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Introduction

The education of students in general education courses presents an important challenge to educators; the courses are almost always outside a student's focus on a particular field, which is usually signified when they declare a major. In some cases, general education becomes an opportunity for students to explore other ideas and disciplines that are of interest to them. But in other cases the spirit and the practice of general education requires students to take courses in areas that are neither interesting nor, from a personal perspective, inviting to them. The problem is perhaps worsened when the requirements for a particular component of general education is also associated with a specific training requirement for a student, as often occurs in pre-professional programs such as nursing (which may require sociology), criminal justice (psychology), and education (natural science and mathematics). And almost all students in the humanities are also expected to read and analyze texts and other materials, both to enhance their communication skills and to increase their understanding of human experience as expressed through culture. Thus, general education is not aimed just at exposing students to ideas: it also seeks to give students particular abilities that they can later use in new situations. This, in turn, means that students must somehow link the new knowledge to their own identity as it emerges during college and young adulthood.

Different approaches can be used to address this problem, including the use of courses that teach a discipline in the context of a particular practice (e.g., the sociology of health care; literature courses that use texts from a specific cultural or professional milieu). Selection of content in this manner has the potential to increase the inclusiveness of a course, especially if the teaching is associated with indications of how the course is drawn from the lives of women and non-majority cultures (Middlecamp and Fernandez 390–91). However, we are also aware that such methods, where content is imposed on students, runs the risk of "essentializing" students by imposing a belief about student interest on the course (Barad, "Agential Literacy" 221–23). Therefore, using understandings of feminist pedagogy and epistemology as a theoretical framework, we include student-selected projects to give the student the opportunity to respond to content by identifying a specific activity or topic related to the content. This, we hope, positions the student to shape the instruction in some way to fit his or her identity. In addition, by opening the course to student interests, we hope to obtain insight into the material that we *should* be teaching, ultimately allowing students and their own identities to shape the course content.

As presented in this paper, we have chosen to alter our teaching to include student-selected projects in order to meet program goals and to recognize the needs of the students. The students in these courses are predominantly women and under-represented minorities, who are rarely viewed as participants in science, even though as teachers their view of science will be a critical part of their own teaching of the subject (Bianchini et al. 522–27). This history of alienation is tied to specific unmet needs that, if addressed, are potentially excellent ways to both reshape curricula and engage students in a learning experience that would begin to undo the alienation itself. Finally, by informing the course with their perspectives, we demonstrate to students that their participation is important by actively using their work, not just telling them of its importance (Richmond et al. 900–907, 912–15). Although this study focuses on one particular course in one discipline, we feel that the strategy we have may be generalizable. In addition, our research has allowed us to develop ideas about patterns within student work that may also occur in other disciplines, even those quite different from science.

Feminist Epistemology, Pedagogy, and the Development of Student Identity

Our work proceeds in accord with several different ideas about the teaching of science, including alignment with standards-based education of future teachers, inquiry teaching, and writing-to-learn. But we recognized from the beginning of our program that a key outcome would entail enabling students to develop their own sense of ownership of the material, in alignment with our understandings of the principles of feminist pedagogy and epistemology.

Two specific strands of feminist thought about pedagogy and epistemology provided the basis of our approach. Both speak to the question of why identity with and within science is a critical aspect toward achieving larger feminist goals of equity, inclusion, and reconfiguration of knowledge away from epistemically privileged positions (such as science) and toward distributed, multiple perspectives as the basis of knowledge.

The pedagogical importance of student identity begins with recognizing that students have the right and educators the responsibility to incorporate opportunities for self-authorship within learning (Baxter Magolda 3–36). Student responses to their learning will be affected by what they feel are opportunities for themselves to develop their own understandings of material and their relationship to the subject. Students entering into research work, for example, have been shown to develop a "scientific identity kit" involving understandings of technical language, collaboration, inquiry, and uncertainty (Richmond and Kurth 681–93), a finding aligned with results for science teachers engaged in research experiences (Varelas et al., "Beginning" 500–501). However, identity must also be developed for individuals considerably less involved in science, including those who take general education science courses such as those often used to prepare future elementary teachers. Forming an identity with science in such contexts often begins with attempts to shape instruction around "relevant" themes, although these are fraught with problems of not knowing who the students actually are (Wink 54–55). Bringing student voices to the fore of this discussion, however, has the potential to allow them to feel that they are constructing a course—or at least a portion of a course—in a way that both responds to their own needs and provides a basis in their own lives for the articulation of their knowledge of science.

