JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 41, NO. 4, PP. 392–414 (2004)

The Cultural Production of Science in Reform-based Physics: Girls' Access, Participation, and Resistance

Heidi B. Carlone

School of Education, The University of North Carolina, Greensboro, 346 Curry Building, Greensboro, North Carolina 27402

Received 17 September 2002; Accepted 12 August 2003

Abstract: Recent literature in science education suggests that, to transform girls' participation, learning, and identities within school science, we must think about ways to engage girls in different kinds of educational activities that promote broader meanings of science and scientist. This study was designed to examine more deeply this call for a changed science curriculum and its implications for girls' participation, interest, and emerging science identities. In this ethnographic study, I examine the culturally produced meanings of science and scientist in a reform-based physics classroom that used a curriculum called Active Physics, how these meanings reproduced and contested larger sociohistorical (and prototypical) meanings of science and scientist, and the ways girls participated within and against these meanings. The girls in this upper middle class school were mostly concerned with accessing and maintaining a good student identity (rather than connecting to science in any meaningful way) and resisted promoted meanings of science and scientist that they perceived as threatening to their good student identities. Their embrace of the ways school defined success (via grades and college admission) produced a meaning of Active Physics as a way to get credentials on a transcript and ensured their disconnection from real-world, meaningful science and science identities. The story of girls' participation and resistance in Active Physics complicates our quest for gender-fair science and highlights the power of sociohistorical meanings of schooling and science in producing educational subjects. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 41: 392–414, 2004

Recent literature in science education suggests that, to transform girls' participation, learning, and identities within school science, we must think about ways to engage girls in different kinds of educational activities that promote broader meanings of science and scientist (Eisenhart & Finkel, 1998). This implies that we must make substantive changes to both science pedagogy and curriculum so that girls might begin to see themselves as people who can do and

Contract grant sponsor: American Association of University Women Educational Foundation's American Fellowship.

Correspondence to: H.B. Carlone; E-mail: hbcarlon@uncg.edu

DOI 10.1002/tea.20006
Published online in Wiley InterScience (www.interscience.wiley.com).

learn science (Brickhouse, 2001; Carlone, 1999). These ideas about how to create a more gender-inclusive science and science education have evolved over the years from accounting for or trying to overcome girls' biological, cognitive, and/or social differences (e.g., Benbow & Stanley, 1980; Gilligan, 1982) to encouraging more equitable classroom treatment without changing the prototypical science curriculum (e.g., AAUW, 1992; Irvine, 1986; Kahle, 1996; Sadker & Sadker, 1994) to calling for transformation in the prototypical science curriculum itself (e.g., Barton & Osborne, 1998; Eisenhart & Finkel, 1998; Kyle, 1998). In other words, calls for addressing the gender gap have shifted from attempting to fix ‘‘problems’’ with the girls to attempting to fix the problems with school science (Barton & Yang, 2000; Brickhouse, 1998).

I designed this study to examine more deeply the call for a changed science curriculum. I wondered whether a different kind of school science, one that promoted alternative (and broadened) meanings of what it meant to ‘‘do science’’ and ‘‘be a science person,’’ would make for a more inclusive and interesting science for girls. To address this research problem, my study examined the meanings of science and kinds of science identities that were produced in a reform-based high school physics classroom that centered on the study of physics on real-world themes such as sports, medicine, home, and transportation (called Active Physics). What did it mean to do science and be a ‘‘good’’ science participant in this setting? How did girls participate within and against the cultural meanings produced in this classroom?

The results described herein are framed around a pivotal (and initially, surprising) interaction in the classroom during my first day of data collection. This study began with an expectation that Active Physics would be a more inviting, inclusive science for girls than a traditional physics course. However, as the following vignette illustrates, this expectation was complicated during the first day of data collection.

> *Day One of Data Collection: Resisting Active Physics*
>
> *Active Physics, 10:30 a.m. It's my first day of data collection. I sit in the back of the Active Physics classroom with my eyes peeled to notice subtle nonverbal responses and interactions and my ears ready to capture hard-to-hear exchanges between students. I want to capture the girls' joy, their excitement, and their resistance. Will I recognize these when I see them? I want to take this first day to really experience the classroom as an outsider—to question taken-for-granted practices and to denaturalize the natural.*
>
> *Before Mr. Stewart (the teacher) begins with the instructions for today's activity, he gives students a "heads up" on the schedule for the last week and a half of the semester.*
>
> *"Okay, everyone! We have about a week left in the semester—"*
>
> *A girl sitting in the middle of the classroom raises both arms, pumps them victoriously and cheers, "Yahoo! I'm outta' here! I'm droppin' this class baby!"*
>
> *My heart sank. So began my first day of data collection in Active Physics...*

This girl's reaction to Active Physics was representative of a certain amount of frustration many of the girls felt about the class. Although there were girls who embraced certain aspects of Active Physics, many were conflicted about the emergent meanings of science and the implied science identities in their class. In this investigation, I describe the unfolding of this story by highlighting social practices that promoted particular meanings of what it meant to do science and be a ‘‘good’’ participant in Active Physics and girls' participation within and against these promoted meanings. What, exactly, were girls embracing and resisting about Active Physics? What meanings of science emerged and shaped these reactions?

To address these questions, I use ideas from cultural anthropology that draw attention to the ways structure and agency interact in producing cultural practice. For those interested in transforming science education, part of what comprises the ‘‘structure’’ we contend with in enacting reform is the sociohistorical legacy of science and science education, which I describe in more detail in what follows. Understanding the ways that this legacy shapes practice provides a starting point in thinking about alternative, more inclusive science education realities. At the same time, we should understand that girls do not passively accept promoted cultural scientific practices. Therefore, we must pay attention to girls’ agency in shaping, accepting, and resisting the promoted cultural practices. Below, I also describe two concepts from practice theory—cultural production and situated learning—that help frame my research.

Conceptual Framework

Sociohistorical Legacy of Science and Science Education

Science carries a powerful sociohistorical legacy and is reproduced as an objective, privileged way of knowing pursued by an intellectual elite (Barton & Yang, 2000; Duschl, 1988; Fensham, 1997; Lemke, 1990). As previous research has shown, school science plays a role in reproducing these alienating meanings of science via classroom activities, discourse, and social organization (Cunningham, 1997; Lemke, 1990; Moje, 1997; Roseberry, Warren, & Conant, 1992; Rosenthal, 1996). Over the past century, traditional ideas about what science is, who does science, and historical practices of science education have left us with a legacy about what ‘‘good’’ science education looks like. Angela Calabrese Barton and Kimberley Yang (2000) call this the ‘‘culture of power’’ in science education. This culture gets reproduced by practices that include: transmission models of instruction; boring, repetitive tasks (e.g., verification laboratory activities, defining vocabulary words from a list in the book); a tacit or explicit privileging of dry, technical rational discourse; a tacit or explicit denigration of students’ knowledge and ideas; a goal of producing future scientists, rather than a goal of teaching science for all students; and the narrow disciplinary view of the science curriculum that treats social issues, technology, and engineering as diversions. This list represents a small sample of practices that comprise what I call prototypical science education. Although recent reform efforts aim to counter how prototypical science education gets done, these prototypical practices, for many practicing teachers, serve as a model of what a good (‘‘rigorous,’’ ‘‘challenging’’) science education looks like. The practices privileged in school science also point to a narrowly constructed vision of ‘‘good’’ participants; a construction that leaves out many students (Brickhouse, 2001; Carlone, 1999; Eisenhart & Finkel, 1998). Throughout this study, I use the phrase ‘‘prototypical science education’’ to represent these taken-for-granted notions about science and science education that comprise the alienating nature of school science.

