ''I belong'' in their previous degree program, ED3512 challenged prospective teachers to communicate with those in other discourse communities and to realize that conversations both extend power to and exert power over individual voices.

Discussion: The Nature(s) of Science and the Professional Development of Teachers

The programme to introduce prospective teachers into the conversation about the nature(s) of science is justified on many fronts. First, it may improve the efficacy with which science-content is taught (although as noted, research-results are mixed on the point). Second, the nature of science itself promises to become an important content-element of the school science curriculum, and today it broadly informs many calls for the reform of science teaching, sometimes in contradictory ways; two of us have discussed this development in another publication (Turner & Sullenger, 1999). And in general, few would deny that science teachers ought to be aware of epistemological underpinnings of science, its historical and cultural roots, and the debates over its contemporary social and cultural impact.

We argue here a different point—that the invitation to join the nature-of-science discussion, such as that extended by ED3512, can be critically important to the professional development and professional identity of prospective science teachers. Moreover, our team's findings about ED3512 suggests a need to rethink the kinds of experiences teacher education programs provide prospective teachers of science. We offer three issues raised by our study to initiate the discussion.

Grappling With Complexity

A growing number of researchers contend that willingness to grapple with complexity is at the heart of being able to overcome the barriers created by too simplistic organizations of knowledge. Whatever the justifications for avoiding excessive complexity in introducing learners to new and difficult material, the approach carries inherent liabilities. In typical school science texts, for example, the understandable need to reduce the complexity of early science study results in the appearance that ideas are sure and knowledge well-organized, thus introducing a possible future barrier to students' appreciation of the dynamic and contested nature of science-in-the-making. Science in texts and university lectures is often presented in ways that minimize controversy or the creative leap from evidence to inference. Students who master the straightforward introductory story of science sometimes find it difficult to comprehend the more complex aspects of the enterprise when they continue their studies. Avoidance of complexity can also complicate students attempts to move from knowledge to practice. Spiro (e.g., 1987, 1994) found that medical students who excelled at classroom knowledge had difficulty during their first rotations in the emergency rooms. Patients did not exhibit the symptoms in the clear sets laid out in the texts and introductory lectures.

Teacher education programs can create these same liabilities. To various degrees of sophistication, these programmes still frequently promote the belief that ''becoming a good

teacher'' means acquiring a set of skills, e.g. learning to demonstrate an instructional approach or sets of teaching strategies, writing good objectives and lesson plans. Reducing teaching to technique requires avoidance of complexity. We perceived ED3512 to be an important antidote to these tendencies. ED3512 invited students, indeed compelled them, to grapple with complexity. Our study supports arguments that the complexities of teaching and learning and of understanding science can best be understood by engaging in experiences that simulate the complexities of thinking, decision making, and practice these prospective teachers will encounter. Exposing prospective teachers to these situations, and introducing them to the complex issues and debates in which academics and scholars were engaged, offered them an opportunity to challenge their own thinking, expose them to the sometimes radically different experiences and beliefs of other prospective teachers, and allow them to consider how they might practice teaching differently. We argue that learning to grapple with complex issues is an indispensable foundation for life-long learning and is essential to students' professional development.

Developing Professional Identity: Locating One's Self in the Conversation

Richardson (1990) argues that the goal of professional development should be that of initiating prospective teachers into the observance of ''warranted practice.'' By warranted practice she means commitment to a practice that is embedded in a theoretical framework, and, furthermore, commitment to engage continuously in conversations with other professionals about warranted practice. Warranted practice requires being able to articulate one's beliefs and locate oneself in the conversation about practice. Obviously, Richardson's conception of professional development radically deemphasizes the functions of skills- and knowledge-acquisition; it undermines the position of faculties of education as gatekeeper institutions, creates a new sort of dialogue between theory and practice, and it encourages the notion of teacher-development as a long-term process that has begun long before university and will continue long after it. The notion of ''warranted practice'' is the understanding of professional development that informed ED3512, and the experience of the course is important for illustrating the obstacles to realizing such a concept in practice.

Prospective teachers came to ED3512 with strongly-held (if usually unarticulated) expectations about school science, about teacher-education, and about teaching practice; most of these were inimical to the concept of professional development as warranted practice. Perhaps the most strongly-held expectation was that education courses and teacher educators were to tell you what to do, how to do it, and thus, ease anxieties about being an effective teacher. Prospective teachers were frustrated and sometimes hostile when, instead of satisfying these expectations, the instructors raised questions which were often left unresolved, created uncertainty, and offered no techniques for classroom practice. In addition, most prospective teachers came to ED3512, as to their professional education, with pessimistic and limited expectations about their autonomy and responsibilities as teachers. Schools had fixed curriculums, teachers were hired to teach curriculum, and they would have little control over what concepts were covered, especially, with standardized assessment. Open-ended debate over esoteric questions like the nature(s) of science, and what these questions might mean for teaching, struck many as impractical and irrelevant. Given their performative understanding of professional practice, it seems understandable, if not predictable, the demand for critical engagement in the course, including being forced to expand on their ideas, defend points of view, and take positions within the conversation, struck many as unnecessary and threatening.