The pedagogical principles associated with student identity are aligned, in our teaching and in the research for this paper, with several feminist perspectives. In particular, developing voice is fundamental to ideas of feminist teaching, including the idea of "constructing, or reclaiming, a consciously positional voice" (Maher and Tetreault 100). This, along with mastery and steps to reconstruct authority in the classroom, are the reasons we have chosen to have students participate in defining what counts as content in this course, we believe in much the same way (and with the same limitations) as that described by Muriel Lederman when she considers how her reconstruction of a virology class may or may not adhere to feminist principles (197). Another useful general categorization of feminist pedagogy has been given by Webb et al., who present six particular principles that they use in organizing instruction and research in a research methods course (418–21). Elements of these are also present in our work, both in general and in the design and implementation of the particular big theme project reported here (Table 1).

Feminist pedagogy is also a specific component of other science teacher education efforts. For example, Gail Richmond et al. report on feminist pedagogy within four different science teacher education efforts, including one for a general education course for students preparing to work in elementary education. They present three objectives (900) for their feminist teaching and their research work:

- Helping our students rethink their connections with science
- Helping our students to re-envision science
- Helping our students to transform these perspectives into a pedagogy they own and that attracts, enlightens, and empowers the students they teach.

These same goals are found in our program. First, rethinking connections with science is supported through student journals that have a specific connections component and through the student-directed project described in this paper. Second, re-envisioning science is an outcome we seek by having students read about and watch depictions of science as done by those outside of the scientific mainstream. Finally, our teaching is done in a way that can link multiple aspects of the course to the students' futures as teachers, supporting—we hope—their use of feminist and inquiry pedagogy in their own teaching.

A third feminist pedagogical perspec-

Table 1. Alignment of coursework in *The Chemical World* with "Principles of Feminist Pedagogy" presented by Webb et al. (2004)

Principle	Alignment with *The Chemical World*
1. Reformation of the professor–student relationship	Student selection of project topic is done with support of professor, including professor providing content instruction as requested by the particular student.
2. Empowerment	Student projects permit students to direct resources of the course onto a problem of their own interest.
3. Building community	Student projects are developed and presented in public space, permitting students to learn from each other and to publicly share their interests.
4. Privileging the individual voice.	Students select their own projects and are encouraged to include in their work and their presentations their own reasons for developing the project, emphasizing the source of the idea within their individual interests.
5. Respect for diversity of individual experience	Students are encouraged to discuss the basis of their choices within their own lifeworlds, bringing their standpoints to form a basis of the course work.
6. Challenging traditional views.	Multiple readings and a film assignment problematize the question of "who does science" and the concept of scientists as privileged sources of knowledge to the community.

tive that describes our course objectives is provided by Brenda M. Capobianco (3–5). She frames a collaborative action research project and her case studies work on the project in terms of a continuum of feminist pedagogies in science teaching. These range (without hierachical implications) from "equitable practices with emphasis on gender," to "more inclusive categories of difference," to "transformative practices with emphasis on activism." In our case, we feel that our project aligns most closely with the goal of inclusion and, if we are able to change students' perspectives of themselves and their teaching, the goal of transformation.

Another dimension of this idea of self-identity as a necessary component of learning relates to the values extant in the classroom (Hodson 243). Teaching for meaning making requires that the classroom environment value and be responsive to students' own prior and developing meanings in dialogue with the meanings held by the community, as represented by the teacher (Palmer 89–113). This requires clear opportunities for students to shape parts of the curriculum, including presenting their own ideas to shape the meaning associated with different questions.

Developing student voices for the dialogue about what is important in the science classroom also has epistemological dimensions well recognized in feminist science studies. Donna Haraway, for example, indicates that the science question of feminism is in part about building "partial views and halting voices into a collective subject position that promises a vision of the means of ongoing finite embodiment, of living within limits and contradictions are views from somewhere" (590). Such a distributed epistemology is quite different from traditional views of science as an activity of obtaining results that describe reality in ways that are defined for the learner.