Reform-based Science Education and Active Physics

Science educators have struggled to transform prototypical science education, via one reform effort or another, for over 50 years (Bybee, 1997; DeBoer, 1991). Contemporary ideas about science education reform are represented in the *National Science Education Standards* (National Research Council [NRC], 1996). A key feature of the *Standards* is the emphasis on science as inquiry, which includes the ‘‘abilities necessary to do scientific inquiry’’ and ‘‘understandings about scientific inquiry’’ (NRC, 1996, p. 121). These abilities include engaging scientifically oriented questions, using evidence to develop, evaluate, and revise scientific explanations, and communicating and justifying scientific explanations (NRC, 2000). Understandings about scientific inquiry include the nature of science, scientific knowledge, and scientists' work. A curriculum based on the *Standards*, then, would provide students opportunities to engage in activities that promote these abilities and understandings. There are multiple ways to create an inquiry-based classroom, ranging from more teacher-direction and structure (e.g., learner engages a question posed by the teacher, is given data and told how to analyze it, is provided steps for communication of explanations) to more learner self-direction (e.g., learner poses a question, determines what counts as evidence, forms a logical argument to communicate explanations) (NRC, 2000). The learning opportunities provided by the enacted Active Physics curriculum typically fell in the middle of this spectrum—sometimes representing a more structured approach and sometimes representing a more learner-centered approach.

Developed by the American Association of Physics Teachers and the American Institute of Physics, the Active Physics curriculum frames the study of physics around real-world themes (e.g., home, medicine, sports, transportation), promotes inquiry-based learning, and includes students' interests and social issues as part of the physics curriculum. Active Physics was developed explicitly as a response to the traditional physics curriculum to make physics more accessible, relevant, and interesting to a broader range of students. As Eisenkraft (1998) noted in his introduction to the text:

> The usual physics course has so much math and so much reading that many students miss the beauty, the excitement, and the usefulness of physics. Many more students simply refuse to take the course. Active Physics began when a group of physicists and physics teachers wondered how to pass on their enjoyment of physics to high school students.

The inclusion of relevant, real-world themes and collaborative, inquiry-based problems had the potential to broaden the meaning of science and scientist in ways that were consistent with much of what science education reformers called for. For example, a traditional physics class might promote a meaning of science that stresses science as a body of knowledge disconnected from real-world applications through repetitive tasks, cook-book labs, and assessments that focus on the finished body of knowledge of physics. The Active Physics curriculum, on the other hand, emphasized students as *producers* of scientific knowledge. As such, it had the potential to introduce students to the context and processes that give rise to the products of science. For instance, in one activity, students were to design the best (safest) car bumper, subject their designs to various tests of force and momentum, and revise their designs accordingly. In this activity, students had to apply their existing knowledge to the design of a model, test their model, and revise their models based on evidence garnered from their investigations. In doing so, they experienced the frustrations of less than perfect equipment and uncertain results, as well as the joys of successful, creative design work. As Christine Cunningham and Jenifer Helms (1998) argued, infusing the messiness and contingent nature of scientific knowledge into the science classroom may erode students' idealized image and unquestioning acceptance or rejection of science, may give students more faith in their own findings (rather than relying on the teacher or text to ratify their findings), and perhaps will allow students to see themselves as future participants of the discipline.

Using Practice Theory to Define Culture

My work draws on an anthropological theory that informs how scientific practices in settings of science learning are not only constitutive of, but might also work against, sociohistorical legacies of science and science education. Practice theory (as defined by Eisenhart & Finkel, 1998) is an evolving perspective in cultural anthropology that focuses on the ways in which people, in their daily practice, make meaning in such a way as to reflect and/or counter larger social structures (see also Buxton, 2001; Carlone, 2003a; Holland & Eisenhart, 1990; Levinson, Foley, & Holland, 1996). I argue that using practice theory for understanding settings of science learning allows us to see how school science (and local meanings of science) both reproduces and contests sociohistorical legacies of science and science education. Two primary concepts from practice theory—cultural production and situated learning—are particularly helpful in creating an interpretation of girls' access, participation, and resistance in this reform-based physics classroom.

Cultural Production. Margaret Eisenhart and Elizabeth Finkel (1998) define cultural productions as "meanings developed by groups in their everyday activities" (p. 44). A focus on cultural production provides us with a different way to think about settings of science learning. It promotes a critical examination of how the local meanings of science and scientist vary depending on the social organization of the classroom and the context in which the classroom is positioned. Thus, we might examine the ways new (more liberatory, transformative) meanings of science emerge in new school science contexts. Yet, the concept of cultural production also forces us to recognize how participants produce the meanings of science and scientist in local settings within and against larger, more powerful and pervasive (i.e., prototypical) meanings (Carlone, 2003a). That is, one is not free to create *any* meaning of science in a setting of science learning. History plays a large role in shaping possible meanings. This history is reified in the forms of values, beliefs, and taken-for-granted actions of peers, teachers, and administrators, all of which imply certain meanings of a "good" science education and "good" science participants. Thus, the concept of cultural production enables us to account for how larger sociohistorical meanings shape participants' values, beliefs, and actions, but also the ways new meanings of science might emerge depending on the context in which the classroom is positioned. It draws attention to the intersection of the local and global, the micro and macro.

Situated Learning. Jean Lave and Etienne Wenger's theory of situated learning (1991) provides another aspect of practice theory. Situated learning differs markedly from psychological theories of learning. Instead of viewing the learner as an individual meaning maker, Lave and Wenger draw our attention to the learner's increasing participation in a community of social practice. This alerts us to the ways in which activities represent certain knowledge, learning, and identities (the meaning of being a scientist, a woman, an expert), and make these socially available to group members as they participate in activities over time (Brickhouse, Lowery, & Schultz, 2000; Eisenhart & Finkel, 1998; Lave & Wenger, 1991).

An important aspect of situated learning is examining how participation in relevant social practices promotes the formation of certain kinds of identities. Instead of viewing learning with a predetermined outcome measure, learning becomes measured in new ways of talking, acting, being in the world, describing oneself, or relating to others (Brickhouse, 2001; Eisenhart & Finkel, 1998). New identities develop when one begins to take on new roles in the learning community, gains more knowledge, and has access to the discourse, tool use, and more central aspects of participation in the learning community.

Lave and Wenger's (1991) argument that participation in relevant social practices promotes the formation of certain kinds of identities is tempered with a recognition that structure and power relations within a community may encourage and/or inhibit access to legitimate participation for individuals within the community or for those who seek membership. In other words, the promoted science identities may not be socially available, achievable, or interesting to all participants. Thus, these alternative, "inappropriate" identities may become marginalized within the community.

A focus on situated learning shifts the perspective of learning from an internalization of knowledge to a focus on how people organize science activity, represent science in activities, and the kinds of identities implied by the activities. A perspective grounded in situated learning raises questions such as, "How do learners participate (or not) in social practices?" or "What kinds of people do well (or are interested) in this activity?" Through an examination of local practice and the ways learners participate within and against these practices, one can garner rich information about the kinds of people for whom a science class is designed—for instance, creative types, logical thinkers, political activists, collaborators, geniuses. Put another way, these are the promoted science identities or meanings of "scientist" in the local setting.

Remembering that a primary aspect of situated learning includes a focus on learners' participation in relevant activities, one might ask of a science learning context, "What are the ways that students are given opportunities to engage in relevant science practices?" Thus, one might argue that if students are not given opportunities to engage in practices that represent scientific knowledge and identities, then they will not come to see themselves as participants.

The articulations of situated learning with cultural production give us a rich understanding of the culture of a science education classroom. In other words, in this study, while I describe girls' opportunities to engage in science practices, I also outline the meanings of science those practices evoke and the kinds of identities implied by the activities.

