Innovative Science Within and Against a Culture of ‘‘Achievement’’

By: Heidi B. Carlone

This is the accepted version of the following article:

Carlone, H. B. (2003). Innovative science within and against a culture of “achievement”. *Science Education, 87(3),* 307–328. doi: 10.1002/sce.10071,

which has been published in final form at http://dx.doi.org/10.1002/sce.10071.

Abstract:

As science educators struggle to reform science education, we need a better understanding of the conundrums associated with the ways educators enact innovative science within and against the “academic,” “rigorous,” and “elite” sociohistorical constructions of science. I ethnographically investigated the meanings of an innovative, reform-based curriculum (Active Physics) in various micro (classroom) and macro (school and community) contexts. I conducted the study in a high school serving primarily upper middle class students, the majority of whom (97%) planned to attend college. I explored how meanings of the curriculum transformed as the curriculum traveled across space and time. While certain aspects of the context enabled innovative science (e.g., support from the administration, pressure to serve a wider range of students), other aspects of the context constrained the potential of the curriculum (e.g., the need to establish for students, parents, and administrators the legitimacy of Active Physics as “real” and “rigorous” physics). Using practice theory to understand the influence of context and agency in shaping school science practice, this study demonstrates the potential for viewing meanings of science in local settings as partially fluid entities, sometimes reproducing and sometimes contesting sociohistorical legacies.

Keywords: Education | Curriculum | Physics | Science Education

Article:

INTRODUCTION

Since the publication of leading reform documents in the United States in the early to mid 1990s (AAAS, 1989, 1993; NRC, 1996), science educators have worked toward common visions of reform at all levels of the system (i.e., the classroom, district, state, and national levels). These visions are designed, in part, to realize a more equitable science education or a “science for all.” Recently, there have been some critiques of the reform documents (e.g., Eisenhart, Finkel,&Marion, 1996; Rodriguez, 1997). Yet, there has been surprisingly little written about what actually happens in reform-based classrooms (Anderson & Helms, 2001) and the conundrums associated with the realities of enacting a "science for all" within and against the "academic," "rigorous," and "elite" sociohistorical constructions of science. These conundrums become especially pronounced when talking about the implications for a more inclusive *physics*—a discipline whose boundaries are among the most tightly guarded of all the sciences.

In this paper, I investigate the meanings of an innovative, reform-based physics curriculum (Active Physics) in various micro- and macrocontexts. I argue that the eventual meanings of Active Physics *within* the classroom were shaped by various meanings of Active Physics *outside* of the classroom. In this paper, I treat Active Physics as the unit of analysis, examining the ways its meanings got transformed, enabled, and constrained as the curriculum traveled across space and time.

CONCEPTUAL FRAMEWORK

The practice of science carries with it a powerful sociohistorical legacy. The media, science educators, and scientists themselves maintain and reproduce science as an objective, privileged way of knowing pursued by an intellectual elite (Duschl, 1988; Fensham, 1997; Lemke, 1990). Many studies of science classrooms have revealed the ways in which the activities, discourse, and social organization of the classroom reproduce these elitist constructions of science (e.g., Lemke, 1990; Moje, 1997; Rosebery, Warren, & Conant, 1992; Rosenthal, 1996). Throughout this paper, I use the term "prototypical science" to represent these taken-for-granted notions and sociohistorical legacies of science and science education that comprise the alienating nature of school science. As previous research has shown (e.g., Eisenhart & Finkel, 1998; Keller, 1985; Nespor, 1994; Traweek, 1988), the ways of "doing" science and types of allowable identities are defined very narrowly in traditional contexts of science learning (i.e., school science). There is a lot of baggage associated with what makes a "good" science education, including socially constructed notions about what science is, who does science, what belongs in the science curriculum, and how best to "deliver" the content. Thus, I define "prototypical science" as the combined, taken-for-granted practices of and beliefs about science and science education.[1]

Time and time again, we have seen how settings of school science sustain and make "natural" prototypical science. These practices of science undermine the goal of "science for all." Less often, however, we have heard about how settings of school science struggle within *and against* this powerful sociohistorical legacy of science. This study 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 prototypical science. 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 practical lives, make meaning in such a way as to reflect and/or counter larger social structures (see also 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 reproduce and contest sociohistorical legacies of science and science education. Two primary concepts from practice theory—cultural production and networks of power—inform this study.

Cultural Production

Eisenhart and Finkel (1998) define cultural productions as "meanings developed by groups in their everyday activities" (p. 44). The notion of cultural production developed as a response to the deterministic theory of social reproduction. While social reproductionists saw students' school performance and life opportunities as largely determined by societal structures, a move toward ethnographic studies forced scholars to focus on meanings produced by people participating in their everyday activities (rather than assuming that these meanings were determined a priori by one's position in society). Willis (1977) was particularly influential in prompting thought about the complex ways in which structure and agency interact.