One way to bring epistemology and pedagogy together is by shaping instruction, including content, in ways that specifically reflect the voices and ideas of students. If we allow student voices to contribute to the instruction in science there is the potential for these voices to be heard by instructors and, ultimately, by researchers themselves. In this way, students may be able to exercise the role that Steve Fuller (28) suggests they have as members of the "community of recipients" that confer scientific status on something by virtue of its utility better than the traditional source of knowledge, the "community of producers." This is similar to the suggestion by Marelee Mayberry, who calls for pedagogies that actively ask students to question what goes on in science as a means of inducing "new theories, methods of investigation, and practices that fundamentally alter descriptions and explanations of the natural world and question who benefits from the uses to which science is put" (452).

As suggested, there are good examples of courses designed around these and similar feminist pedagogical and epistemological principles that work to develop student identity through personalized activities that activate their voices. An example is the general approach of "Agential Literacy," which Karen Barad developed as a specific example of implementing ideas about agential realism for science ("Meeting the Universe Halfway" 164–70). This has a goal of making the study of science and the intersection of science and students' lives an explicit part of coursework, inviting students to shape their responses beginning from their own histories.

Within chemistry similar work has been presented by Catherine H. Middlecamp and Anne-Marie L. Nickel. Working from an explicitly feminist perspective in chemical education, Middlecamp and Banu Subramaniam describe exercises to allow students to present questions that help shape a course, either at the level of a multi-week unit or within particular lessons and lab activities. This is part of a wider effort to document the issue of engagement in a systematic way, including showing where student identity may matter in fostering connections (Middlecamp 18–19). Similar work (Larson and Middlecamp 166–69) has been described for a companion course to a general chemistry program, in this case with a focus on pre-service teachers and their developing understanding of science and pedagogy for science. Finally, Richmond et al., cited earlier, includes several reports of linking student identity, feminist pedagogy, and science teacher preparation. Most notable in this regard is the discussion of Lori Kurth, who incorporates a semester-long project in her elementary science methods course, and who had students conduct a semester-long scientific investigation of their own design (900–905).

Course Background

The course under study is a result of a multi-campus effort to provide instruction in science content to pre-elementary education majors in ways that are appropriate to their needs as persons and as future

K–8 science educators (Varelas et al., "Inquiry"). The project involves a research university with a large teacher preparation program that has become the largest single source of teachers for a large urban district. Although many of the students take their general education courses at the same campus, many others are transfer students from other institutions, typically community colleges. This created the opportunity to design courses that could be taken by students at the community colleges or at the university, making use of the pedagogically richer environments found in the community colleges' smaller classes. Four courses are taught in the program. One is a one-credit hour capstone project-based seminar. The others are content courses: The Physical World, The Biological World, and The Chemical World. The courses meet standards established by the state and by the National Science Teachers Association. They also incorporate in a variety of ways principles of inquiry learning (Abraham 46–49, Greenbowe and Hand 143–44), following on ideas described by Gail R. Luera and Charlotte A. Otto for a set of natural science courses for elementary education majors (245–48). In this way, students receive well-aligned instruction in a variety of scientific fields, with a goal of having them learn more thoroughly a view of science that is accurate and that they can translate into their own practice as teachers (Akerson et al. 203).

The particular course we focus on is The Chemical World. The course has four credit hours, including three lecture hours and three lab/discussion hours. There are four sections to the course. The first includes a topic *about* science, as is also the case for the other "World" courses. In The Chemical World this meta-course is on "The Sociology of Science." For this component students typically do two activities. One is to read and reflect upon Alison Gopnik's idea of "the scientist as child," which connects the activities of science sociologically and philosophically to the theory development architecture of young children. The second activity is to view the popular movie *Lorenzo's Oil* (Miller), which is based on a true story of two parents whose son develops a rare metabolic disorder that is certainly fatal. They learn the necessary biochemistry to determine that a competitive inhibitor (the oil of the title) will block the buildup of the very long chain fatty acids that cause the disease. The course then turns to the basic content of chemistry, with three units organized around "Chemistry and Life," "Chemistry and the Earth," and "Chemistry and Society," where content associated with molecular chemistry, reaction chemistry, and thermodynamics are developed. Within the "Life" and "Earth" units students also have to do short projects on nutrition and minerals, respectively.