Research Context

Sunnyglen High School[1]

Located within a largely upper middle class suburb of a major metropolitan area, Sunnyglen High School serves some of the wealthier students in the district. During the study period the school's population was mostly white (84%), with 4% Hispanic, 4% black, and 9% Asian. Approximately 3400 juniors and seniors attended Sunnyglen High School, with 97% of the school's 1998 graduates attending college (84% 4-year college, 13% 2-year college). The school was well known for its high-achieving students.

Approximately 50% of the students at Sunnyglen High School enrolled in first year physics, well above the national average (e.g., 29% of all high school students completed physics in 1998, according to NSF [2002]). As a result of this high enrollment, the physics department was extremely large (11 full-time faculty members). There were five different kinds of physics courses offered: (1) Advanced Placement (AP) Physics C (second year physics with calculus); (2) AP Physics B (second year physics without calculus); (3) Honors Physics I (first year physics); (4) Regular Physics I (first year physics); and (5) Physics I–Active Physics (first year physics). The focus of this study is on Active Physics, which, along with Regular Physics I, was considered to be the lowest level physics option.

The Active Physics Classroom

Mr. Stewart, the Active Physics teacher, had a master's and a bachelor's degree in chemistry. He taught chemistry for 10 years before switching to physics. One assistant principal described him as one of the "strongest and most academic teachers" in the physics department. After teaching a traditional physics course for 2 years, he decided to pursue training with the Active Physics curriculum because he was intrigued by reaching more students with a more inquiry-based approach.

The Active Physics class that I studied had 28 students (juniors and seniors; 14 girls and 14 boys), and most of them were white (with the exception of 2 Asian Americans). Students had been randomly placed in the class—the option of enrolling in Regular Physics or Active Physics was not made public to students.[2] All students in this class reported that they planned to attend a 4-year college upon graduation from high school.

Ethnographic Methods

The results I describe are part of a larger ethnographic study (Carlone, 2000). Elsewhere, I have reported the ways in which girls participated in ‘‘Regular Physics’’ (a class that used a traditional physics curriculum) at Sunnyglen High School (Carlone, 2003a) and the ways in which the meaning of the Active Physics at Sunnyglen High School curriculum got transformed as it traveled across space and time (Carlone, 2003b). The results of these ethnographic studies help make sense of the data I present here; thus, I will refer occasionally to the findings of these studies in my analysis.

In general ethnography allows one to better understand the culture of a group—the meanings produced by people in their daily lives that shape and are shaped by the ways they think, feel, and act. Spradley’s (1980) model for understanding meanings produced by people in their daily activities allows the ethnographer to make cultural inferences about the group by using three types of information: (1) cultural behavior (what people do); (2) cultural artifacts (e.g., tools and products); and (3) speech messages (what people say). A participant observer ‘‘learns’’ the culture by making cultural inferences. In this section, I briefly describe the kinds of data I collected and the methods of analysis I used to make cultural inferences about the meanings of science and scientist in the setting and girls’ participation within and against these meanings.

Data Collection

I spent approximately 6 weeks (December 1998 to May 1999) acting as a participant-observer in the classroom. During class activities, I took fieldnotes and audiotaped whole-group and two or three small-group conversations. Each trip to the research site was approximately 1 week long with periods between visits spent transcribing audiotape data and doing preliminary analysis of the data to help inform subsequent observations.

Other sources of data included: artifacts from the classroom (e.g., student work, sample handouts), e-mail correspondence with students and the teacher (used as a form of member checking), and survey data (to gather background information about students’ academic performance, future plans, perceptions of the physics class, and identification with physics and science). In addition, I conducted formal interviews with ten Active Physics students (three boys, seven girls), three Advanced Placement Physics students who had taken Active Physics the previous year (two boys, one girl), the physics teacher, two guidance counselors, and the assistant principal of curriculum and instruction. I had many opportunities to hold informal conversations with the teacher and students, which also became part of the data set. Finally, I held two focus group interviews with girls from the class (toward the beginning of data collection), so that I could interact informally with them, develop rapport, and focus subsequent data collection.

Data Analysis

My primary method of data analysis (applied to the entire data set) was Spradley's (1980) method of semantic structure analysis, which involved three, iterative stages of analysis.[3] The first stage, called a domain analysis, involved searching the data (line by line) for categories of cultural meaning or ''domains.'' Each domain included a cover term (the name of the domain) and a semantic relationship (that describes the relationship between the cover term and the domain). So, a sample cover term and semantic relationship was ''kinds of student questions,'' with ''student questions'' representing the cover term and ''kinds of'' representing the semantic relationship. A different semantic relationship with a similar cover term might be ''ways of asking questions.'' As domains were identified, they became codes whereby data could be chunked. So, underneath ''kinds of student questions,'' for example, I included the following actual student questions (among many others): ''What would happen to your electric bill if you left your computer on all day?''; ''Do we have to know this?''; ''Are you saying that . . . ?''; ''Was that in the book?''; ''Do we redraw the bars on the graph?''; ''Are you going to answer the question I asked earlier?'' At this stage in the analysis, the researcher used the participants' language as much as possible and simply chunked the data underneath relevant domains. Other domains and semantic relationships (for this study) included: reasons for being frustrated, characteristics of good work; ways to express creativity; ways to handle unexpected data; and uses of textbook. Thus, I searched my data for domains and associated semantic relationships using my conceptual framework as a loose guide to focus my analysis. At one point in the analysis, there were over 100 domains, which were later collapsed as the analysis grew more focused.

The second stage of analysis, called taxonomic analysis, involved looking for relationships among the data included in each domain. This stage helped define how the cultural domains were organized and involved looking for relationships among the data underneath each domain. So, for example, in the domain noted earlier (kinds of student questions), students' questions could be categorized as curiosity questions (''What would happen if . . . ?''); questions about physics content (''Do you mean that all three of these share wattage?''); questions about accountability (''Is this going to be on the test?''); questions that challenged the teacher (''How was I supposed to know that?''); and procedural questions about labs (''Should we graph our results?''). This process allowed me to refine the meaning of the domains (the cultural categories) and the data included underneath each domain.

The final stage of analysis, called a componential analysis, involved looking for dimensions of contrast that highlighted different meanings of the cultural categories for different members of the group. This stage of analysis provided a way to compare and contrast two or three domain lists, which resulted in juxtaposing dimensions of contrast (e.g., girls' participation in small-group activities vs. girls' participation in whole-class activities) and the data included under each domain.

These stages of analysis were done iteratively with data collection. For example, after examining dimensions of contrast in the componential analysis and finding gaps and unanswered questions, I returned to the field to try to fill in the gaps. I also reexamined the taxonomies to look for new relationships and reconsidered evolving themes via the componential charts.

Results

In this section, I describe meanings of science and accompanying science identities promoted in the Active Physics classroom. As practice theory implies, everyday practices in a science classroom will reproduce and/or contest larger sociohistorical meanings of science and scientist. These everyday practices give rise to local meanings (cultural productions) of science and scientist. Thus, when I make note of the meanings of science or science identities in Active Physics, I am referring to the *local* meanings produced via the everyday classroom activities and social practices. I also examine the ways these local meanings reproduce or contest larger sociohistorical meanings of science and scientist. In this way, the practice theory framework enables a dual analytic focus on micro and macro practices.[4] In the case of Active Physics at Sunnyglen High School, there were both new (broadened) and traditional (narrow, prototypical) meanings of science and scientist being promoted. In the first subsection, I describe the ways the social practices of the Active Physics classroom *challenged* prototypical meanings; the promise of the written curriculum translated into new kinds of activities, new ways of participating in physics, and new ways of being a physics student. In the second subsection, I describe the ways the social practices of the Active Physics classroom *reproduced* prototypical meanings; certain classroom practices promoted alienating meanings of science (as difficult and hierarchical) and scientist (as a super-intelligent male). Throughout, I draw attention to the ways girls participated within and against these meanings of science and scientist and provide my interpretations of why they responded as they did.

