Teaching about Ethics through Socioscientific Issues in Physics and Chemistry: Teacher Candidates' Beliefs

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Abstract: The purpose of this qualitative study was to identify and explain the origins of physics and chemistry teacher candidates' beliefs about teaching about ethics through socioscientific issues (SSI). This study utilized a series of in-depth interviews, while the participants ($n = 12$) were enrolled in a 9-month teacher education program at an urban university in Canada. Our data analysis revealed that beliefs about teaching physics and chemistry using SSI derive from a complex web of fundamental beliefs exemplified by four *archetypes* representing the subject-specific identities of our teacher candidates—Model Scientist/Engineer, Model Individual, Model Teacher, and Model Citizen. Furthermore, we found that the justification for belief change required by a particular teacher candidate depends on these subject-discipline identities. Thus, the presence of each archetype in preservice classrooms has ramifications for the way a teacher educator should encourage his or her students to include SSI in their teaching. © 2009 Wiley Periodicals, Inc. J Res Sci Teach 47: 380–401, 2010

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The purpose of this study was to explore physics and chemistry teacher candidates' beliefs about teaching ethics through socioscientific issues (SSI) and the relationship of those beliefs to subject discipline identity—that is, the way these teacher candidates see themselves with respect to the main science which they studied in university. We also aimed to develop a model of teacher beliefs, tracing the origins of their beliefs about including ethics in their teaching.

SSI are defined as involving "complex problems subject to scientific data as well as ethical considerations" (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006, p. 354). The inclusion of SSI in science teaching is meant to develop students' skills in moral discourse (Zeidler & Keefer, 2003) by providing class time to discuss ethical issues related to science. This practice during class time (or lack thereof) has ramifications for future citizenship (Barrett & Nieswandt, 2008; Zeidler & Sadler, 2008) partly because, without it, science students tend not to use their scientific knowledge when considering SSI (Sadler, 2004).

The inclusion of ethics, through SSI, in science curricula is often part of a larger framework called science-technology-society (STS) education, which aims to make connections between science, technology, and society in science education. In spite of its inclusion in official curricula in several jurisdictions (see, e.g., American Association for the Advancement of Science, 1993; Ontario Ministry of Education and Training, 2000), STS has not been widely implemented in science courses and, in particular, in senior physical science courses (Cross & Ormiston-Smith, 1996). We were curious about how teacher candidates thought about teaching ethics through SSI within physics and chemistry. Teacher candidates are in a unique position because they are students of science striving to become teachers of science. We believe that making

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connections between teacher candidates' identities as science students and their developing science teacher identities could yield interesting insights about how best to work with future teachers to change the way physics and chemistry are taught. We define identity as a negotiation between the self, other people and the context in which people live and work. It can be described as identity with respect to communities of practice (Wenger, 1998).

To make sense of the data collected, we discuss three different concepts (1) ethics (since SSI explicitly consider them), (2) beliefs (the object being studied), and (3) identity (the theoretical basis of our analysis) and how it relates to ethics and beliefs. The findings section will summarize the teacher candidates' beliefs about teaching ethics through SSI, drawing connections between these beliefs and their identities as science students and future science teachers. The themes within the data corresponding to each research question will then be used to build archetypes–exemplars of subject discipline identities that might be found in a science teacher education class. Finally, the themes will be used to describe the origins of the teacher candidates' beliefs.

Conceptions of Ethics and Socioscientific Issues

Through discussions of SSI, students are given the opportunity to consider the ethical aspects of science and their ramifications for society (Zeidler, Sadler, Applebaum, & Callahan, 2009). Our conceptions of ethics affect the way we approach ethical dilemmas and determine courses of action. Thus, the definitions of ethics that our participants held were expected to impact their beliefs about the inclusion of SSI in their teaching.

We conceive of ethics in terms of (1) to whom the moral agent is responsible in a given moral dilemma and (2) the content of the dilemma. For responsibility, we focus on two authors; Noddings and Freire, who base their conception of ethics on what it means to be human. Noddings (1984) states that all human beings need to be cared for and to care for someone, therefore when we act in a way that denies this we are diminished as human beings. By basing moral decisions on relationship rather than moral principles, this conception of ethics locates responsibility in relation to individuals.

Freire's (1998) conception of ethical responsibility begins with the idea that all living beings are essentially unfinished because none have fulfilled their full potential as living beings. He argues that our ethical responsibility derives from the fact that human beings are the only ones which are aware of that unfinishedness. This parallels Derrida's (1995) understanding of ethical responsibility being a consequence of our inability to know if we are making the right decision. Freire's (1998) conception of ethics locates responsibility in relation to society or a collective because his focus is with people being moral agents within society. Thus, we have two ''views'' regarding to whom we are ethically responsible: to individuals, as Noddings (1984) advocates and to society as Freire (1998) advocates.[1]

The content of ethical dilemmas is the second part of our conception of ethics. For science, the content may pertain to either the processes or products of science (Allchin, 1999) which we will call procedures and applications respectively. The procedures of science relate to the way science is done. The applications of science relate to the consequences of scientific research. Allchin (1999) refers to values apparent in the procedures of science practice, including testability, reliability, novelty, minimizing suffering for animals, and informed consent for human beings. We would add issues of inclusivity (e.g., the underrepresentation of women and people of color in science research careers) to this as it pertains to the actions of those engaged in science practice. The values revealed by the applications of science arise from the thin line between pure and applied science. Students' consideration of SSI has been investigated by others (see, e.g., McGinnis, 2003; Sadler, 2005; Sadler & Zeidler, 2005). In this study, we focus on awareness of the ethical aspects of the procedures or applications of science or what we might call *moral sensitivity* (Sadler, 2004) where participants may be more likely to recognize ethical issues about procedures than they are about applications and vice versa.[2] Teacher candidates' beliefs about teaching ethics through SSI were expected to relate to both their moral sensitivity with respect to SSI and their conceptions of ethics.

Beliefs

Beliefs have been described in the literature as the foundation for action and learning, theoretical frameworks in which to judge and filters for accepting or discarding new information (Feldman, 2002; Kane, Sandretto, & Heath, 2002; Pajares, 1992). Our definition of beliefs is based on Kane, Sandretto, and Heath's (2002) work, which classified beliefs or *action theories* (as they call them) into two categories—*espoused theories* and *theories-in-use*. Espoused theories are those beliefs which a person describes when asked. Theories-in-use are beliefs which seem apparent through a person's actions. We will refer to these as *espoused beliefs* and *beliefs-in-use*, respectively.

We were especially interested in the teacher candidates' espoused beliefs about what counts as legitimate content to be studied in physics and chemistry. Students of physics and chemistry learn this through their undergraduate studies and, in some instances, graduate work (Becher & Trowler, 2001). They would have learned what prerequisite knowledge and skills they need to ensure their future students possess in order to be successful when they go to university. Further, high school teachers may believe that their way of teaching physics or chemistry—their focus on abstract concepts, their avoidance of context except where it might enhance the learning of the abstract concepts (Carlone, 2004)—is the proper way to study physics and chemistry. Thus, inclusion of SSI in high school physics and chemistry courses is unlikely unless beliefs about physics and chemistry as subjects of study are identified and interrogated (Bryan & Atwater, 2002).

Teachers' beliefs-in-use are easy to ascertain but difficult to explain because, although they are, by definition, beliefs that can be inferred from a person's actions, they are further complicated by their context based espoused beliefs about what they can accomplish given resources available, time constraints, and their students' abilities and interests (Friedrichse & Dana, 2005). As teachers' beliefs about a subject of study and context based beliefs interact, it becomes difficult to tell which of their actions are based on what they want to do and which are based on what they believe they have to do in spite of their desire to act differently (Barrett & Pedretti, 2006). Thus the differences between espoused beliefs and beliefs-in-use must be examined carefully, in light of context, as clues to the commitment teachers have to their espoused beliefs.

One study of high school science teachers' beliefs about teaching through SSI (Sadler et al., 2006) found that the teachers could be divided into five groups: Group A (committed to including SSI), Group B (committed but unable to realize goals due to contextual constraints), Group C (not committed to including SSI), Group D (does not believe SSI belong in science because science should be value-free), and Group E (believes ethics should be part of all education). These results were consistent with a similar study of Korean teachers' beliefs (Lee, Abd-El-Khalick, & Choi, 2006) which also found that the teachers' number one priority was preparing students for exams. Neither study sought to explain the origins of these beliefs. Our study may shed some light on this.