Throughout the course students are carrying out reflective writing for their learning and for course assessment: journals, lab reports, and a course portfolio. These complement unit exams that combine conventional assessment questions with assignments to write extended answers. The journals of the course are important because they allow students to demonstrate emerging understandings of critical topics and also to provide direct feedback on their progress in the course and with their course project.

The course project, known in our implementation as the "big theme" project, is another part of the coursework. In this case the projects are unique to each student, developed over the course of the semester in dialogue with the instructor.

Students are required to identify several ideas and, by the fifth week of the semester, one of these should have emerged as the basis of their project work. With guidance they are then to do background work on the topic. At the end of the semester they then present an oral presentation on their work to their classmates and also turn in a ten-page paper detailing their findings. On multiple campuses and with different instructors we have found that slightly more than half of the students chose a topic related to health or a non-nutritional aspect of their body, while one-quarter pick some aspect of nutrition or food and the remainder work on something other than these topics.

Methodology

Our methodology is to present cases for review of the different issues that have developed in our implementation of this assignment with students. Our purpose is to provide observations about student identity construction in positive and negative ways. At this point, development of conclusive categories will not be possible. But we do hope that our work will provide more data such as those developed by Richmond and Kurth, who pointed out that "we know little about how identity is constructed by those new to the practice of science; claims about such processes are based largely on anecdotal information. What is needed are data about what novices learn and what is salient to them with respect to scientific content and culture when given the opportunity to participate directly in the enterprise" (678).

The final product in the "big theme" project is an essay by students about their project accompanied by a poster presentation. Our work also draws on students' reports of the development of the project throughout the semester. These reports, made in journals and portfolios, allow the students to receive guidance on how to maintain focus on the science aspects of their topic of choice. Our purpose is to observe student identity construction (both positive and negative) as they learn the science related to their topic; progress was closely studied by monitoring their journal entries and giving feedback. We chose a case study approach because we attempt to present a thorough description of the way students construct their identity throughout this project, and the cases we selected demonstrate categories to which other students would likely belong. Detailed descriptions of different intrinsic cases allow for the demonstration of different student backgrounds, their reasons for the project choices, their identity constructing process and, consequently, the minimization of their feeling of alienation from science. Also, this approach describes negative outcomes of the students going through these projects in the similarly detailed way. These cases are transferable; others who teach this type of course may encounter similar cases.

Results

There are two parts to our results. The first is to show three types of student identity development seen in final project work. This allows us to begin to understand what it means for a student to be engaged. The second part of the results looks at actual development of these kinds of identity, profiling six students who exemplify what an instructor might view as particularly encouraging or problematic types of identity development.

TYPES OF STUDENT IDENTITY DEVELOPMENT

One way we recognize strong identity in a final project is if a student connects it to (A) *particular personal interests* in his or her own life. For example, a student did a project about chemicals involved in love. Her[1] goal, she said, was to "better understand how chemicals in our body are responsible for the feelings and emotions that we experience when we are in love, where they come from, and how they affect us." This is something that she reported as particularly interesting to her because of her own personal situation at the time. Another student presented work on global warming that, although rapidly assembled, was described as something that strongly concerned her.

Other students showed example of strong identity with projects directly related to (B) *professional interests*. In one case a student discussed her work as an artist, and her big theme project included creating a painting in which she made her own tempera paints and then used them not only in her creative painting but to explore the chemical connections among the pigment, the support material, and the canvas. In this particular case, she used simple chalk in her egg tempera as a way of economically creating the paint she used.

Of course, with many future teachers in the course, several projects related to some aspect of teaching. Although these sometimes involved questions of the teaching of science, in other cases students thought to learn more about their future students. This was the case for a student who was interested in autistic children. The reason was her own interest in special education and what she reported about "my own personal experiences with autistic kids during the past two summers. I was a teacher's aid at [school name] elementary school in the summer program." In this case, she had particular personal experience of students having a condition, not in her own family but in the context in which she might one day work.