Science as Active/Scientist as an Energetic Problem Solver

> I consider paying attention in most classes optional. I'll take the notes, fine, because . . . really, if you give me the notes, I don't need to listen to you. I'll figure it out later on my own. I'm capable of that. So, just let me do your redundant homework and I'll be through with it. . . . But, this class, it drives me nuts 'cause I can't do that. (Amy, Focus Group #2, 3/3/99)

Amy's comments indicate that this class required one to be a different kind of student. This class promoted a different kind of participation than is the norm for a high school physics class (or, for most classes in general). The students worked on activities in small groups (of three or four) approximately 3 or 4 days per week. Mr. Stewart emphasized learning by doing, which demanded that students bring their ideas and knowledge to the tasks and hindered the ease with which they could memorize the material as they might have done in a more traditional setting. Mr. Stewart was attracted to Active Physics for its opposition to a traditional instructional approach:

> [T]he students that really enjoy this type of approach are the ones that like to get their hands dirty and like to get in there and figure out how something works, and enjoy that. The [student] that looks for the details and tries to memorize those details . . . has a difficult time. They get real frustrated. Because, I mean, it's worked in the past, but it's not gonna work in the approach that I use. (Mr. Stewart, Interview, 3/1/99)

The important aspect of this active participation, for me, was the way it countered students' laboratory participation in prototypical settings, where labs are considered diversions from lectures and seat work and most students spend their laboratory time socializing with peers and engaging in non–science-related talk (Gallagher & Tobin, 1987; Tobin & Gallagher, 1987). In this setting, students had to be active, work well in groups, and be able to make sense of what the lab activities implied about physics concepts to do well in the class. Students knew that "lab time" did not mean "free time":

> Kids consistently stay on task while we are engaged in a lab/activity. An attitude of ‘‘work’’ develops. (Mr. Stewart, Survey):

> You have to be more of an energetic type person [to do well in Active Physics]. You can’t be like kind of an anal person where you just sit and read a textbook. Active is more enthusiastic. You kind of have to be willing to learn. You can get into Active and just start doing the labs and having fun, just playing with the stuff without learning. But, to really learn [and do well] you have to kind of *want* to understand. (Max, Interview, 5/6/99)

Students engaged in in-depth problem solving, working through uncertainty to solve problems of relevance to their lives and interests. Many problems that students were asked to solve in lab activities involved ambiguity, did not have easy answers, and demanded that students bring their knowledge of physics to the task. This was also a challenge to prototypical school science laboratories, which are ‘‘places where students follow recipes, perform routine procedures, rehearse technical skills . . . , demonstrate the reliability of selected scientific ‘laws’ or phenomena, and falsify their data when procedures and demonstrations produce inconclusive or ‘unexpected’ results’’ (Gough, 1992, p. 6).

Mr. Stewart was committed to having students puzzle through the material. He made choices about the kinds of physics topics he wanted to cover based on whether or not students would be able to construct their understanding of the physics through experimentation. Certain topics that were ‘‘standard’’ in prototypical physics courses (e.g., modern physics) were left out in Active Physics because they were too abstract or too hard to design experiments for. On the other hand, Active Physics covered some topics that a traditional introductory physics course did not cover or touched on only briefly. Those who took Advanced Placement (AP) Physics after taking Active Physics did not feel as though they were at any disadvantage:

> In some topics, we were prepared better [than the Regular or Honors students], like potential energy. Max and I were great in that. We did a project and had it finished in almost half the time the other people did because we were so well thought out in that subject . . . . Lens and focal points—Active did a lot of that, too, so we were ahead in that, too. (Christopher, an AP student who took Active Physics, Interview, 5/4/99)

> We’ve had it easier than some of the Regulars . . . . This year actually, we might have a carousel or something and we have to find out the velocity at a certain point. It sounded like the Regulars didn’t have any problems like that. It was more like just plug-and-chug problems. Last year we had problems that would be like real-world experiences. We’d have to calculate velocities here just like you can relate it to something. . . . I think it’s made it a little bit easier. (Max, an AP student who took Active Physics, Interview, 5/6/99)

Ms. Carpenter, an Active Physics teacher who also taught AP Physics, told me that there were a number of topics that the former Active Physics students (enrolled in AP) excelled at in comparison with the former Regular Physics students:

> Ms. C.: Active kids excel at work/energy problems.
>
> Author: Why is that?
>
> Ms. C.: Because they’ve spent so much time with these concepts. The roller coaster unit did a great job with that. [In AP], they are just as apt to apply a work/energy format [to new problems] as a kinematics approach. Also, Active kids excel with the light unit. They do more with light intensity, properties of light rays, and ray diagrams. (Phone Conversation, 3/17/2000)

I use these quotes from the AP students and teacher to help support my observations that the kinds of problems the Active Physics students were being asked to solve were worthwhile, involved conceptual understanding of physics, and prepared them for further study in physics. These problems, juxtaposed to the "plug-and-chug" type problems common in Regular Physics (Ms. Carpenter, Phone Conversation, 3/17/00), demanded that students not only know the formula, but also gain an understanding of the meaning of the formulas. As a result, the work they did in Active Physics in trying to work through conceptual problems gave them an understanding of physics that helped them in AP Physics.

Girls Accept and Resist the Active Science Learner Identities

The attitudes of work and persistence evident among the Active Physics students were part of the "active" meaning of science and scientist. In some ways, this new kind of participation was exciting and more interesting. Thus, it should not be surprising that many girls embraced the active meaning of science. Yet, in other ways, this new kind of participation demanded more from students than the prototypical student roles to which they were accustomed. Also, taking into consideration the local community context, where students were expected to "achieve" (with achievement marked by superior grades), the more demanding student roles were risky for girls. Thus, it should also not be surprising that some girls resisted the active meaning of science and the accompanying implied science learner identities (energetic problem-solver, hard-worker).

The girls that were successful and interested in Active Physics defined themselves as "hands-on" people and "energetic" people who liked doing labs and working with groups. The Active Physics class, in this sense, gave them space to feel good about themselves as learners and to see themselves as capable in a learning community:

Author: What kinds of people do well in Active Physics?

Tanya: Visual learners, people that have to do hands-on stuff to learn. People like me. (Interview, 5/6/99)

Kelly: I heard about [Active Physics] and figured that was the kind of person I was .... The counselor said it was hands-on, and I thought I'm that kind of person. (Interview, 5/4/99)

Thus, it was apparent that the promoted active science learner identity appealed to some girls. They saw themselves as active "kinds of people." Although it took some of them a bit of time to adjust to the new identities, they made this adjustment and embraced it[5]:

> If you would have asked me first semester [whether to recommend the class to others], I'd be like, "It's not that bad. You can get through it." Now, I'm like, "Go for it!" (Kelly, Focus Group #2, 3/3/99)

Author: What do you think about the science class this year?

Meg: I'm glad I'm in Active.

Christy: Me too.

Meg: My boyfriend hates Regular [Physics]. Book work. That's all they do.

Author: Tell me why you like Active over the idea of Regular.

Christy: They just go by the book. I don't learn by the book. I learn by seeing it or doing it. (Interview, 5/5/99)

> I like the class. It was fun for me to do the stuff rather than sit there and listen. I really think if I was in Regular Physics it would be really hard for me. You can tell, I can't just sit there and listen to [Mr. Stewart] lecture. I get bored. If I only see it, I don't understand. When we analyze graphs and he just shows us the bowling ball falling and coming back up—if he just says, "This is where it's in free fall. This is where the acceleration is," I can't see it at all. If we go and do it ourselves and get the data ourselves, I can visualize. Doing labs really helps me. (Tanya, Interview, 5/6/99)

Not all girls embraced all aspects of the new active science learner identities. Some thought (perhaps accurately) that their grades would have been better had they taken Regular Physics:

> Author: Would you choose Active or Regular, knowing what you know now?
>
> Missy: I'd probably choose Regular because it's just a lot easier from what I've heard.
>
> Author: What about interest? If you took grades out of the picture, what class would you choose?
>
> Missy: Probably Active Physics. It's really interesting. It's fun, exciting. You get to do cool labs and stuff, compared to sitting at a desk and reading and just listening. (Interview, 5/5/99)

Missy was not necessarily contesting the active (local) meaning of science and scientist; in fact, she embraced her role as an active participant. She was, however, contesting the fact that she was held accountable for these new roles and that her grades were dependent on being successful in her new role.