Subject Discipline Identity

Besides learning what content belongs in a given discipline, students also learn how to *be* students of the discipline. An example of this is the archetypes described by Costa (1995) and later enhanced by Aikenhead (2001) of students of science: *potential scientists*, *other smart kids*, *I want to know students*, *I don't know students*, *inside outsiders* and *outsiders*. These were identities that were in relation to science and were therefore what we would call *subject discipline identities*. The potential scientists and other smart kids might be expected to go on in science in university, choosing a particular discipline on which to focus. As students, they become initiated into that discipline and adopt an identity in relation to that community. Beliefs about an area of study, like all beliefs, are connected to identity (Larochelle, 2007). Becher and Trowler (2001) described the importance of what they called heroic myths as the foundations of subject disciplines. In chemistry and physics, stories about the intellectual achievements of Isaac Newton, Niels Bohr and Ernest Rutherford not only put a human face on scientific development, they also act as exemplars of the kinds of scientists students should aspire to be. These scientists are heroes because of their achievements and mythical because of the lack of historical and social context in the stories about those achievements. Students of physics and chemistry develop their identities with respect to the discipline in light of these heroic myths. This is the reason why we chose to study teacher candidates as participants. Teacher education programs are the first formal opportunity for most teacher candidates to consider the question of what constitutes legitimate physics and chemistry content in high school and are likely the first time that their identity as a science teacher is formally addressed.

Various researchers propose that identity is an important factor in teachers' choices in the classroom (Barrett & Pedretti, 2006; Beijaard, Verloop, & Vermunt, 2000; Sachs, 2001). The conception of identity that we use is derived from Wenger's (1998) concept of identity with respect to communities of practice—a negotiation between the self, other people, and the context in which people live and work. Wenger (1998) contended that people derive their identity partly from the way they see themselves in relation to those with whom they work professionally in the present and who they expect to be working with in the future. This conception of identity consists of five components: learning trajectory, community membership, nexus of multimembership, relation between local and global, and negotiated experiences.

Learning trajectory is that part of identity based on who one wishes to be in the future. For teacher candidates, learning trajectory relates to where they see themselves in their professional futures. There are four trajectories: peripheral, inbound, inside, or boundary (Wenger, 1998). A person with a *peripheral* learning trajectory does not feel part of the community of practice but is interested in what the community has to say. We expected that many teacher candidates would have peripheral trajectories, not seeing themselves as members of the community of scientists/engineers[3] but still interested in what scientists and engineers have to say about the content they teach and, perhaps, how to teach it. An *inbound* learning trajectory indicates the person sees herself belonging in the community in the future. Individuals with an *insider* or a *boundary* trajectory feel like a part of the community in question, however the latter also see themselves as a liaison between different communities.

Community membership is a person's recognition of the familiar and the unfamiliar, the culture and norms which make one feel at home or in foreign territory. The implicit values we come in contact with in a given setting and the way we define ourselves in relation to them form this part of the identity negotiation. Conceptions of ethics are an important aspect of this negotiation for we often define who we are based on values we do or do not share with a given community. Teacher candidates are attempting to become members of the community of science teachers and are attempting to determine what a teacher's ethical responsibilities are as they do so, however, they also belong to other communities. *Nexus of multi-membership* is the complex interaction between a person's various community memberships, including but not limited to work communities. The communities we focused on in our study are the teacher education program, scientists/engineers, and teachers. Our participants (preservice physical science teachers) were seeking membership in the latter but their conception of ethics with respect to science derived from all of the communities in which they were a member, wished to be a member or by which they were influenced. A *relation between local and global*, in our study, refers to how the teacher candidates saw their actions in the classroom fitting into the broader purposes of education and the expectations of scientists and society. *Negotiated experiences* derive from the way we view ourselves within specific contexts and how we believe others perceive us in those contexts. This aspect of identity is shaped and, in turn, shapes the way we behave or intend to behave in a given context. The teacher candidates in this study had all developed a perception of themselves as science students and teachers which was based on past and present experiences. These negotiated experiences are where beliefs (both espoused and in-use) and identity interact and where teacher candidates' ideas about themselves as teachers and students of science form.

Research Questions

Our intention was to describe some subject discipline identities in the form of archetypes, in much the same way as Costa (1995) and Aikenhead (2001) did with types of science students. But we also wished to take it one step further by explaining the origin of the beliefs that define the archetypes.

Our specific research questions were the following:

(1) What beliefs do physics and chemistry teacher candidates have about the importance of teaching about ethics through SSI in physics and chemistry?
(2) What are the origins of teacher candidates' beliefs about teaching ethics through SSI?
(3) What is the significance of subject discipline identity on the answers to the above questions?

Methodology

Participants and Sampling

All participants ($n = 12$; 6 males and 6 females) in this study were enrolled in a 1-year post-baccalaureate teacher preparation program at an urban university in Ontario, Canada—labeled in the following as "The Faculty." In Ontario, teacher candidates who wish to be qualified to teach in high school must have taken a certain number of courses in two areas of specialization or teaching subjects. One of our participants (Franco[4]) had physics and chemistry as teaching subjects; five had physics and mathematics (Maura, Bill, Paul, Nadeem, and Renate); and six chemistry and mathematics (Brenda, Candice, Ellen, Richard, and Pietro). During their 1-year program, all preservice teachers complete two full-year discipline-specific curriculum and instruction courses in their teaching subjects. The science discipline-specific courses provide teacher candidates with theoretical and practical understanding of instructional methods, as well as strategies for assessment/evaluation, unit and lesson planning in a variety of classroom contexts, the integration of technology into teaching, and creating inclusive and motivating learning environments. Our participants were enrolled in the chemistry and physics curriculum and instruction courses. They were purposefully selected from the larger group of chemistry and physics teacher candidates ($n = 76$) based on their answers to an open-ended questionnaire (Barrett, 2008). This questionnaire asked about academic background, goals for science education, and beliefs about including SSI in their teaching of senior high school physics and chemistry students. The open-ended structure of the questionnaire reflected the exploratory nature of the study. It was designed merely to provide enough information to choose the 12 participants for the interviews. However, the focus on grade 12, university-bound physics and chemistry courses was deliberate. We believed that, in order to bring the teacher candidates' beliefs about the disciplines of physics and chemistry into the mix, we needed to eliminate considerations of classroom management and ability from the equation. It was assumed that the teacher candidates would expect that they would be able to ignore classroom management issues when teaching grade 12, university bound students. Also, we needed to make the influence of future university studies a consideration. Focusing on the final year in high school and advanced courses was the route we chose to do that.

To minimize the influence of instruction, the questionnaire was administered in the first week of classes at The Faculty. Based on the questionnaire responses, we used theoretical sampling (Creswell, 1998) to choose a total of 12 participants. Twelve participants provided a form of triangulation through more than one source for the same construct (Lincoln & Guba, 1985). That is, we were investigating the connections and interactions between identity and teaching ethics through SSI in order to construct a model of teacher candidates' beliefs, and these 12 participants provided 12 different examples of that construct. We chose participants based on having a wide range of academic backgrounds (six physics and six chemistry majors with a variety of degrees: engineering degrees, masters and undergraduate), questionnaire answers, and a range of opinions with respect to including SSI in their teaching. Our selected group included six participants who had a Bachelor of Science degree (Franco, Maura, Bill, Paul, Brenda, Renate, and Pietro), three with a Bachelor in Engineering (Meera, Candice, and Ellen), one with a Masters degree in Engineering (Nadeem), and two had a Masters degree in Science (Paul and Richard). Thus, the majority of our participants had undergraduate degrees ($n = 9$) and only three had a graduate degree.

Research Instruments

Since beliefs cannot be directly observed, are affected by context and can change over time, we conducted a series of three 1- to 2-hour semi-structured interviews to understand our participants' beliefs (see Appendix A). The first interview occurred at the beginning of the academic year in September, the second occurred in November after their first round of practice teaching ($4\frac{1}{2}$ weeks of full-time teaching in a local school, under the supervision of a practicing teacher), and the final interview occurred in March, after their 5-week second round of practice teaching.

Each interview served a specific purpose (Seidman, 2006). The first focused on background, the second on experiences and the third on reflection. Specifically, the first interview started with their answers to the questionnaire in order to get a deeper understanding of their beliefs about including SSI in their teaching of grade 12 physics and chemistry courses prior to starting their teacher preparation program. In addition, the interview questions about academic background were more in depth than the initial questionnaire. The second and third interviews focused on the teacher candidates' experiences during practice teaching. The starting point for these questions was their answers from the previous interview. Such an interview technique allowed us to access possible changes in participants' beliefs over time and at the same time contributed to data triangulation. The teacher candidates were also asked if and how their instructors had discussed SSI in their curriculum and instruction courses. In addition, the third interview asked participants to reflect on their beliefs about teaching SSI and the effect of context and identity on those beliefs.

All interviews were conducted by the first author who did not reveal her own beliefs about teaching SSI to the participants. She often played devil's advocate to challenge participants to think more deeply about their beliefs. This approach also made it more difficult for participants to provide answers that they thought would please the researchers.