Prospective teachers also brought to ED3512 ingrained expectations about how they should be taught. Fifteen years of schooling had persuaded most that the teacher is the authority, the teacher is right, the teacher is to be pleased, and—most insidious—that academic success involves reading the mind of the teacher to properly assess expectations. When the instructors in ED3512 attempted to remain as unobtrusive as possible and refused to foist their voice onto their pupils, many students were suspicious and frustrated. In the process, however, many prospective teachers did learn to state their beliefs and to defend their positions without constant reference to instructors' supposed expectations. Most prospective teachers tried out different voices throughout the course, shifting back and forth from critic to supporter, doubter of science to doubter of self, and speaker to listener. In the spirit of warranted practice, they discovered that finding one's voice is a part of establishing a professional identity.

Assessing Professional Development: Participating in Conversations

Teacher education programs succeed best when they aim at introducing prospective teachers to the big ideas, questions, and issues surrounding science education. Education programs are best at introducing them to the wide array of alternative approaches to teaching science and to new practices, especially the theoretical frameworks underlying these approaches and practices. Finally, education programs could be good at providing models for professional thought, practice, and growth as educators of science; much like Linn & Muilenburg (1998) argue for teaching science by providing models for becoming life-long learners of science. To accomplish this, university educators would have to introduce prospective teachers to more complex understandings of science, engage them in conversations about warranted practice, and relinquish the notion of a standard understanding of the nature(s) of science. Teacher education programs should expect prospective teachers to be willing to grapple with complex ideas, articulate what it is they believe, move beyond parroting what teacher educators believe, and to teach in ways that acknowledge the influence of beliefs on practice.

Accepting these claims, however, has important implications for how teacher education programs, and the profession itself, assess professional development. Philosopher Richard Rorty (1979) argues that conversation is the ultimate context of meaning-making. ''If we see knowing not as having an essence, to be described by scientists or philosophers, but rather as a right, by current standards, to believe, then we are well on the way to seeing conversation as the ultimate context within which knowledge is understood.'' But if Rorty is correct, then the willingness of a prospective teacher to ''participate in conversations'' must become a recognized standard of professional development and assessment. The conceptualization of understanding needs to be broadened to include the act ''of being involved'' as well as ''knowing''. Understanding the various perspectives and beliefs people hold about the nature(s) of science is an example of ''knowing'' or what Rorty refers to as ''alternative standards of justification.'' ''Being involved'' requires articulating one's own belief's and being able to locate oneself within the conversation. House, Mathison, & McTaggert (1989) contend that most knowledge is intuitive, elicited during problem solving; we suggest from our experience in Ed3512 that most beliefs are intuitive and best elicited in the context of a problem or conversation. Conversations about the nature(s) of science are rich in opportunities to help prospective teachers articulate their beliefs, compare them with others, and ultimately link them with decisions they make about practice. Conversations provide a model for moving from personal to professional frameworks for thinking about teaching science, and should be recognized as such.

Conclusion

Our research suggests the cultural wars experienced by prospective teachers are about dissonance between the science story portrayed and experienced in schools and undergraduate programs and the science stories experienced in courses like ours, as well as dissonance between the pedagogical cultures portrayed in teacher education programs and displayed in schools. We suggest the current science-wars debate and the issues it raises are an effective way to encourage prospective teachers to bring their own dissonant experiences and beliefs about science to the fore despite the limited, and often derailed, discussions they are able to initiate and maintain about ''nature(s) of science'' issues. Prospective teachers perceived the course to be about fundamental questions like: Where do I put my trust? Where do my beliefs fit? What do they expect me to teach and how should I be teaching? And why, if this is what people believe about science, are they still teaching science the way I learned it in school? The value of this experience is not expertise in the nature(s) of science, although there is considerable evidence these prospective teachers have advanced their understanding, but that many of the prior conceptions pervasive in school science and reinforced in university science programs are made public and become topics of discussion.

We argue that responsible professional formation and future practice require these experiences and beliefs be articulated, faced, discussed, and their implications be related to future practice. More importantly, the discussions raise questions that are central to prospective teachers finding their own voice and making their own decisions. Viewing teacher education programs as benchmarks in professional development, requiring prospective teachers be active participants in directing their own professional growth, and using standards of professional development as guidelines for success is a way to invite prospective teachers to be part of the dialogue about learning to teach science.

A question our experience raises for university educators in teacher education programs is, What should instructors, gatekeepers of further access into the profession, hope or expect prospective teachers to have as an understanding of science? Equally important is the question, If these prospective teachers are engaged in the kinds of critical and reflective debates about science and teaching we say we want, should we rethink what contributes to successful understandings? We argue being engaged in conversations about the nature(s) of science regardless of the barriers prospective teachers may face is essential to their becoming more effective professionals. Being engaged in conversations about the nature(s) of science and its implications for teaching science raises vital questions for university educators and prospective teachers alike. As Randall argues at the outset of this paper, vital questions are relevant to our lives and arise from our understanding of ourselves, which in turn affects the way we act to promote change, which ultimately affects the way the world is.

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