Some girls, however, were put off by and contested the active science learner identities. There were four girls in the class (out of 14 girls) who were unhappy with the class for various reasons.[6] These girls were vehemently opposed to the active approach and found ways to denigrate it whenever possible:

> Survey question: Knowing what you know now, would you choose to enroll in Active Physics (vs. Regular Physics)? Why or why not?
>
> Karen's response: Absolutely no way no how. Hate labs. Hate teaching style.
>
> Amy's response: No. It has been a living hell.
>
> Survey question: What kinds of things do you have to do to be successful in Active Physics?
>
> Amy's response: One must be in class and actively participate, have extreme patience for the slower intellects or nonintellects. It might even be useful to be one of the nonintellects who can't learn in a conventional manner, or rather, doesn't try to learn in a conventional manner.

Those who opposed the active approach were frustrated by their new student roles. They were frustrated with the attitude of work and persistence that the class demanded:

> Survey question: Did you *choose* to enroll in Active Physics? Why or why not?
>
> Amy's response: No! I wanted an easy class with a *textbook*. I didn't want to think beyond what equation to use.
>
> Survey question: How is this class different from/the same as other science classes you have taken?

Karen's response: It's more challenging, which might be good for someone, but that someone sure isn't me.

Author: What kinds of people do well in Active Physics?

Melissa: I don't know. Maybe I just don't care enough about physics, but they're anal people. They concentrate on details. And I'm not like that. I'm just like, all right, if I get it, I get it. If I don't, I don't. But they're like—even in my lab period. Peter Brown? He can concentrate on all the details. And like Kelly?

Author: She's detail oriented?

Melissa: They don't give up. I guess that's it. (Interview, 5/5/99)

In many ways, they were resisting the active, locally produced meaning of science and scientist that was different from prototypical meanings. These three girls defined themselves in opposition to the active science learner identity. They claimed that they were not ''lab people'' or ''group people.'' It was interesting to examine the ways that these girls defined themselves in opposition to active science learners. For example:

Olivia: I think in Regular, you just sit through lectures—

Amy: I would be really happy.

Karen: Yeah, I think me and Amy would rather have—I'm a notes person, just like her. (Focus Group #2, 3/3/99)

It was clear that the ''notes'' people were not excited about embracing an ''active'' identity. Also, perhaps, the teacher could have nurtured this new active identity more than he did. I am not convinced he did enough to make it safe for girls who were reluctant to take on active roles to do so. That is, there was not a lot of teacher support for ''notes'' people to embrace an ''active'' role. One either embraced this role (to succeed in the class) or one did not. Those who did not were left to fend for themselves. Also, in an interesting example of cultural production, they defined themselves as different kinds of people—people who did not ''fit into'' the celebrated science learner in this class.

The three students who most vehemently resisted the active science learner identity saw themselves as capable students in other arenas. For example, Amy defined herself as an ''intellectual'' and Melissa described herself as a ''smart math person.'' One could argue that these girls contested the active identities on the grounds that it threatened their ''good student'' identities or, perhaps, threatened their perceptions of what it meant to be a ''good student.'' A transformation from ''good student'' as listener, memorizer, and recipient of knowledge to ''good student'' as active, hard-worker, problem-solver, troubleshooter, and producer of knowledge is difficult. The active identity is more risky and more demanding with no more (or even less) of a ''payback'' (read good grades and credit on a transcript) than a traditional ''good student'' identity in a prototypical science class.

Despite this resistance from some girls in the class, there were girls who enjoyed the active, challenging nature of the class. In examining these girls' active participation, interest, and success in the class, it was interesting to note their continued disconnect from what they perceived as legitimate science identities. That is, at the end of the year, the girls who were successful and interested in the class (and who defined themselves as ''lab'' people) did not define themselves as ''science people'' and opted not to pursue further study in physics. Perhaps some of this can be explained by the fact that most of these girls were taking this class for credit on their high school transcripts, which looked good for college admission (rather than as a way to learn more about and become connected to science). While this purpose cannot be understated, it is also fruitful to examine other possible reasons for girls' disconnect from science. In examining the culture of the classroom (the taken-for-granted, local meanings of science and scientist that emerged in the classroom), there were prototypical meanings of science that may have overshadowed the potential of transforming girls' science identities and relationship to science. I describe these meanings in what follows.

Science as Difficult/Scientist as Someone with "Raw Ability"

In this section, I describe classroom practices that promoted meanings of science as difficult and hierarchical. Initially, these meanings were surprising contradictions to me, given the central reason (to make physics more accessible to more students) for the development of the Active Physics curriculum and Mr. Stewart's reasons for adopting the curriculum (to reach more students). As a caveat, in describing the more alienating meanings of science and scientist in Active Physics, I do not wish to denigrate the teacher's efforts in enacting a reform-based science. Elsewhere, I provide an explanation for why this course became more traditional and "difficult" as it traveled across space and time (see Carlone, 2003b). In examining the local context and history of Active Physics at Sunnyglen High School, I found that its difficulty in gaining legitimacy in the school (to be seen as a "real"/"rigorous" physics class) put pressures on the course in ways that might explain the course's evolution from an "accessible" physics course to what the other Active Physics teacher described as a difficult, "college level course." Yet, the issue to consider for this discussion is how girls responded to these prototypical meanings of science.

The difficult and hierarchical nature of the enacted Active Physics curriculum implied science identities (e.g., someone who is "naturally" smart, has "raw talent," and is male) that were alienating, inaccessible, and/or uninteresting for girls. At the same time, these meanings did not challenge girls' taken-for-granted assumptions about who is "good" at science. Thus, most girls (even the successful ones) did not actively resist these celebrated science identities unless they perceived the practices as threatening to their grades or their "good student" identities.

Students came to understand that aspects of physics were difficult, and not everyone would be able to do and understand every aspect of the class. When introducing laboratory activities to students or telling students about upcoming tests, Mr. Stewart would often alert students to the stair-step difficulty of the problems they had to solve. In most labs and tests, there were problems that were fairly "easy" (i.e., that everyone would be able to solve), problems that were "challenging" (i.e., that only some would be able to solve), and problems that were "difficult" (i.e., that only a few would be able to solve). These were not implicit categories of meaning; Mr. Stewart made these levels of difficulty explicit for students. For example, he introduced an acceleration/time activity in the following manner:

> *Tomorrow, you will have 15 minutes to solve eight problems. There are three levels on that sheet. Level one is gonna be a piece of cake. If you follow and understand what today's worksheet is, level one is gonna be a piece of cake. Level two is gonna be a piece of cake. Level one is a 70%. Level two is an 85%. Level three is gonna separate the A's from the B's. It will not be a piece of cake. All right?* (Fieldnotes, 3/4/99)

He introduced a laboratory activity about air resistance in a similar way:

So, part I is easy to do, but difficult to explain. I'm looking for good explanations. Part II, the section labeled "optional" will not be optional for you. It will be difficult. The last thing you're going to do, and this is the fun one, is looking at how spin might affect a tennis ball on the moon . . . . But this is only for whom? Those who are efficient and finish the first ones. (Fieldnotes, 12/2/99)

For the air-resistance activity, being able to move on to the "fun" problem was a reward for those who got through the "difficult" sections. For the computer activity, an "A" was a reward for those who got through the difficult problems successfully. Mr. Stewart's message, continually reinforced with statements like those just expressed, made it clear that not everyone would be able to solve every problem.