Data Analysis

All interviews were audio taped and fully transcribed. We employed three levels of analysis. First, we surveyed the transcripts for emerging themes (Bogdan & Biklen, 2006), which involved carefully examining the data for emerging themes, then categorizing these themes into broader ones. This process generated a list of themes that were then collapsed into larger themes. To organize the data and facilitate the first level of analysis, we used the qualitative data software N6. This first level of analysis occurred in between interviews to allow us to fine-tune and personalize subsequent interview questions.

The second level of analysis involved projecting Wenger's (1998) theory of identity onto the larger themes to attempt to discern the influence of identity. At this level, the goal was to develop a set of archetypes representing the different subject discipline identities within the group of participants. Themes within each of Wenger's aspects of identity were used to develop *archetypes* or categories of individuals representing subject discipline identities. Each theme was a criterion for the characteristics of each archetype.

The third level of analysis was what we are calling a microgenealogy (Barrett, 2007), where we attempted to trace the origins of the teacher candidates' beliefs. A microgenealogy is a version of Foucault's approach to history, the genealogy. Foucault (1977) considered the origins and influences of discourse on society's conception of itself and the individuals within it. These analyses demonstrated that as much as our understandings of taken-for-granted concepts seem logical or independently derived by individuals, they were, probably the product of the discourse in which we operate. Recognizing the contingent nature of beliefs, opens up the possibility of considering alternatives. Such an approach to teachers' beliefs would be useful because so much of teaching practice is based on practitioners passing their beliefs uncritically from one generation to another (Munby & Russell, 1994). Perhaps such an analysis of teachers' beliefs would provide spaces for the consideration of alternatives to the way we have traditionally taught science.

Thus, with a genealogy of beliefs, we try to go past surface beliefs about teaching science to determine what lies beneath. This study was not a discourse analysis in as much as we did not attempt the type of analysis of language described by Lemke (1990) or Brown (2006). Nor was it an attempt to describe the origins of the idea of ethics within society. Rather, our focus was on the beliefs about teaching ethics represented by the ways in which the individual participants discussed their academic and professional careers and lives.

In summary, the microgenealogy resulting from the third level of analysis amounted to a model of the origins of teacher candidates' beliefs, while the archetypes developed at the second level were exemplars of the consequences of that model. As a way to increase confidence in our interpretation of the data, we sought the professional reactions of three other science education researchers. Privately, we presented them selected parts of transcripts. We also presented preliminary results at professional conferences. Our interpretations were often modified as a result of these conversations. We also treated the initial questionnaire as a pilot inasmuch as we compared the interview data to the general population from which they had been chosen. An analysis of the questionnaire (Barrett, 2008) indicated that the participants' responses were not atypical. Member checks were done by giving the interviewees transcripts between interviews and clarification questions within interviews 2 and 3. The interviewer's interpretations were also discussed with participants in the final interview.

Findings and Discussion

The following sections will be organized using the different aspects of identity described by Wenger (1998), beginning with learning trajectory in order to explain the development of the archetypes. Although they are specific examples of the implications of the microgenealogy, the description of the microgenealogy itself is left for the conclusion.

Learning Trajectory

Each participant saw her or himself in specific ways with respect to the community of scientists or engineers, and this is represented through their different learning trajectories (see Table 1). Bill, Meera, and Nadeem identified almost completely with the community of scientists or the community of engineers, more so than with teachers. Thus, they expressed an insider learning trajectory. For example, Bill expressed what distinguished scientists from non-scientists by saying, ‘‘I'm getting the impression that there's a bit of a rift between people who have a more technical background and people who don't. In terms of the types of evidence that they accept.’’ Bill used the term ‘‘technical background’’ as a euphemism for ‘‘science background’’ here. He had been complaining about how non-scientists use irreproducible and debatable evidence when making decisions in life and, in his view, this was one characteristic that distinguished them from scientists, such as himself.

Only one participant, Renate, stated an ‘‘inbound’’ trajectory. She still expressed a desire to be a full-time scientist in the future. More importantly, Renate said that ‘‘understanding yourself as a scientist’’ is important. This is a direct reference to identity and its importance in teaching. Renate's espoused belief was that the way a teacher views him or herself has a direct effect on how she or he teaches science because who you are dictates what you do.

Table 1
Learning trajectories of participants with representative quotes

Name[a]	Learning Trajectory	Quote
Bill	Insider	I'm getting the impression that there's a bit of a rift between people who have a more technical background and people who don't. In terms of the types of evidence that they accept. (2nd interview)
Brenda	Peripheral	I would describe myself as like 70% teacher and 30% scientist. (3rd interview)
Candice	Peripheral	Well, I'd have to say a small percentage . . . I see myself as scientist, maybe 5–10%, enough that I feel confident reading a news article or maybe a scientific journal article and being able to make sense of it and being able to be critical of it and being able to connect it. But, as far as building on the science, discovering and developing the science, no. I would just rather touch the lives of students. (3rd interview)
Ellen	Peripheral	I see them as very similar but teachers are always learning or should be. And then passing on what they've learned. And I think scientists do a lot of the same things. (3rd interview)
Franco	Peripheral	To be a good science teacher you still have to be very involved in science. You have to be current and keep educating yourself about it. (3rd interview)
Meera	Insider	Obviously I am an engineer. I'm a 60% engineer. 40% teacher. (3rd interview)
Maura	Peripheral	I don't think I really wanted to be a scientist. I wanted to be more a student of science. (3rd interview)
Nadeem	Insider	Being an engineer, I understand these things . . . I do not know how many science teachers would be aware . . . (3rd interview)
Paul	Boundary	But I don't necessarily see myself purely as a teacher but as someone who sort of constructs learning environments . . . as an engineer who constructs. (3rd interview)
Pietro	Peripheral	There's part of me that likes to learn things. I'm forever learning and things that in science interest me too so I continuously learn and continuously read and understand it. However, I don't only stop myself at teaching sciences. (3rd interview)
Richard	Boundary	I have always seen science or scientists write in a language that was elitist. So I wanted to write things, or learn how to write in a language that was accessible so that we could get rid of this elitist view of science that it was inaccessible to certain people. (1st interview)
Renate	Inbound	I'd like to be more of a scientist. Definitely in order to teach this material, it's important that you yourself maintain somewhat of an understanding of yourself as a scientist. (3rd interview)

[a]All names are pseudonyms.

The learning trajectories of the other participants were as expected. The peripheral trajectory of Candice, Ellen, Maura, Franco, and Pietro matched their desire to be students and teachers of science rather than scientists or engineers. A typical stance for the participants with peripheral trajectories is shown through Maura's statement, "I don't think I really wanted to be a scientist. I wanted to be more a student of science." (Maura, 3rd interview)

The boundary trajectory of Richard and Paul reflected their feeling comfortable in both the community of scientists/engineers and teachers. What distinguished them from the rest of the participants was their desire to act as bridges between the two. Richard said:

> I have always seen science or scientists write in a language that was elitist. So I wanted to write things, or learn how to write in a language that was accessible so that we could get rid of this elitist view of science—that it was inaccessible to certain people. (Richard, 1st interview)

The position that Richard took was an interesting one on two levels. First, he is critiquing the culture of science without wishing to withdraw from it and second, he wants to open the lines of communication between "certain people" and scientists. Interestingly, both Richard and Paul were concerned with the ways in which science can exclude certain people, though who the excluded were in their minds were quite different—Paul being concerned with concrete thinkers and Richard with women and people of color.

Learning trajectory is a fundamental indicator of subject discipline identity especially with respect to how this trajectory affects the kind of teachers the teacher candidates wished to become. However, we were particularly concerned with how learning trajectory related to their beliefs about teaching ethics through SSI and so the participants' conceptions of ethics were examined as well.

Community Membership, Nexus of Multi-Membership, and Conception of Ethics

As noted earlier, community membership relates to what is familiar and unfamiliar. It is concerned with the underlying values and norms of the community with which a person identifies. Therefore we related the participants' conceptions of ethics to two aspects of Wenger's model of identity: community membership and nexus of multimembership.

We developed a scheme on which to map interviewees' conceptions of ethics in science along two axes (see Figure 1). The horizontal axis represents *moral sensitivity* (Sadler, 2004), or to what aspect of science—procedures or applications—did the participants appear most morally sensitive. The vertical axis indicates *responsibility*. Within our understanding of where ethical responsibility lies the question to be asked is: Did

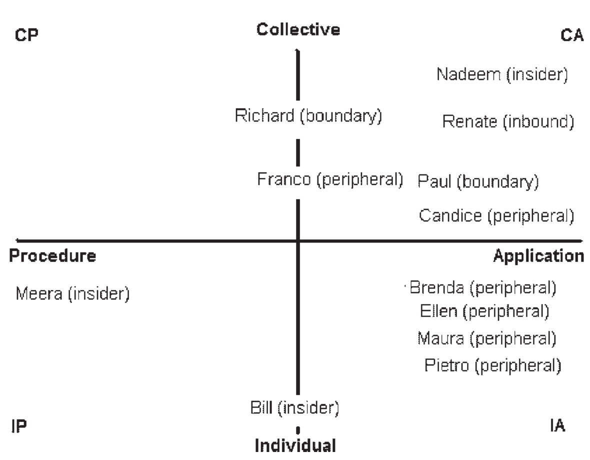


Figure 1. Ethics conceptions of participants mapped on two axes (IP, individual-procedure; IA, individual-application; CP, collective-procedure; and CA, collective-application).

the participant believe she or he had an ethical responsibility to a collective (Freire, 1998) or to an individual (Noddings, 1984)?