A third way which a strong identity occurs is in projects where students develop knowledge related to (C) *specific health issues* in their lives or in the life of family members or other close persons. One example of this comes from a student who feels she now understands well enough how mineral supplements affect her body. As a result she is ready to begin taking the supplements for the first time. A second and very poignant example comes from a student with a family member who reports that a cousin's daughter was diagnosed with a metabolic disease, which then became the basis of her project work as she sought knowledge that would help her family.

These indications of strong identity with a project are all taken from the final project reports. Such "snapshots" offer insight into what students can present at one moment in time. But following Richmond and Kurth, we are interested more particularly in how this identity does—or does not—develop over time. From this we hope to develop better ideas about how pedagogy, including instructor feedback, can be used to direct student work in these kinds of projects.

ISSUES IN THE DEVELOPMENT OF STUDENT IDENTITY

Strong personal interest: love The first case for us to consider is of a student who had otherwise indicated a strong general interest in the subject. In such cases, the tactic of a student-selected project can be a way for a student to join together a content interest (in this case chemistry) with something specific in her life. Proceeding from this strong content background, she explored several different ideas for her project. For example, she thought about studying a drug, aspirin. She pointed out, "That's something I've always kinda wondered about, I mean if your ankle hurts and you take aspirin, how does the aspirin know to make your ankle stop hurting?" Notice in this case she knew already she had an interest in an aspect of the subject ("always kinda wondered"), indicating prior identity with science. However, when she investigated the molecular action of aspirin further she concluded that it was too complicated for her to study. At about the same time, though, she mused that the chemical system that she was most aware of related to an ongoing relationship with another person, and she therefore turned to the chemistry of love and attraction. Her project linked directly to her feelings at that time, as she participated in a relationship that she wished to understand from a chemical level. She started with chemicals that "fuel" affection: endorphins, oxytocin, and vasopressin. But she also reflected on the chemicals of attraction: pheremones, dopamines, and phenylethylamine. Later, she did go into the literature and cited a study that linked vasopressin to memory associated with attachment.

Interestingly, this student also chose to focus her final exam work on questions about persons and science. She did not connect her big theme project, but she did point out that becoming a teacher or professor of science allows the person to spread knowledge of science and also, perhaps, to lead a child to become a scientist. Arguably, from the beginning of the course, she saw chemistry as a place for her to do things that would make strong connections, and when she talked about applying chemistry to her life, she learned that there is more to things that we see with our eyes. After she connected science with components of her own life, her identity advanced to an understanding that there are more than surface reasons for knowing science.

Strong personal interest: global warming It can be very difficult and even intimidating to students in any general education course to be asked to select a topic they want to explore for a major project, especially in a subject area in which they do not believe they have any interest or prior experience or from which they feel alienated. Thus an important tension for students and instructors alike is found in the initial selection and the subsequent stability of those choices about what to present in their projects throughout the semester. Student interests change with time, and this is especially true in a course where students encounter new content information as the course progresses. As a result, initial ideas may not persist to the final project. On the other hand, student changes can be seen as good evidence that the student *is* strongly engaged. Nevertheless, interests that are only developed and maintained for short periods of time may lack the depth or breadth of a well-constructed personal project.

For example, a student at a suburban community college indicated at the beginning of the semester that her interest in chemistry was "more on a medium level" not because she did not like chemistry, but because she was more interested in biology. Her preference for biology over chemistry may have been influenced more by the teachers than the subject matter, as she also stated she “loved her biology teacher and hated her chemistry teacher.” She also indicated at the start of the course that this course was not what she had expected. She had expected a course focused on how to teach science, not “with chemistry issues. I think the class and the work involved were more geared for science majors.” This indicated, in part, her idea that science content was not a topic of concern to her, either because she was satisfied with her content knowledge or because she felt content knowledge would not help her know how to teach.