While it may be understandable to give students opportunities to solve problems of varying levels of difficulty, the message that not everyone would be able to do and understand the difficult problems reinforced prototypical meanings of scientist. Mr. Stewart's goal was not to alienate students, but to "give kids an opportunity for success, and then continue to challenge them in new areas of things they don't understand" (Interview, 3/1/99). Mr. Stewart made it clear to students that this class was not like a "typical" science class in that memorization was not going to help them succeed:

Mr. Stewart told the students that he doesn't really want them to memorize for tests. He says he "stays awake at night trying to figure out test questions that will trick anybody who tries to memorize things."

The students, he said, respond to this with complaints, such as, "Why do you do that?!" "Why do you want to trick us?" (Fieldnotes, 2/25/99)

This was another way that the difficulty of the class was established. Strategies students used in the past to succeed (i.e., memorization) would not work in this setting. As Brenda said, "I've been memorizing stuff [in other classes]. And, in this class, you can't memorize really. "Cause you have to apply it all" (Focus Group #2, 3/3/99). By creating new rules for success, Mr. Stewart created a more challenging environment. And, defining his course as different from (and more challenging than) typical science courses was a source of pride for Mr. Stewart. His enthusiasm about "difficult" problems and conceptual questions was evident in how he talked with me about these problems before or after class, how he talked with students about these problems in debrief lectures and discussions, and how he pointed out differences in the kinds of activities he had his students do in comparison with those in Regular Physics.

Mr. Stewart saw his course as different from "other" science courses (and other physics courses). Also, I believe part of that difference was operationalized for him in his emphasis on concepts and relationships rather than facts that could be easily memorized by students. The students, in turn, internalized this message as part of what made the course more difficult.

As the leading science education reform documents indicate, an emphasis on concepts and relationships versus facts should be a prominent characteristic of a reform-based classroom (e.g., American Association for the Advancement of Science, 1993; National Research Council, 1996). In such a classroom, students have opportunities to learn the subject matter in more robust ways and apply it to new situations. Thus, Mr. Stewart's emphasis on concepts and relationships versus facts of science was actually a way to challenge prototypical meanings of science. He made some adjustments to the written curriculum that made the curriculum more "difficult" and "rigorous," yet in meaningful ways. For example, the text might ask students to collect data and sketch a graph. Mr. Stewart would add to that by asking students to interpret the graph and draw a free body diagram, which infused more meaning making (and also, difficulty) into the lab activities. However, his celebration of the ''difficult'' aspects of the content and expectation that only a select few would be able to understand the most ''difficult'' concepts and relationships brought prototypical meanings of science and scientist back to the fore.

Interestingly, it was not always clear that the ''difficulty'' of the class was entirely due to new kinds of problems that required more sophisticated physics knowledge. The difficulty of physics was not always based on students' ability to do and understand physics, but was established by giving students a limited (and overly short) period of time to solve problems. This time factor was prevalent in many of the laboratory activities and tests. Students often felt like they did not have enough time to finish laboratory activities and tests, even if they stayed on task the entire period. For example:

> *Mr. Stewart announces to the class that they'll have to work efficiently and that none of the lab groups have finished the test all day.* (Fieldnotes, 1/28/99)
>
> *Tanya tells me, ''That test yesterday was so uncool. First of all, it was like four pages long. That was ridiculous. He knew we would never finish. I hate it when teachers do that.''* (Fieldnotes, 1/29/99)

Because students' grades were partly determined by how much work they were able to do (or how many problems they were able to solve) in a given period of time, those who took more time on given tasks were left feeling as though they were not ''good'' or ''bright'' students. This notion of ''difficulty'' was fairly arbitrary and had little to do with students' physics knowledge. In addition, it may have sent the wrong message about what it means to be able to do science. It reinforced meanings of the super-intelligent scientist that were inaccessible for many students in the class.

There were practices that established an explicit hierarchy among those who could do and understand physics and those who struggled. Amy described the class as follows: ''The class was very much an illustration of who just plain 'got it,' who had to work to 'get it' and those who flat out 'missed the boat' '' (e-mail correspondence). Methods of grading and grouping students and assumptions about being able to do science in terms of ''natural'' ability reinforced and made more explicit the classroom hierarchy.

There was a perception among many of the girls that the ''smarter'' people in the class (the top of the hierarchy) were the boys:

> Author: What are characteristics of people that do well in this class?
>
> Samantha: Guys! (She laughs) Like my brother and Lance. My brother is just like an average guy. And, like, he's strong in English and math and has points that he's high at, but physics, he just got. I don't know why.
>
> Carly: Yeah, the guys in our class just treat this stuff like common sense. (Focus Group #1, 3/3/99)
>
> A lot of guys in our class are really smart. They're not just like, mediocre kids. I can't really think of any guys that are struggling. (Christy, Interview, 5/5/99)

Despite what these girls thought, there *were* boys in the class who struggled. Mr. Stewart also tended to place the boys at the top of the hierarchy despite the fact that there were girls in the class who consistently outperformed (via grades) the boys he placed at the top of the hierarchy. His rationale for this classification system was based on a system that differentiated between the students who worked hard and the students who were naturally ‘‘smart.’’ The naturally smart students were the ones that Mr. Stewart saw as being ‘‘scientist’’ types. Mr. Stewart identified the ‘‘scientist’’ types in this class, and they were all boys:

> Probably very few will go into careers in science. I could see, uh, Adam Lee doing something in science. I could see Steve Cousins. Jacob Richardson. Engineer. Steve could be an engineer. Henry. Definitely. He’s very insightful into how things work, so he’s got some great insight into stuff. Now, those four, they have talent. They have a raw ability in that area. (Interview, 3/1/99)

Girls who did well, some of whom had better grades than the boys just mentioned, were not seen as having this same ‘‘raw ability.’’ Mr. Stewart interpreted their success in the class differently:

> Tanya, Christy, and Meg are all great students, but I don’t see them, you know, I see them as good students in wanting to do good. And they can follow along. Christy’s probably, out of the three, she doesn’t score as well, but the kind of questions that she asks tend to be curious and that sort of thing. I think she has more of a raw interest than the other two. The other two are real aggressive students in wanting to do well. And be successful. (Interview, 3/1/99)

So, while the boys had ‘‘talent’’ and ‘‘raw ability,’’ Christy was described as having ‘‘raw interest.’’ Tanya, Christy, and Meg were more vocal in class than any of the aforementioned boys, and they were willing to voice objections to some of the practices in the classroom they thought were unfair (especially practices they perceived as threatening to their grades). This resistance might have been what Mr. Stewart meant by the ‘‘aggressive’’ description of the girls. Yet, Tanya, Christy, and Meg also performed well on tests, laboratory activities, and answered and asked many of the science-related questions in whole group discussion. There were quite a few instances where these girls would help the boys’ groups in small group tasks, finish a ‘‘difficult’’ task before the rest of the class, and score at the top of the class on a test or laboratory activity. Despite this, they did not see themselves, nor did the teacher see them, as being the ‘‘smart,’’ ‘‘scientist’’ types:

> Science is not a strength for me. I have trouble getting into it enough to want upper level thinking. (Tanya’s Survey Response, 5/18/99)

> Yeah, he totally thinks we’re stupid. I think he thinks, ‘‘You girls in the back. What’s your problem?’’ (Christy, Interview, 5/5/99)

> I wouldn’t say I rely on the teacher, like I wouldn’t figure things out on my own, but I’m not a whiz like Joseph where I can figure everything out. (Meg, Interview, 5/5/99)