The placement of participants on the grid was based on comparing their reasoning when discussing ethics related to science and ethics in general with (1) each other and (2) the borders between the different quadrants in Figure 1.

As Figure 1 shows, most participants saw the ethical aspects of science rooted in the applications of science rather than the actual procedures of science. This is consistent with Sadler's (2004) findings, but what differentiated our participants from each other was their understandings of to whom they were ethically responsible. Pietro, for example, saw ethics in terms of being a virtuous person and was mostly concerned with being true to oneself in all actions. He said:

> I come from a Catholic background. And what is taught in all our classrooms, no matter what subject, is learning and belief, and believing. Learning our faith, you learn how to act as a Catholic. And there are certain moral values which go along with this. And from that the teacher is responsible not only to teach the lesson but to show, by example, how people act in society. In a Catholic school, we have this belief added to it, this faith, this sense of morals. (Pietro, 1st interview)

While Pietro's comments are couched in religious terms, he is essentially talking about an individual approach to ethics. We see here how ethics is related to community membership—for him, being a member of the Catholic Church. We call this an individual approach because Pietro was concerned with relationships individuals had with each other rather than larger societal issues. Nadeem, on the other hand, believed he was responsible and accountable to the global human population in his own work:

> [My graduate education in engineering focused on] how you would use your skills for the betterment of the society and the nation and humanity in general . . . And not to use this knowledge or apply it to things that are detrimental to the society or the country. (Nadeem, 1st interview)

Nadeem concentrated on the ways in which our behaviors in Canada affect the health and welfare of the poor overseas. Again, community membership comes into play because Nadeem saw himself as part of the global community (representative quotes for each participant are shown in Table 2).

Throughout our discussions, both Nadeem and Pietro, and most of the participants focused on the applications of science rather than the way science is done. They did not seem to be aware of ethical issues related to the processes of science such as, obtaining research funding and representation of women and people of color among physical scientists.

In contrast to the majority of our participants was Meera's conception of ethics. She seemed to believe that professionalism amounted to avoiding reprimand through adherence to ethical codes. The following quote from Meera is typical:

> I went to engineering school so we had like a separate course on ethics where they told us, "these are the boundaries of engineers. Even if an engineer is under pressure, he is supposed to do this . . . you have to maintain your ethics even if you're under pressure and everything." (Meera, 2nd interview)

Meera's interview responses showed, over the course of the study, that ethics consisted of adhering to rules and procedures, thus protecting the integrity of the profession. Thus, she was placed close to the border between individual and collective but quite far to the left for procedure application.

Another unique participant was Bill, who recognized and understood the ethical aspects of science both procedurally and with respect to its applications. However, he described himself as a relativist and was adamant that our ethical responsibility was to be true to our own principles and leave everyone else to their own. Hence, his placement near the bottom of the collective-individual axis.

Our participants also viewed the relationship between their personal ethics and the ethics of science in various ways (see Figure 2). They saw both as completely separate and essentially unrelated (Maura, Meera, Bill, and Pietro), overlapping (Candace, Ellen, and Brenda), or completely integrated (Nadeem, Paul,

Table 2
Representative quotes about participants' conceptions of ethics

Name	Representative Quote
Bill	Ethics I don't really view as objective because you are always making an underlying assumption. Whether a certain value is good or a certain value is bad . . . You can never use scientific knowledge to prove that the assumption itself is in any way objective. (1st interview)
Brenda	God created it and left it up to humanity to take care of it, so if we disrespect it and treat it the way we are right now then it's going to go downhill—the environment—and it's going to be our fault. We're in charge of it. It's our responsibility while we're here, to take care of it. And not just the environment but people as well. (2nd interview)
Candace	My academic background in engineering is tied in really closely with . . . what's practiced in society . . . So we had to look at people who blew the whistle or didn't blow the whistle and then something exploded or people died. Lives were lost. We had an entire course on that. So it really opened my eyes to its importance. (3rd interview)
Ellen	I think a lot of [my ethics] come from my parents and wanting to do what's right and what's good for society and the community and thinking beyond myself to the larger community. (2nd interview)
Franco	If you're in science and if you're just into the whole idea that science is always good and you shouldn't probe at . . . the science . . . then, when you're faced with [ethical] decisions, you're biased already without even looking into it. You don't see the other side, the social impacts of it. (2nd interview)
Maura	[High school is] a time when so much of your own world philosophy is developed. It is a pivotal, important time in terms of understanding who you are, understanding your role in society and there's a lot of pressures to fit in and become an individual and you have all these thoughts and I think it should be a time when those moral decisions that you're developing have a chance to be communicated with an authority figure—with the teacher and with your peers. (1st interview)
Meera	I kept . . . the things I learned in ethics . . . The way I approached students was very professional. I kept my distance from the students. I did give them ample like help assistance but I kept my distance. If students pushed too much to know the type of questions on the test, I knew when to stop even when I was teaching them. (2nd interview)
Nadeem	[My graduate education in engineering focused on] how you would use your skills for the betterment of the society and the nation and humanity in general . . . And not to use this knowledge or apply it to things that are detrimental to the society or the country. (1st interview)
Pietro	I come from a Catholic background. And what is taught in all our classrooms, no matter what subject, is learning and belief, and believing. Learning our faith, you learn how to act as a Catholic. And there are certain moral values which go along with this. And from that the teacher is responsible not only to teach the lesson but to show, by example, how people act in society. In a Catholic school, we have this belief added to it, this faith, this sense of morals. (1st interview)
Paul	I took the way my parents did things but I was able to refine it much more than them because I had much greater experiences to apply, not only in my own experiences but a broadening of experience I could get from the people I talked to [at University]. (2nd interview)
Richard	In the chemistry class that I had, there was nothing really discussed . . . We focus on the technical end of things for the course and not really about how to bring a lot of real-life situations into the classroom. There is the, "OK, let's make this problem a real-life problem by introducing it into someone's kitchen." but not really introducing it in someone's society. (2nd interview)
Renate	As part of my faith community, I've grown up believing that we've all been created with gifts and with interests . . . As I began to understand more about the community I was living in [and] the God that we worshiped, and who that forms me to be . . . the focus changed from worrying about securing my financial security in the future to what do I have to offer to those around me as part of a witness to living the way that I was understanding that I was called to live in my community. (1st interview)

Richard, Franco, and Renate). Interestingly, none of those who viewed the two as separate—Maura, Pietro, Meera, and Bill—saw their ethical responsibilities as towards a collective. The same was true, for the most part, for those who understood the two as overlapping. All of those who saw the ethics of science as integral to their personal ethics also saw their ethical responsibilities as towards a collective. For us, this emerging pattern was the beginning of the development of the archetypes, as will become apparent in the following sections.

In summary, community membership is an important aspect of subject discipline identity because it indicates the values that underlie the participants' conceptions of what is an ethical issue and to whom they are ethically responsible.

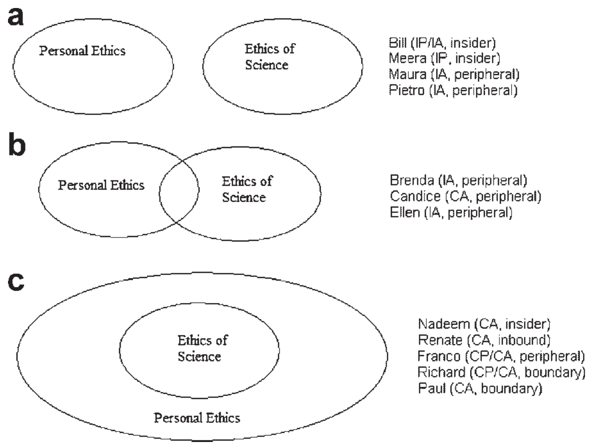


Figure 2. The relationship of personal ethics to ethics in science for the participants with conception of ethics and learning trajectory in brackets for each participant (IP, individual-procedure; IA, individual-application; CP, collective-procedure; and CA, collective-application) (a) Personal ethics as separate from the ethics of science, (b) personal ethics and ethics of science overlapping, (c) ethics of science as part of personal ethics.