She initially had two ideas for projects, and early in the course she decided to go with the one regarding diet rather than pollution. Interestingly she selected the topic that perhaps she viewed as more related to biology. Although the instructor and this student spent a long time on macronutrients and nutrition, she failed to see a connection between her topic and chemistry. As she said about two-thirds of the way through the semester, “My project is doing well. I am still interested in my topic. I have learned that the Atkins diet is not as good for you as the South Beach diet because of the high levels of fat intake. I’m not quite sure how I am going to relate it to our chemistry class though.” Shortly thereafter she offered assurances that her research was progressing and that she didn’t have questions. Two weeks later, however, she abruptly switched her topic to global warming. As she wrote prior to the final presentation, “I had chosen to do Atkins vs. South Beach diet, but as my research went on I had seemed to lose interest in my topic. Then one day we took a pre-assessment and one of the questions was on global warming. I knew I had heard about it before, but I just couldn’t remember what it was. It was then I chose to switch my topic to global warming because I was curious to know more about it.” Her final project was not well developed, but she did make a personal connection by indicating how she may change some behaviors as a result of her research. In this case, the content in the course had provided, in contrast to her expectations, something that she could make use of in her understanding of herself.

Engagement with career: student artist In this particular general education course we are working primarily with students who have identified a particular career intention. We might expect that such students would be able to link learning a subject to future practice, and indeed a few students have done projects that prepared activities for their future use. Student identity that directly serves professional practice is potentially a powerful incentive for a project. One example of this was for a student who was an art education major. The student did not show strong interest in science overall, pointing out happily that her transfer work from community college meant she was taking the last science course of her life. Nevertheless, although she seemed to dislike coursework in science, she indicated that her interest in science in general was high because she was interested in why things are the way they are and how things work. When the semester began she very quickly (three or four weeks into the semester) indicated that this would be a good place for her to consider some of the chemistry of art. Specifically, she asked, “What elements are contained in the paints and materials

I am using in my art class? Can having a better understanding of the elements that are present in my materials improve my artistic ability?" Notice in this case, the student does not just look at the project as a way of understanding more about science but improving herself as an *artist*.

As the semester progressed, she continued to discuss the importance of this reason for her project, accepting a suggestion to understand how pigments are put together. From this she conceived an idea of making the paint at home and then using her own paint in a project. Her final project did involve exploring different kinds of paints, including some she made by mixing chalk, egg, and water. She also talked about some of the chemical issues that were involved, such as the role of egg yolk in egg tempera as a binder and also as a material that anchors the paint permanently as it reacts with air. She indicated that the experience would make her a better painter since she now had an understanding of how her materials worked in chemical terms and, in her recipe for egg tempera, how to generate authentic materials on her own.

Engagement with career: Special education and autism The pre-existing identity with a career (art education) enabled the previous student to build a stronger project. However, strong purposeful identity can also distract students from attending to the content requirements of a student-selected project. As mentioned earlier, one student did a report on autism that emerged early in the course at the same time as she was indicating her general disinterest in science. She did, though, have a very strong and creative interest in math, including the connection of math to science. For example, when a laboratory associated with the building of models was given to determine different isomers, she reported that she was able to understand something associated with the fact that she was a fan of math puzzles and "this lab kind of reminded me that I really like trying to figure out how many isomers I could make." In this case, the student was able to turn the learning of chemistry into the puzzle and engage in a very interesting exploration. In principle she could have chosen a project that linked math and chemistry. But she had a greater emphasis on her hoped-for career in special education with autistic students. So this, not the content-rich link of math and chemistry, became her project theme.

This student knew autism had something to do with the brain, but she wasn't sure what it was. She was advised to consider fairly well-defined potential chemical issues that are associated with autism (specifically, that a certain mercury-containing antibacterial additive in vaccines has been suggested as a link to autism). But the causes of autism were not salient to her career focus: she wanted to explain how autistic children are managed from a special educational perspective. She did do a project in which she indicated how different materials, particularly pictorial materials, are used with autistic children—an interesting description of pedagogy and student management, but not chemistry. Although her project mentioned a very small bit of chemistry associated with possible problems in glutamine transport, her work did not actually deal with any chemistry in any particular way. In this case, the student's strong interest in a topic, autism, was something that she was very willing to bring to the course and proceed with throughout the course of the semester. The application of this to the learning of chemistry, however, was minimal.