Thus, in this class, the meaning of ‘‘scientist’’ as a super-smart male did nothing to challenge prototypical meanings of scientist. It was hard for the girls to see their identity as a ‘‘part’’ of this scientist group, despite the fact that some of them were the top performers in the class. This notion of ‘‘raw talent’’ strengthened the hierarchy in this class. Those who ‘‘had’’ it did not have to work as hard as those who did not have it. Some of the girls (Melissa, Lucy, Samantha) who ‘‘could have done well in physics’’ (according to Mr. Stewart) were puzzled as to why they were not doing well. They were good students in other classes but did not do well in physics. For example, Melissa and Samantha considered themselves smart ‘‘math’’ people, which made their performance in physics puzzling to them:

> Melissa: Don't you think that, normally, if you're good in math, you should be good in science?
>
> Author: Yeah, that makes sense.
>
> Melissa: Well, I'm making a 92 in pre-calculus and I'm failing in here. It doesn't make sense. (Fieldnotes, 2/25/99)

> I have a 97 average in Algebra II, so that's not why I'm not doing well in this class. I have about a 67 average in here! I work so hard in here, but my grades don't show it. I just don't get physics. (Samantha, Fieldnotes, 12/3/98)

Other girls in her position had similar feelings. They were puzzled as to why they were not doing well in the class and were not sure what needed to happen for them to do better. In response to a survey question that asked, ''What kinds of things do you have to do to be successful in Active Physics?'' Carly wrote, ''If I knew, then I would have better grades. I feel very in the dark.'' This uncertainty about what one needed to do to succeed in physics fostered the idea that those who do well have natural ability.

The difficulty and hierarchical nature of the class invoked alienating meanings of science and an inaccessible and uninteresting meaning of scientist for the girls. In general, the girls did not *actively* resist these alienating meanings. In other words, the girls' resistance did not contest prototypical classroom roles nor did it alter the social organization and everyday practice of the classroom in any significant way. The girls who were successful in the class resisted these meanings by disengaging during activities in which the ''difficult'' and ''hierarchical'' meanings of science were the most pronounced (e.g., during lectures). The girls who struggled in the class were frustrated by (but nonetheless accepted) the alienating meanings. They were not particularly upset about not being seen as having ''raw talent'' in science, but they were frustrated by the fact that certain aspects of the class seemed to be geared toward the ''smart'' students. All girls in the class, interestingly, overwhelmingly accepted these alienating meanings as ''the way science is.'' This acceptance reinforced their disconnect from legitimate scientist identities—they were not produced as, nor did they see themselves as, ''science people'' based on the science identities promoted in the class.

Conclusion

This study was prompted by the question: Would a different kind of school science, one that promoted alternative (and broadened) meanings of what it meant to ''do science'' and ''be a science person,'' make for a more inclusive and interesting science for girls? The answer in this setting, it turns out, is not straightforward. First, despite the teachers' commitment to creating a different kind of school science experience, it is not clear that prototypical meanings of science were entirely challenged. Aspects of the classroom culture promoted broader meanings, but other aspects reinforced prototypical meanings. Second, girls' responses to Active Physics were mixed. The girls who were successful learned to negotiate the rules of this new school science game; some embraced this challenge, while others merely tolerated it. These girls learned how to access a good student identity, and sometimes created alternative meanings to alienating practices in order to do so. For example, for the girls who were successful, Mr. Stewart's lectures about ''sophisticated concepts'' were seen as diversions or ''tangents'':

> The funniest thing—a couple of days ago, he was explaining [something] and we got lost. Everybody raised their hands to say that they were lost. It was probably something that we did not need to know anyway. It was so funny! . . . We've learned that he goes off on these tangents. (Meg, Interview, 5/5/99)

On the other hand, the girls who struggled (or perceived themselves as struggling) generally did not create alternative meanings of practices that promoted alienating meanings.[7] They were frustrated by various classroom practices, but did not create new meanings that might undermine or dilute the promoted science learner identities and meanings of science. For example, for them, the ''difficult'' nature of science and the implied genius science identity were just ''the way things were.'' These taken-for-granted meanings left them feeling frustrated and placed the good student identity out of reach:

> [Mr. Stewart is] always talking about how the ideas are so sophisticated. He says that and they go right over my head. (Missy, Interview, 5/5/99)

> This is the first class I've been the dumb kid in. Usually like I'm the smart one that everyone wants in their group. Then I came here and I'm the dumb kid in the class and no one wants to be in my group. (Lucy, Interview, 5/5/99)

In trying to make sense of their responses to Active Physics, I found strong evidence to support the assertion that these girls were most concerned about maintaining their good student identities. Girls (both successful and unsuccessful) resisted promoted science learner identities and meanings of science that they perceived as threatening to their good-student identities. Every girl in this classroom reported to me that she was taking this class because ''it was the next one in the sequence for college-bound students'' or because ''it looks good on my transcript.'' These girls, within a culture of achievement in which it was a near certainty that they would attend college (Carlone, 2003b), accepted what Paul Willis (1977) called the dominant educational paradigm; they believed in teaching as a fair exchange, and they believed in the ways school defined success (i.e., via grades and college admission). In this sense, the Active Physics class was not *supposed to be* anything other than what it was—a way for them to get the credentials to put on their transcript so that they could gain access to an institute of higher education. Not only did this meaning of the value of science ensure their access to higher education, it also ensured their disconnection and alienation from real-world, meaningful science. As long as enrollment in science is seen as a way to get a ''credit'' rather than as way to be empowered, then science education cannot easily be transformed. The story about girls' eager embrace of the dominant educational paradigm highlights a complexity about gender-fair science that needs serious consideration. We attempt to transform school science by coming up with ''empowering'' alternatives to the prototypical school science curriculum. Yet, where is one left when the girls reject empowering science in favor of prototypical science that makes their role as good students and their quest for their end of the exchange (i.e., good grades and college admission) easier?

This question not only crystallizes problems with the calls for transformative school science, but also further complicates the notion of ''science for all.'' I am drawn back to my experience (as a high school science teacher) working with diverse students, some of whom bought into the dominant educational paradigm and some of whom actively rejected it. Those who rejected it may have possibly been open to a different kind of science, but those who accepted it might have had a hard time embracing a different kind of science. Science educators have recently spent time talking about what a different kind of science might look like for those who are disenfranchised with school and school science (and we need to spend a lot more time with this question), but we must also understand the power of the exchange paradigm in producing educational subjects.

My interpretation of girls' participation and resistance in Active Physics is supported by my study of girls' participation in a traditional physics class in the same school (see Carlone, 2003a), which foregrounded girls' acceptance and embrace of prototypical school science. Upon reflection, my question—''Would a different kind of school science promote a more inclusive science for girls?''—may have been premature. It underestimates the tenacity of the socio-historical legacy of school science. The results of this study raise questions for our quest for gender-fair science and ''science for all.'' The practices that we (science educators) ''know'' to be effective ways to teach science (e.g., students as active, problem solvers; science as messy and uncertain) are the same practices that may promote resistance with students. While I am not advocating an embrace of prototypical school science, I merely point out how comfortable a traditional approach is—and how risky and uncertain a new kind of science education might be.

As a science education community, we need to spend more time with these tough issues regarding reform-based science. This study forwards a core line of research pursued recently by feminist scholars—What are the implications of the social construction of school science for girls? (see Barton & Osborne, 1998). In studying girls' participation in a *reform-based setting*, this study follows recommendations made by Anderson & Helms (2001), who called for more nuanced understandings of the complexities of reform in science education and students' roles within reform-based classrooms in ordinary school contexts. However, the study raises additional questions and prompts further research. Is the strength and comfort of traditional school science a resource for resistance of reform-based science for *all* populations (e.g., for girls who have not traditionally been successful in science)? What are the ways that students who have been marginalized by prototypical practices of schooling participate within and resist meanings in reform-based science classrooms? How might we engage girls in relevant science practices so that they begin to develop identities as legitimate participants of the local and even global science learning community? What do these ''relevant science practices'' look like in an ordinary school setting? How do we transform the meanings of science and scientist in school science to mesh girls' agendas, interests, and motivations with relevant science practices that might lead to legitimate science identities? These questions are not completely new to science educators nor especially to feminist scholars, but, as this study suggests, demand continued attention. I expect that our answers to these questions will provide a different kind of science for students who are marginalized from science and open up new possibilities for what it means to ''do'' science and ''be'' a science person.