Relating the Local to the Global: Goals for Science Education

At the beginning of the teacher preparation program and thus, before their first round of practice teaching, some but not all teacher candidates wanted to prepare students for the next level of schooling. Also, at the beginning of the program, two participants—Nadeem and Brenda—wanted to develop environmental awareness in their students. Brenda had worked as an environmental consultant, and said the following:

> I think it's important that they learn how things work and what the consequences of what they do in the world are for the environment or the world around them [or] people that are around them [or] what they're consuming. (Brenda, 1st interview)

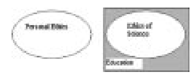
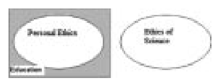
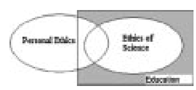
Nadeem, Paul, and Richard were also concerned with developing citizens who are able to think critically about societal issues. However, after the first round of practice teaching, all of the teacher candidates saw preparation for the next level of schooling as their main goal for science education.

From the beginning of the study to the end, the majority (all but two) believed that there is a place for ethics within science education but it was the form and purpose that varied. For example, Maura and Pietro saw it as their duty to prepare students to be of good character. Eight of the participants also thought it was important to develop ethical scientists and informed citizens. In contrast, Meera and Bill were adamant about excluding their personal ethics from teaching completely. As a result, we envisioned their approach as shown in the fourth column of Table 3. Here is how Bill described his ideas:

> I think there's an ethics of science but I don't really think there is a science of ethics. I don't think it works in both directions . . . If you're talking about what qualities a scientist should have—they should have some sense of what the scientific method is [and] they should be honest with the way they are recording data. (Bill, 3rd interview)

Bill and Meera's reluctance to acknowledge a conception of ethics in science education that went beyond honesty may have been due to their understanding of what science should be, that is, value-free and objective. There was no indication that either of them believed science was actually performed that way but rather that they believed it should be. Thus, Bill and Meera believed in bringing ethics into science class in a very limited way (being honest) but saw no reason to bring personal ethics into the discussion.

Table 3
The four archetypes of teacher candidates

Archetype	Conception of Ethics of Science (Learning Trajectory With Respect to Science)	Goals for Science Education	Place of Ethics in Science Education	Espoused Belief: Should SSI be in Science Education?	Belief-In-Use: Include SSI When Teaching?
Model Scientist/ Engineer (Bill and Meera)	IP/IA (insider)	Preparation for next level Develop scientists		No	No
Model Individual (Pietro and Maura)	IA (peripheral)	Preparation for next level Develop scientists Develop people of good character		Yes	Unlikely
Model Teacher (Brenda, Candice, Ellen, and Franco)	IA/CA (peripheral/ boundary)	Preparation for next level Develop informed citizens Develop ethical scientists		Yes	Maybe
Model Citizen (Nadeem, Paul, Richard, and Renate)	CP/CA (boundary)	Preparation for next level Develop informed citizens Develop ethical scientists		Yes	Yes

IP, individual-procedure; IA, individual-application; CP, collective-procedure; CA, collective-application.

In contrast, neither Pietro nor Maura recognized that an ethics of science existed. Rather, they believed good people do good things and, as a result, they focused on developing people's ability to be of good character (see Table 3). The ethics of science in general was largely invisible to them and was thus excluded from their teaching. It appears, then, that since Bill, Meera, Pietro, and Maura's conceptions of science were limited in scope, their ability to view ethics as part of science education was also limited.

Most of the teacher candidates did not completely separate their personal ethics from the ethics of science. They viewed the local classroom in which they will teach as a microcosm of the larger global scientific endeavor which, in their eyes, does not explicitly exclude ethics. However, the integration of personal ethics and ethics of science had different purposes. Brenda, Ellen, and Candice saw the connection between personal ethics and the ethics of science as an opportunity to increase students' interest in the subject (see Table 3). As Brenda puts it, ''Everybody likes a scandal. So I still think it would keep some people's interest.'' In other words, for these participants, the purpose of including ethics was to get students interested long enough to teach them the facts and theories of science or get them to like science for its own sake.

In contrast, Renate, Franco,[5] Paul, Nadeem, and Richard did not separate their personal ethics from the ethics of science. Separating the actor (scientist) from his or her actions (science) did not make sense to them. Renate stated her reasons for including ethics in her science teaching this way:

> It's reminding yourself of who you want to be. And so it is a training of sorts. And it's practice of sorts. The more times you go through a decision of that kind of nature, the more times you remember what you should be focusing on. What are your passions? What are your values? What are your priorities? So that you don't forget. Because it's easy to forget. (Renate, 2nd interview)

While this may sound like Renate is describing a ''be true to yourself'' philosophy, her idea is broader than that. Renate had chosen to teach as part of a responsibility to her faith community (see Table 2). In the same way, she aimed to develop good citizenship in her students for the sake of the community not for the sake of self-respect as an end (as Pietro wanted) or for self-empowerment (as Maura wished). That is, individual responsibility to oneself was not the goal of Renate, Paul, Richard, Franco, and Nadeem. They were interested in the individual's responsibility to the community. They also viewed the ethics of science as integral to the personal ethics of the scientist (see Table 3).

If we consider how participants' conceptions of ethics affected their beliefs about the place of ethics in science education, there are obvious trends. For example, without an understanding of the ethics of science as a subset of personal ethics, recognizing a scientist as an active citizen did not seem possible. Only Nadeem, Richard, and Paul envisioned a scientist as an active citizen. Ellen, Brenda, Pietro, Meera, Maura, and Bill found it very difficult to imagine the responsibilities of scientists to society because they did not recognize ethics as a responsibility to a collective. As for ethical responsibility (beyond the responsibility to be honest), only Richard, Nadeem, and Renate mentioned it. Again, all of these individuals viewed ethics as a responsibility to a collective. What this shows is that the participants' conceptions of ethics interact in fundamental ways to determine their goals for science education.

Negotiated Experience: Espoused Belief versus Beliefs-In-Use

Negotiated experience is identity in practice (Wenger, 1998). We are concerned with how identity interacts with belief; therefore, we analyze the relationship between espoused beliefs and beliefs-in-use in our study. Only one participant, Bill, changed his espoused beliefs at the end from what they were at the beginning of the study, when he recognized that honesty was part of the ethics of science. The other teacher candidates believed that bringing ethics into science class through SSI was a good idea and this did not change over time. As discussed above, their conceptions of ethics had a profound effect on what they thought including ethics in science class should entail. Most of our participants (Renate, Candice, Nadeem, Paul, Franco, and Richard) who had been mapped onto the collective-application quadrant (see Figure 1) stated that the inclusion of ethics in their teaching was a priority. Brenda, Ellen, Maura, Pietro, and Meera stressed that including ethics through SSI could be part of science education, if there was time for it.

We know that context affects the way people act. People often behave in a way that contradicts their beliefs (Friedrichse & Dana, 2005). In the interviews, we judged the participants' commitment to teaching ethics through SSI based on the participants' reactions to their behavior during their practice teaching. For example, though only five of the participants (Pietro, Renate, Nadeem, Richard, and Brenda) managed to include SSI in their practice teaching, Pietro did so only because his supervising teacher during the practicum told him to and he admitted as much. Pietro did not see his supervising teacher's approach to ethical issues as a priority for his own future teaching.

In contrast to Pietro, Franco did not include SSI during his school practicum due to fear of reprimand from his supervising teacher. In the interview, Franco seemed to deeply regret his failure to teach science in the way that he had been saying it should be taught (his espoused belief). Pietro, too, taught science in a way that was contrary to his espoused beliefs during his practice teaching. While Franco had been afraid of his supervising teacher's reaction if he included SSI, Pietro may have been afraid of his mentor teacher's reaction if he had not included SSI. In contrast, Paul emphasized that his real commitment was to getting people interested in physics and wondered if including SSI might threaten that.

> If you take time out to discuss ethical issues, it's not going to hurt the strong students . . . At the same time I have to recognize that it could academically hurt the students that are struggling with the material in the first place . . . If I just spent more time doing problems on the board, and more time teaching students at their desks in physics, then those students are going to do better in physics . . . That I see as the biggest trade off. (Paul, 3rd interview)

Based on the contrast between espoused beliefs and beliefs in use, the participants displayed the full range of commitment from "none" (Maura, Pietro, Meera, and Bill) to "maybe, if time" (Candice, Ellen, Brenda, Paul, and Franco) to "committed no matter what" (Renate, Richard, and Nadeem). This is consistent with the findings of Sadler et al. (2006). Bill continued to view bringing ethics into science as inappropriate:

> If you're talking about something which is value oriented, you run into the problem where students might be trying to guess what you're expecting them to say or what your values are so that they can mirror that. So, I sort of view it as a bit dangerous, in that respect. (Bill, 3rd interview)

Other than teaching his students to be honest, it was obvious to us that he would not include SSI in his teaching of science. Ellen did not have a problem with the idea of bringing ethics into science but worried about covering ''content,'' saying, ''The problem I saw was that there was a lot of content in the course. But I think [alternative energy sources] would have been an interesting discussion.'' She, like most of the other participants, made a distinction between ''content'' and STS, in spite of the fact that both the content (basic concepts) and STS (alternative energy sources in this instance) are in the official curriculum documents for the science courses in Ontario, Canada. Renate was aware of these distinctions and responded to them in the following way:

> I think, even though it might be poorly received at first . . . It's maybe not the conception that even this generation of teachers has grown up with. So once we've started working through it and once those students that are coming through the system now have seen it, I think it will become more integrated. (Renate, 3rd interview)

Renate's commitment to bringing ethics into her teaching was such that we were confident that she would do so when she had her own classes to teach.