Personal health connections: minerals This student's interest and confidence in science strengthened throughout the course; she did not, however, engage with the big theme project. This student indicated a low interest in science early in the semester: "I am confident in the fact that I hate science and math and my prior experiences in both subjects have helped to suggest that they are not strengths of mine." But toward the end of the semester, the student's dislike of science had changed, and she realized the significance of chemistry to herself: "I feel pretty confident about the ways that I am letting all of the information learned within our class sink in and still be remembered when I can apply it to something within my everyday life."

For her big theme topic, the student expressed an interest in nutrition and diet throughout the semester; her personal relationship to this topic was that she was "always going back and forth on diets," and that she was anemic. In one journal during the latter half of the semester, she expressed an interest in the ozone layer, suggesting that she may have been losing interest in her nutrition/diet topic and/or that little work had been done on the nutrition/diet topic. Ultimately, the student chose to focus her big theme project on multivitamins. Her final paper, though, was a general report on multivitamins, common information that was presented in class and the textbook. The student could see how multivitamins are related to chemistry, and that by taking them, she involves herself in chemistry; however, she did not appear to engage herself with the project.

Personal health connections: family metabolic disease Our last case is of the student who showed strong student identity development over the course of the semester with a project associated with her family health issue. She pointed out in her introductory essay that she had only a medium interest in science because she just is not a fan of science classes. But after that student watched the movie *Lorenzo's Oil,* she pointed out in her very first journal that her cousin's daughter had passed away as a result of a disease that is not well researched and, like Lorenzo's disease, has no treatment. She further indicated she became very interested in how she could help influence the study and research of that disease. Later in the semester, she talked in more detail about a particular disease that affects her family, identified as Leigh's syndrome, a mitochondrial disease where aerobic metabolism is severely compromised. During the semester she revealed that she had lost one niece to the disease and had another niece, still alive, affected with the disease. Her final project did involve an explanation of the role of mitochondria in aerobic metabolism. She recognized that, in contrast to *Lorenzo's Oil,* there were no putative cures available, in part because the disease doesn't involve a pathway that can be fixed by an inhibitor. Nevertheless, she developed the idea that the critical problems that cause many of the symptoms stem from the lack of aerobic metabolism, resulting in lactic acid and carbon dioxide build-up. She did come to understand, then, that because these chemicals lower blood pH, patients are treated with intravenous sodium bicarbonate to restore the acid-base balance in the body. She was then able to go back to her family and discuss the reasons some of the treatments were used.

On the final exam, this student gave an interesting answer to the personal question of how nonscientists participate in a process of science. She summarized her understanding by saying "They [nonscientists] greatly influence what research is conducted . . . When individuals contract diseases and disorders—then that is when scientists are provoked to look for a cure or treatment . . . " Of course, through her own family's experience she knew there are diseases that are not as thoroughly studied as others. She also recognized this as an important way for a nonscientist with a particular problem to have connections to what goes on in science.

Importance in Teacher Education

There are two aspects of the outcomes of this effort that we feel inform our ongoing teacher education efforts. The first has to do with the students themselves, who are now emerging into work in their own classrooms. The second is connected to the courses and the instructors.

As we have seen, students demonstrate different levels of progress in their work on the project. This fits a three-fold understanding of the ways in which students can build or expand knowledge, developed from longitudinal and ethnographic studies by Marcia B. Baxter Magolda and her coworkers. Students can make progress in their understanding of science, developing themselves *cognitively*. This is seen whenever a student is able to present a rich understanding of the science involved in a project. There are also cases where students develop ideas they wish to share with others, including the instructor, indicating their progression in *interpersonal* modes. This certainly occurred in the case of the student who chose to study a disease that afflicted members of her family. Third, students can sometimes reconsider their own view of themselves in their engagement with science, refining their *intrapersonal* understandings of the relationship they have with students. That these students do not always develop equally well in all three areas is also apparent: the student who studied autism did not develop much cognitively during this project. Similarly, students who make a personal decision to alter behavior, whether in diet or in lifestyle, may not necessarily know the science in a deep way. However, it is apparent that these multiple dimensions of personal development vis-à-vis science do manifest themselves in altered views of what they might do with their understanding. This, we feel, is a key to the integration of science into their possible practice as teachers.