The opinions expressed in this article are solely those of the author and are not those of the American Association of University Women Educational Foundation. The author thanks Ronald Anderson and Margaret Eisenhart, who provided feedback on earlier drafts of this paper.

Notes

[1]All names used in this article are pseudonyms to protect the anonymity of the participants.

[2]Some students did, however, request to be in Active or Regular Physics and were sometimes granted their requests.

[3]I did not progress through these stages in a linear fashion. Each stage of analysis informed and previous and subsequent stage; I simply separate out the description for ease of discussion.

[4]While it is true that the move from local meanings of science and scientist to broader, sociohistorical meanings of science and scientist may be more inferential than empirically grounded, these inferences are well supported by science educators' work in the past decade (e.g., Barton & Yang, 2000; Brickhouse, 2001; Duschl, 1988; Eisenhart & Finkel, 1998; Fensham, 1997; Gough, 1992; Lemke, 1990). These scholars argue that social practices of school science (e.g., lab activities, discourse, social organization) play a role in reproducing alienating meanings of science.

[5]For example, many girls mentioned to me that they ''hated'' the class during the first 6 weeks because it was so different from previous science classes. Once they learned what their new student roles entailed, many girls came to embrace the active nature of the class.

[6]The fourth girl, Sabrena, who was unhappy, transferred to a different school in the middle of the second semester.

[7]Amy was one exception to this statement. She defined the class as a class for "nonitellects." By designating the class as such, she was, in a sense, contesting the promoted science identity and meanings of science.

References

American Association for the Advancement of Science (1993). Benchmarks for science literacy. Washington, DC: Author.

American Association of University Women (1992). How schools shortchange girls: A study of major findings on girls and education. Washington, DC: Author.

American Association of University Women (1998). Gender gaps: Where schools still fail our children. Washington, DC: Author.

Anderson, R.D. & Helms, J.V. (2001). The ideal of standards and the reality of schools: Needed research. Journal of Research in Science Teaching, 38, 3–16.

Barton, A.C. & Osborne, M.D. (1998). (Eds.). Theme issue: Pedagogies in science education. Journal of Research in Science Teaching, 35, 337–471.

Barton, A.C. & Yang, K. (2000). The culture of power and science education: Learning from Miguel. Journal of Research in Science Teaching, 37, 871–889.

Benbow, C. & Stanley, J. (1980). Sex differences in mathematical ability: Fact or artifact? Science, 210, 1262–1264.

Brickhouse, N. (1998). Feminism(s) and science education. In K. Tobin & B. Fraser (Eds.), International handbook of research in science education. Dordrecht, The Netherlands: Kluwer.

Brickhouse, N.W. (2001). Embodying science: A feminist perspective on learning. Journal of Research in Science Teaching, 38, 282–295.

Brickhouse, N.W., Lowery, P., & Schultz, K. (2000). What kind of girl does science? The construction of school science identities. Journal of Research in Science Teaching, 37, 441–458.

Buxton, C.A. (2001). Modeling science teaching on science practice? Painting a more accurate picture through an ethnographic lab study. Journal of Research in Science Teaching, 38, 387–407.

Bybee, R.W. (1997). Achieving scientific literacy: From purposes to practices. Portsmouth, NH: Heinemann.

Carlone, H.B. (1999, April). Identifying and expanding the meaning of "scientist" in school science: Implications for the participation of girls. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Carlone, H.B. (2000). The cultural production of "science" and "scientist" in high school physics: Girls' access, participation, and resistance. Unpublished doctoral dissertation, University of Colorado, Boulder, CO.

Carlone, H.B. (2003a). (Re)Producing good science students: Girls' participation in high school physics. Journal of Women and Minorities in Science and Engineering, 9, 17–34.

Carlone, H.B. (2003b). Innovative science within and against a culture of "achievement." Science Education, 87, 307–328.

Cunningham, C.M. (1997). Who knows: The influence of teachers' sociological understanding of science (SUS) on knowledge, authority, and control in the classroom. Journal of Classroom Interaction, 32, 24–34.

Cunningham, C.M. & Helms, J.V. (1998). Sociology of science as a means to a more authentic, inclusive science education. Journal of Research in Science Teaching, 35, 483–500.

DeBoer, G.E. (1991). A history of ideas in science education: Implications for practice. New York: Teachers College Press.

Duschl, R. (1988). Abandoning the scientistic legacy of science education. Science Education, 72, 51–62.

Eisenhart, M. & Finkel, E. (1998). Women's science: Learning and succeeding from the margins. Chicago, IL: University of Chicago Press.

Eisenkraft, A. (1998). Active physics. Armonk, NY: It's About Time, Inc.

Fensham, P. (1997). School science and its problems with scientific literacy. In R. Levinson & J. Thomas (Eds.), Science today: Problem or crisis? (pp. 119–136). New York: Routledge.

Gallagher, J.J. & Tobin, K. (1987). Teacher management and student engagement in high school science. Science Education, 71, 535–555.

Gilligan, C. (1982). In a different voice: Psychological theory and women's development. Cambridge, MA: Harvard University Press.

Gough, N. (1992, March). Laboratories in schools: Material places, mythic spaces. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Holland, D. & Eisenhart, M. (1990). Educated in romance: Women, achievement, and college culture. Chicago: University of Chicago Press.

Irvine, J.J. (1986). Teacher–student interactions: Effects of student race, sex, and grade level. Journal of Educational Psychology, 78, 14–21.

Kahle, J.B. (1996). Opportunities and obstacles: Science education in the schools. In C.-S. Davis, A.B. Ginorio, C.S. Hollenshead, B.B. Lazarus, P.M. Rayman, & associates (Eds.), The equity equation: Fostering the advancement of women in the sciences, mathematics, and engineering (pp. 57–95). San Francisco, CA: Jossey-Bass.

Kyle, W.C. (1998). Theme issue: Viewing science in a different light: Making meaning of the science education goal 'science for all.' Journal of Research in Science Teaching, 35, 835–961.

Lave, J. & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

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

Levinson, B.A., Foley, D.F., & Holland, D.C. (Eds.) (1996). The cultural production of the educated person: Critical ethnographies of schooling and local practice. Albany, NY: State University of New York Press.

Moje, E.B. (1997). Exploring discourse, subjectivity, and knowledge in chemistry class. Journal of Classroom Interaction, 32, 35–44.

National Research Council (1996). National science education standards. Washington, DC: National Academy Press.

National Research Council. (2000). Inquiry and the national science education standards. Washington, DC: National Academy Press.

National Science Foundation (2002). National science and engineering indicators. Retrieved July 19, 2003 from http://www.nsf.gov/sbe/srs/seind02/c1/c1s2.htm#c1s2l1.

Roseberry, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. Journal of the Learning Sciences, 1, 61–94.

Rosenthal, J.W. (1996). Teaching science to language minority students: Theory and practice. London: Multilingual Matters.

Sadker, M. & Sadker, D. (1994). Failing at fairness: How America's schools cheat girls. New York: Macmillan.

Spradley, J.P. (1980). Participant observation. Fort Worth, TX: Harcourt Brace Jovanovich.

Tobin, K. & Gallagher, J.J. (1987). What happens in high school science classrooms? Journal of Curriculum Studies , 19, 549–560.

Willis, P. (1977). Learning to labor: How working class kids get working class jobs. New York: Columbia University Press.