Subject Discipline Identity

Looking at the figures in Table 3, one can see how learning trajectories, conceptions of ethics, and the conceptions of the place of ethics in science education relate to each other. Again, all of those participants who had an individual-procedure conception of ethics also excluded ethics from science education and all of those who integrated the ethics of science within education within personal ethics had collective-application conceptions of ethics. By including goals for science education, espoused beliefs, and beliefs-in-use (see Table 3), we were able to define four archetypes. As archetypes, no individual is expected to fit perfectly into these subject discipline identities, but they can be grouped. Thus, Meera and Bill were classified as Model Scientists/Engineers; Maura and Pietro are Model Individuals; Ellen, Brenda, Candice, and Franco[5] are Model Teachers; and Paul, Richard, and Renate are Model Citizens. In spite of the fact that engineers' work and training involves consideration of ethical issues, being an engineer or not did not seem to affect these groupings. We will elaborate on the archetypes in the following section.

Conclusions

In spite of 7 months of practice teaching and in-class experiences at The Faculty, the teacher candidates' beliefs essentially did not change from the beginning of the study to the end, though they did get much better at articulating their beliefs. Through analysis of the teacher candidates' reflections on the way they taught during their practice teaching, it became apparent that they had varying degrees of commitment to including SSI in their teaching, exemplified through the four archetypes in Table 3.

The teacher candidates' commitment to teaching ethics using SSI seemed to derive from their beliefs about ethics, goals for science education, beliefs about science practice (value-free or value-infused), and beliefs about the place of ethics in science education. For example, when the teacher candidates' conception of ethics is rooted in responsibility to individuals, as is the case with the Model Scientist/Engineer and the Model Individual, developing good citizens is not a goal of science education. Also, these two types do not see personal ethics and the ethics of science as overlapping. Without at least an overlap, inclusion of SSI as a teaching strategy is highly unlikely.

Similarly, with the Model Teacher and Model Citizen, their conception of ethics may be rooted in responsibility to the collective. This allows developing citizens to become a goal for science education. However, their commitment to SSI as a strategy is dependent on how they believe personal ethics and the ethics of science relate. If it is merely an overlap, as the Model Teacher views it, SSI can become a strategy for keeping students interested long enough to get them prepared for the next academic level. If all ethics are integrated, as the Model Citizen views it, including SSI is unavoidable. The corollary is that, to a Model Citizen, not including SSI is being dishonest.

It is tempting to view the four archetypes as a hierarchy with Model Citizen as the ideal, but we would caution against this. For example, while the Model Citizens have sophisticated views about ethics and science, they may have naïve views about other aspects of science. Therefore, these archetypes can only really be viewed as a hierarchy with respect to SSI. As such, they are a representation of part of a complicated web of beliefs.

As a microgenealogy, the model of teacher beliefs is backward-looking by definition but it is meant to give clues about the path to future beliefs. In the past and present, the teacher candidates have had varied life experiences in different school systems, schools, workplaces, careers, countries, religious communities, and ethnic communities. These experiences are on-going just as their negotiation of their identities is ongoing. Nevertheless, they do have a conception of who they wish to be in the future, and the way to that future is the learning trajectory (Wenger, 1998). This is not a set path but a conversation that an individual continuously has with those with whom she or he interacts. However, for simplicity, the trajectory can be traced from the bottom of the model of Teachers' Beliefs in Figure 3 to the top. Identity cannot be separated from this trajectory and, in fact, is defined by it. What follows is a description of the hypothesized reasoning of each archetype through the microgenealogy (Figure 3) from bottom to top.

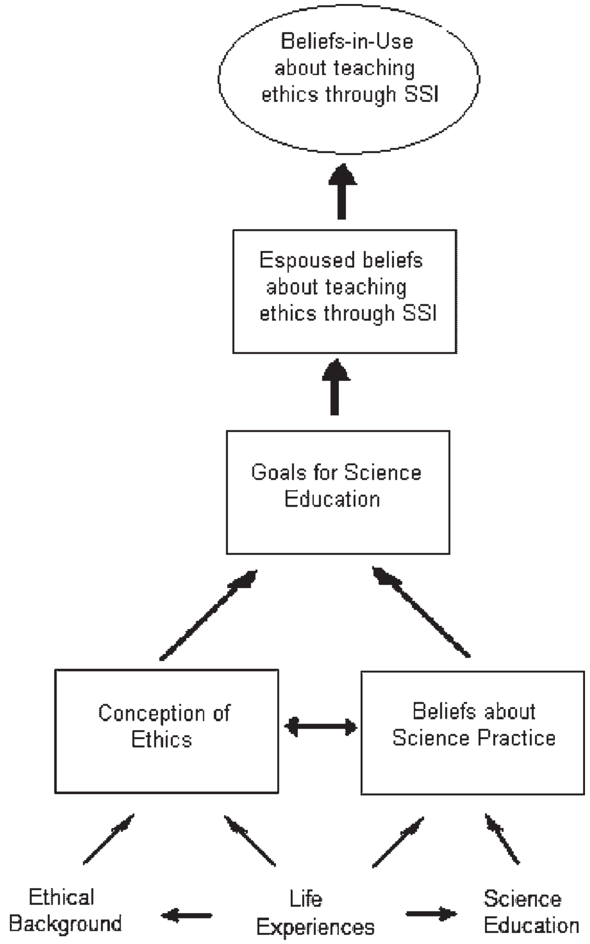


Figure 3. A microgenealogy of teacher candidates' beliefs. Espoused beliefs are in squares, beliefs-in-use in an oval.

The Model Scientist/Engineer with an Insider Learning Trajectory through Figure 3

The Model Scientist/Engineer, feels like a part of the community of scientists/engineers and probably believes that their conception of the ethics of science and beliefs about the science practice derive from that community. Since, they also have a very individualistic view of ethics, their goals for science education serve the needs of scientists and engineers and not necessarily society. Since SSI are not generally a part of university chemistry and physics, the Model Scientist/Engineer's espoused belief is that they would not include SSI in high school chemistry and physics, even if they think it might be interesting for the students. The Model Scientist/Engineer's beliefs-in-use are that SSI are not purposely introduced into class and, if a student attempts to initiate a discussion, time spent is kept to a minimum or the topic is brushed aside without discussion as quickly as possible.

The Model Individual with a Peripheral Learning Trajectory through Figure 3

Model Individuals view themselves as teachers of science who still have interests in the ongoing practice of science. They also have a very individualistic view of ethics. They have difficulty perceiving that an ethics of science exists because they tend to view science as a series of theories and facts rather than a practice. This view of science results in their goals for science education serving the needs of scientists and engineers and not necessarily society. What distinguishes them from the Model Scientist/Engineer, however, is their belief that their role is to help their students navigate across the border between science and non-science. They recognize that the students they teach have lives beyond the science classroom; therefore, their espoused belief is that they must engage their students as whole individuals rather than just potential scientists.

Since Model Individuals have trouble seeing the ethical aspects of science, their beliefs-in-use with respect to the inclusion of SSI are that it is unlikely even if they recognize that it might be interesting for the students. Since the peripheral trajectory is concerned only with a one-way communication, from science to the outside, they believe their students expect them to interpret science for them until they are able to understand it themselves.

The Model Teacher with a Peripheral Learning Trajectory through Figure 3

Similarly, Model Teachers with a peripheral trajectory also try to help their students to successfully navigate the border into science practice. They believe the ethics of science lies in the application of science and they have an unproblematic view of science itself. Believing that our ethical responsibilities lie between individuals, their goals for science education focus on helping individuals to understand science in order to go on to fulfilling careers or to understand science issues when they encounter them. Model Teachers' espoused beliefs express more commitment to including SSI because they see it as a way to get students interested in science. Therefore as they prepare their students for the next level, their beliefs-in-use will not necessarily mean neglecting SSI. They believe their students expect them to make science interesting for them.

The Model Teacher with a Boundary Learning Trajectory through Figure 3

The Model Teacher with a boundary trajectory (as opposed to the peripheral trajectory described above) is attempting to link together scientists and citizens and creating a two-way communication. They see science as a community endeavor that is a part of society as a whole and not separate from it. Seeing the ethics of science as overlapping with the personal ethics of scientists, their goals for science education serve the interests of both scientists and society. Their espoused beliefs are that they bring SSI into their teaching not just to make science accessible to potential scientists but to help potential scientists consider the rest of society in their work. However, since they are primarily concerned with producing ethical scientists and are aware of the structure of the science courses their students will encounter when they enter university, they may sacrifice SSI in order to help their students to be successful at the next level. Nevertheless, their beliefs-in-use include trying to introduce the ethics of science in their teaching.