As we suggested earlier, the opportunity to develop voices that express their own understanding of science allows students a place to present their views to teachers. Our own teaching has therefore been affected, changing the way the course is taught and also the way we interact with other students in their projects. For example, at one point or another, each of the instructors has incorporated aspects of student projects into his or her teaching for new students. This is a specific content change in the course. In addition, knowing that students develop particular ideas more deeply than others allows the instructors to suggest particular venues for further thought. This can have surprising outcomes, as in the case of another student who suggested an autism project. The instructor in this case was able to counsel the later student to look for an aspect of science that wasn't behavioral, and the student responded by considering aspects of diet that are used for autistics subject to bowel disruptions related to their particular level of physical activity.

Conclusion

Our conclusions are of two types. We begin with a reflection as teachers as to what extent our project work has been successful in developing student voices and where there are tensions associated with this goal. Secondly, we consider how this ongoing project aligns with some of the goals of our project, including the vision of reform of pedagogy and epistemology with feminist perspectives. In both cases we frame our conclusion in general terms that, we hope, can be useful to all disciplines interested in what happens when students select a project. We then comment on aspects that might matter also to instructors in science.

Our first conclusion is that students who brought a good idea *into* the course welcome the option to develop it further. These were students who, in one way or another, had *already identified an issue or problem they were interested in investigating through almost any disciplinary lens*. This is generally a positive thing, although as the autism project indicates it can be difficult to support a student in a project where there seems to be little connection between an interest and the discipline. It is our conclusion that the projects did forge a closer identity for these students with the topic of their project, allowing them a venue for expression they would not have found in a conventional course. The challenge for us, however, is that strongly engaged students may not engage with exactly the content we expect, creating a problem when we wish them to be learning content, not just something about a topic of interest to them.

The conclusion that a strong previously existing identity with an issue is a very good sign applies in particular ways in chemistry. Specifically, we note that there are very few subjects that cannot be somehow linked to a molecular viewpoint. On the other hand, some subjects, including autism, are not well defined when it comes to molecular-level descriptions. In those cases, the strong identity means that students reject the invitation to deepen content knowledge through the project.

The second conclusion relates to students who *lacked a strong personal issue that was present in their lives*. Such students tended to drift among several different ideas, settling sometimes at the last minute on something that interested them, but not well enough to study deeply. We conclude that we may be imposing an expectation on these students that they do not share, compromising both the quality of their work and the entire "identity" goal of our work. The challenge to the instructor in this case stems from whether we can require engagement of a student who is not interested in accepting the invitation given in this project. This problem will be particularly strong when students are alienated from a subject, as often happens in science. Here there is a need, which our cases do not yet incorporate, of having a student find an identity when other aspects of her life indicate this is not a worthy goal. Here we find there is some benefit to acknowledging this alienation publicly and also describing how previous student work influenced the course.

Despite these challenges we feel that this kind of student-directed project does advance some of our broader goals. From the point of view of pedagogy there is no doubt that students do give voice to their own interests and understandings—establishing a sense of self within at least some aspect of science and, in some cases, transcending preexisting barriers to their participation. In addition, their projects are places where they may, if they choose, advance issues of value to them—the environment, their own relationships, or the health of a family member.

Perhaps the most important aspect of this project over time, though, concerns the question of "what is science (or sociology, or literary analyses) for people today?" Naturally, the instructors in the course have their own answers to this. But as suggested by both Haraway and Mayberry, feminist epistemology requires that the viewpoints of science must include views from embodied selves. We do feel that we are engaging some students in their own viewpoints, bringing their "views from somewhere" into the overall view of the course. One of the great advantages of projects like this and working with students in this manner is that the students bring up totally new ideas that instructors might never have thought of. This interaction provides a rich and contemporary set of examples for use in our further teaching.

NOTE

1. Readers will note that the pronouns used to describe the students in this paper are female. That reflects the gender of the persons in the cases discussed. It also reflects the fact that very few men take these courses, especially as they are for elementary education majors.

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