The Model Citizen with a Boundary Learning Trajectory through Figure 3

What distinguishes the Model Teacher with a boundary trajectory from the Model Citizen is their conception of the relationship between ethics and science. The Model Citizen views ethics as integral to science. There is no separation between personal ethics and the ethics of science. Though the goals and espoused beliefs of the Model Citizen and the Model Teacher are apparently identical, the Model Citizen struggles with the obligations imposed by the school system and the obligation to develop informed citizens. The beliefs-in-use of the Model Citizen see SSI as integral to science. For them, the question is never whether SSI should be part of science education. It is how to convince scientists who are currently practicing and science students who are likely to become scientists that SSI must be a consideration in their work and a normal part of science education at the post-secondary level.

These four archetypes can partially explain the groups that Sadler et al. (2006) found in their study on high school teachers' beliefs about teaching ethics through SSI. Group A, teachers who were committed to SSI, may have been made up of Model Citizens. The Model Teachers probably constituted Groups B and C (committed but unable to realize goals due to contextual constraints or not committed to including SSI). Model Scientist/Engineers would have been Group D (do not believe SSI belong in science because science should be value-free), though this may be an over-simplification. Finally, Group E (believes ethics should be part of all education) would be the Model Individuals.

Implications

Beliefs and identity are intertwined (Helms, 1998). With respect to bringing ethics into the physical sciences through SSI, we now have an idea of four teacher identities that might be encountered in a science curriculum course at a faculty of education. These teacher identities, or archetypes, may help teacher educators to develop appropriate interventions which address the individual beliefs of their preservice teachers.

Setting aside the question of motivating teacher educators to take this aspect of science education into consideration, our analysis seems to indicate that commitment to including ethics in teaching science is not a fundamental belief but a derived one, based on other beliefs about the subject matter and themselves. If identity is central to teacher candidates' decisions with respect to including ethics, then we cannot approach our task from a cognitive stance alone. That is, giving reasons for including SSI in teaching science is not enough if teacher identities are not taken into account.

For example, since each archetype would have different beliefs about teaching through SSI, different approaches might be necessary for each. When faced with a Model Scientist/Engineer, it may make sense to address their beliefs about science practice and conception of the relationship between the ethics of science and personal ethics. Without changing these beliefs, their goals for science will not likely change. Helping them to recognize the ethical aspects of science or viewing ethics as something more than just rules and regulations might be a start. When faced with a Model Individual, a teacher educator may focus on helping him or her to understand that an ethics of science exists. A Model Teacher with a peripheral trajectory may need help viewing ethics in less individualistic terms while one with a boundary trajectory may need help viewing the ethics of science as embedded within personal ethics. Although the Model Citizen is already enthusiastic about using SSI to teach ethics, they will need help planning their courses in a way that allows them to prepare their students for the next academic level while fulfilling their citizenship goals. All teacher candidates with boundary trajectories need guidance and support as they navigate between and within the cultures of secondary school science and science practitioners (Barrett & Nieswandt, 2008).

The archetypes described above provide a framework around which we can begin to change teaching through teachers. However, they were derived in a specific time, in a specific institution, and were developed based on a small number of teacher candidates. Similarly, the model of beliefs was derived within this specific context. The findings are therefore not statistically generalizable but the model and archetypes can be taken into other contexts as analytical frameworks.

Future research needs to determine if these four archetypes are present in the larger population of teacher candidates specializing in physics and chemistry as well as other sciences such as biology or health sciences. Also, following teachers from their teacher education program through their first years of teaching would help us to develop a deeper understanding of how their beliefs, expressed as the level of commitment to teaching ethics through SSI, may change over the years and actually manifest themselves in the classroom. Despite the need for further research, our archetypes and the proposed microgenealogy of teacher candidates' beliefs are valuable conceptual frameworks for teacher educators and researchers seeking to promote bringing ethics and citizenship into science teaching.

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Notes

[1]Noddings (1999) does extend an ethic of care into society in later works and Freire recognizes our ethical responsibilities to individuals. However, each begins at the individual and society, respectively and this frames their discussion of ethical responsibility.

[2]The ethics of the processes and products of science are an aspect of the Nature of Science (NOS). However, it was not our purpose to examine teacher candidates' views on NOS *per se* for this has been addressed by many researchers in the past (see, e.g., Abd-El-Khalick, 2001; Cobern & Loving, 1998; Lederman, 1992).

[3]We are not implying here that scientists and engineers belong to the same community but, rather, that one of the two communities was relevant for each of the individual participants.

[4]All names are pseudonyms.

[5]Although Franco's beliefs about the place of ethics in science was consistent with the beliefs of the Model Citizen, his commitment to teaching ethics through SSI lead us to place him in the Model Teacher group.

References

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in pre-service elementary science courses: Abandoning scientism, but. Journal of Science Teacher Education, 12(3), 215–233.

Aikenhead, G.S. (2001). Students' ease in crossing cultural borders into school science. Science Education, 85(2), 180–188.

Allchin, D. (1999). Values in science: An educational perspective. Science & Education, 8(1), 1–12.

American Association for the Advancement of Science. (1993). Project 2061: Benchmarks for science literacy. New York: Oxford University Press.

Barrett, S.E. (2007). Teacher candidates' beliefs about including socioscientific issues in physics and chemistry. Unpublished doctoral dissertation, University of Toronto, Toronto.

Barrett, S.E. (2008). Mutual misunderstanding: Preservice teachers' and instructors' mismatching(?) priorities. Canadian Journal of Science, Mathematics and Technology Education, 8(4), 313–330.

Barrett, S.E., & Nieswandt, M. (2008). The role of science education in fostering democracy: Perspectives of future teachers. In: Lund D.E. & Carr P.R. (Eds.), Doing democracy: Striving for political literacy and social justice (pp. 231–246). New York: Peter Lang Publishing.

Barrett, S.E., & Pedretti, E. (2006). Contrasting orientations: STSE for social reconstruction or social reproduction? School Science and Mathematics, 106(5), 21–31.

Becher, T., & Trowler, P. (2001). Academic tribes and territories: Intellectual enquiry and the culture of disciplines (2nd ed.). Philadelphia: Open University Press.

Beijaard, D., Verloop, N., & Vermunt, J.D. (2000). Teachers' perceptions of professional identity: An exploratory study from a personal knowledge perspective. Teaching and Teacher Education, 16(7), 749–764.

Bogdan, R., & Biklen, S.K. (2006). Qualitative research for education: An introduction to theories and methods (5th ed.) Boston, MA: Pearson A & B.

Brown, B.A. (2006). "It isn't no slang that can be said about this stuff": Language, identity, and appropriating science discourse. Journal of Research in Science Teaching, 43(1), 96–126.

Bryan, L., & Atwater, M.N. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. Science Education, 86(6), 821–839.

Carlone, H.B. (2004). The cultural production of science in reform-based physics: Girls' access, participation and resistance. Journal of Research in Science Teaching, 41(4), 392–414.

Cobern, W.W., & Loving, C.C. (1998). The card exchange: Introducing the philosophy of science. In: McComas W.F. (Ed.), The nature of science in science education (pp. 73–83). London: Kluwer Academic Publishers.

Costa, V.B. (1995). When science is "another world": Relationships between worlds of family, friends, school and science. Science Education, 79, 313–333.

Creswell, J.W. (1998). Qualitative inquiry and research design: Choosing among five traditions. Thousand Oaks, CA: Sage Publications.

Cross, R.T., & Ormiston-Smith, H. (1996). Physics teaching, professional development and a socially critical ideology. Journal of Curriculum Studies, 28(6), 651–667.

Derrida, J. (1995). The gift of death. Chicago: University of Chicago Press.

Feldman, A. (2002). Multiple Perspectives for the study of teaching: Knowledge, reason, understanding and being. Journal of Research in Science Teaching, 39(10), 1032–1035.

Foucault, M. (1977). Discipline and punish: The birth of the prison. London: A. Lane.

Freire, P. (1998). Pedagogy of freedom: Ethics, democracy and civic courage. New York: Lantham, Rowman & Littlefield Publishers, Inc.

Friedrichse, P.M., & Dana, T.M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. Journal of Research in Science Teaching, 42(2), 218–244.

Helms, J.V. (1998). Science and me: Subject matter and identity in secondary school science teachers. Journal of Research in Science Teaching, 35(7), 811–834.

Kane, R., Sandretto, S., & Heath, C. (2002). Telling half the story: A critical review of research on the teaching beliefs and practices of university academics. Review of Educational Research, 72(2), 177–228.

Larochelle, M. (2007). Disciplinary power and the school form. Cultural Studies of Science Education, 2, 711–720.

Lederman, N.G. (1992). Improving students' conceptions of the nature of science: The role and influence of the classroom teacher. Research Matters . . . To the Science Teacher, 5, 11–19.

Lee, H., Abd-El-Khalick, F., & Choi, K. (2006). Korean science teachers' perceptions of the introduction of socio-scientific issues into the science curriculum. Canadian Journal of Science, Mathematics and Technology Education, 6(2), 97–117.

Lemke, J.L. (1990). Talking science: Language, learning, and values. Norwood, N.J.: Ablex Pub. Corp.

Lincoln, Y.S., & Guba, E.G. (1985). Naturalistic inquiry. Beverly Hills, CA: Sage Publications.

McGinnis, J.R. (2003). The morality of inclusive verses exclusive settings: Preparing teachers to teach students with developmental disabilities in science. In: Zeidler D.L. (Ed.), The role of moral reasoning on socio-scientific issues and discourse in science education (pp. 195–216). Netherlands: Kluwer.

Munby, H., & Russell, T. (1994). The authority of experience in learning to teach: Messages from a physics methods class. Journal of Teacher Education, 45(2), 86–95.

Noddings, N. (1984). Caring: A feminine approach to ethics & moral education. Berkeley: University of California Press.

Noddings, N. (1999). Care, justice and equity. In: M. Katz, N. Noddings, & K.A. Strike (Eds.), Justice and caring: The search for common ground in education (pp. 7–20). New York: Teachers College Press.

Ontario Ministry of Education and Training. (2000). The Ontario curriculum—Grades 11 and 12: Science. Toronto: Queen's Printer for Ontario.

Pajares, M.F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. Review of Educational Research, 62, 307–332.

Sachs, J. (2001). Teacher professional identity: Competing discourses, competing outcomes. Journal of Educational Policy, 16(2), 149–161.

Sadler, T.D. (2004). Moral sensitivity and its contribution to the resolution of socio-scientific issues. Journal of Moral Education, 33(3), 339–358.

Sadler, T.D. (2005). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. Science Education, 89, 71–93.

Sadler, T.D., Amirshokoohi, A., Kazempour, M., & Allspaw, K.M. (2006). Socioscience and ethics in science classrooms: Teacher perspectives and strategies. Journal of Research in Science Teaching, 43(4), 353–376.

Sadler, T.D., & Zeidler, D.L. (2005). Patterns of informal reasoning. Journal of Research in Science Teaching, 42(1), 112–138.

Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in education and the social sciences (3rd ed.) New York: Teachers College Press.

Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. Cambridge [England]: Cambridge University Press.

Zeidler, D.L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In: D.L. Zeidler (Ed.), The role of moral reasoning on socioscientific issues and discourse in science education (pp. 7–39). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Zeidler, D.L., & Sadler, T.D. (2008). Social and ethical issues in science education: A prelude to action. Science and Education, 17, 799–803.

Zeidler, D.L., Sadler, T.D., Applebaum, S., & Callahan, B.E. (2009). Advancing reflective judgment through socioscientific issues. Journal of Research in Science Teaching, 46(1), 74–101.

Appendix A

First Interview—Focused Academic History:

(1) Tell me a little bit about your academic background—Describe the courses that you took in university.
(2) Why did you choose to study science in university?—Describe your experiences with science throughout your life.
(3) How did you end up becoming a science teacher candidate? What experiences led to your being here? Was there a person in your life that encouraged you to go into teaching?
(4) In your view, why is it important for students to learn science? What is our goal as science educators?
(5) If you had to choose the two most important topics for high school physics/chemistry, what would they be? Why?
(6) In your questionnaire, you noted the following goals for science education: _ _. Please describe how the topics you mentioned fit those goals.
(7) Has there been any discussion of ethical issues in your science education? If so, please describe it in terms of when it occurred (grade level, course), how it was emphasized and some of the teaching strategies used by the instructor (assignment, lecture, discussion, project, reading, etc.).
(8) You gave specific reasons for why ethical issues should/should not be an integral part of chemistry and physics courses in high school. They were _ _. Please expand on that.
(9) Is there anything else you would like to add about what led you to become a science teacher candidate?
(10) I am going to ask you to try to keep in mind those times when socioscientific or ethical issues come up in your practicum (whether spontaneously or through your own lesson planning or your associate teacher's lesson planning). If something comes up, you are welcome to email me about it or, if you include issues in a lesson, feel free to email the lesson plan. I would be very interested. Thank you very much. May I send you a reminder email about the issue prior to the start of the practicum or during the first week of the practicum?

Teacher Candidate Interview Questions

Second Interview—The Detailed Experience:

(1) Describe any experiences with your parents that influenced your view of the place of ethics in your intellectual life.
(2) Some people describe science as having a certain prestige. Do you agree with that idea? Describe an experience that reinforced that idea for you.
(3) Describe your high school science experience. Was it lab based, a lot of text book work? Project work? Was it similar to what you observed in your practicum?
(4) Describe experiences (such as classroom observations, lessons taught or observed or discussions with teachers) in your practicum that seemed to support your goals for science education.
(5) How did you figure out what was expected of you as a science teacher during your practicum?
(6) How did you determine what was expected of the science students? What did you expect from your science students?
(7) Describe activities from your methods courses that helped you to decide on objectives for lessons and overall goals for the courses.
(8) Were socioscientific/ethical issues discussed in your curriculum course? If so, please describe the activities you did in class.
(9) Describe incidents where you felt socioscientific issues were relevant in your practicum. Did you explicitly bring them up in class or did they come up spontaneously? How did you handle it?

(10) During the first interview (and in the questionnaire), you gave specific reasons for why ethical issues should/should not be an integral part of chemistry and physics courses in high school. You said: _ _. How are you thinking about this now?
(11) Do you have anything more to add?
(12) For your second practicum, I am, once again, going to ask you to try to keep in mind those times when socioscientific/ethical issues come up in your practicum (whether spontaneously or through your own lesson planning or your associate teacher's lesson planning). If something comes up, you are welcome to email me about it or, if you include issues in a lesson, feel free to email the lesson plan. I would be very interested. Thank you very much.

Teacher Candidate Interview Questions

Third Interview—Reflection

(1) Were your practica what you expected? In what way(s)?
(2) How did you figure out what was expected of you as a _____ _____ teacher during your practicum?
(3) How did you determine what was expected of the _____ _____ students? What did you expect from your science students?
(4) How do you decide what is important/relevant and what is not important/relevant in grade 12 university physics/chemistry?
(5) Describe activities from your methods courses that helped you to decide on objectives for lessons during your practica.
(6) In your first interview, you said that your goals for science education revolved around __ __. Thinking back to your experiences (such as classes at THE FACULTY, classroom observations, lessons taught or observed or discussions with teachers in your practicum), do those goals still make sense to you? Why or why not? (see pg. __ __ of transcript).
(7) Describe experiences (such as classroom observations, lessons taught or observed or discussions with teachers) in your second practicum that seemed to emphasize your goals for science education. How was this different from or similar to the first practicum?
(8) Were socioscientific/ethical issues discussed in your curriculum course? If so, please describe the activities you did in class.
(9) What have you learned from both practica with respect to what should be taught in chemistry/physics courses?
(10) Describe incidents where you felt socioscientific issues (or ethics) were relevant in your practicum. Did you or your associate teacher plan to bring up these issues in class or did they come up spontaneously? How did you handle it?
(11) How do you feel socioscientific/ethical issues should be handled in grade 12 chemistry/physics, if at all? What are your reasons for this?
(12) Looking at the hand-out on approaches to SSI, which part of the spectrum do you feel most comfortable in? Why? Where do you think your beliefs on this subject come from?
(13) If a parent were uncomfortable with your position, how would you handle it professionally? How much autonomy should a teacher have when teaching about socioscientific issues?
(14) Some would say that helping students to engage in discussions about ethical issues should be a goal of science education at all levels because this is something that students need. What do you think of that proposition?
(15) Some would say that discussing ethical issues would dilute the content of science in a way that is detrimental to the discipline. Not only that, but it is not expressly required according to course expectations. What do you think of that proposition?
(16) In your opinion, when a teacher must choose, is it the teacher's duty to teach what students need or what is in the curriculum? Why?
(17) As a teacher, how do you think you will balance content that students need for later schooling with what students need for life in general?
(18) How did your academic background shape your opinions on this subject?
(19) How did your experiences during this year influence your opinions on this subject?
(20) Think of yourself as a pie. What size portion would be a scientist and what size would be a teacher? Are they mutually exclusive?

(21) How could your experience in the pre-service program have been changed to further help you work through these issues?
(22) Do you have anything more to add?
(23) Has the study been of any use to you in your growth as a teacher? If so, how? If not, why not?
(24) Would you be willing to be interviewed later on your beliefs and how they change once you start teaching? It would probably happen in your second year.
(25) Thank you so much for your time. I can send you a preliminary report of findings if you like.