In Willis' ethnographic account of working class "lads" in school, he asked why working class kids get working class jobs (Willis, 1977). His study highlighted the many ways in which the lads did not agree to and resisted school's sorting of them, and how they produced their own "cultural forms" that countered much of the school's ideology. The lads, who did not do well in school, looked elsewhere to find status and prestige. For example, where school defined success as doing well in school, getting good grades, and behaving, the "lads" defined success as "having a laff," being popular with the girls, and being successful in fighting and "thieving." Ironically, through these alternative ways of acting in school and interpreting success, or "cultural productions," and in resisting what the schools had to offer, the lads inadvertently reproduced their lower status in society.

Though Willis' account did not end happily, there is hope to be found in this story. The school or the family did not solely determine the lads' position in society; the lads themselves, through their social practices and cultural productions, participated in this process (Levinson & Holland, 1996). If one views culture as actively constructed, sometimes in opposition to the status quo, the outcome of education is continually in question (Eisenhart, 2001). In this view, culture is affected, but not determined, by history and structure and, therefore, engages us in the possibility of alternative educational realities.

Applications of Cultural Production to Science Education

A focus on cultural production in science education provides us a different way to think about settings of science learning. First and foremost, it promotes a critical examination of the ways in which the meanings of science vary depending on the social organization of the classroom. It forces us to recognize the ways in which participants produce the meanings of science in local settings within and against larger, more powerful and pervasive (i.e., prototypical) meanings of science and science education. These prototypical meanings of science education serve as structures for participants to contend with in any setting of science learning. Any teacher trying to enact a different (i.e., reformbased) kind of science education encounters these structures in the forms of beliefs of students, colleagues, and administrators about what a "good" science education looks like (among other forms).

A primary question raised by the concept of cultural production is, "How does the meaning of science vary given the context in which the classroom is positioned?" These local meanings of science may be subsequently placed in a larger framework for further examination, that is, one might examine the ways in which larger (macro) structures interact with the local (micro) cultural productions.

Networks of Power

A focus on networks of power draws our attention to the ways in which participation in local practices enroll actors (students and teachers) in larger networks of power. Given such a focus, one can examine how concrete "ways of doing" create microopportunities to learn skills and form identities while simultaneously looking at how those same concrete ways of doing are connected to the macrogrooves of status and power. These "networks of power" have particular implications for physics education and for challenging its sociohistorical legacy.

Positioning Physics within Its Powerful Sociohistorical Context

> When a method of doing things becomes so deeply associated with an institution that we no longer know which came first—the method or the institution—then it is difficult to change the institution or even to imagine alternative methods for achieving its purposes. (Postman, 1992, p. 143)

Such seems to be the case in science education and especially with physics education. The sociohistorical legacy of physics joined with a powerful legacy of science education makes the call for alternative meanings of physics education appear almost ludicrous. Understanding this powerful legacy makes the small contestations that happen in pockets of reform around the country seem all the more amazing. Yet, understanding the limits of these contestations is also important if we are to envision a truly alternative physics education.

Cross and Ormiston-Smith (1996) explain the powerful structures that entrench prototypical physics education and the physics teachers' position within those structures. First, the science teacher has an allegiance to the scientific community, for it "is through the process of accreditation by the 'gatekeepers' of science that the teacher gains accreditation into the institute of science" (p. 652). Thus, it makes sense that physics teachers, at the top of the school science hierarchy, will work hardest to maintain their power and status; they have the most to lose by opening up the gates of physics. There are also artificial boundaries between disciplines, which makes the possibility of an interdisciplinary (and I would argue, more interesting and relevant) science extremely difficult. Most of what is done in prototypical physics education reproduces its status and secures the prestige and power of science; it is an education not only *in* science, but also *for* science (Ziman, 1968, p. 66).

Why does physics have so much power? In addition to its reputation as the "hardest" and most "pure" science, it also has a powerful and tightly enrolled actor-network. Gaskell and Hepburn's and Nespor's explanation of actor-network theory is helpful here (Gaskell & Hepburn, 1998; Nespor, 1994). An actor-network both constitutes and is constituted by human and non-human (e.g., tools, artifacts, curricula, inscriptions) actors. The most powerful network is formed via enrollment of actors "whose interests are bound to a particular formation of a problem" (Gaskell & Hepburn, 1998, p. 66), stabilization of the network and the identity of its actors by weakening the links between the actors and other potential networks (e.g., physics and non-physics), and mobilization of the network so that actors across distant times and spaces can communicate and become more tightly enrolled in the network (e.g., a stable, traditional curriculum).

Actor-network theory helps explain justwhyit is that physics is such a powerful discipline; its tightly enrolled actorsmake for an extremely mobile and stable actor-network. This theory also helps explain the limits to contesting narrowmeanings of physics. Its narrowness and its marginalization of alternative activities and identities constitute it as a discipline, while the power of the discipline legitimizes the narrow activities and promoted identities. Once other discourses and broader, more localized activities are infused into the physics classroom, physics loses its status, power, mobility, and ease of reproduction. Thus, a broader physics may drop away from the larger, more powerful actor-network of physics.

RESEARCH QUESTION

I propose that one can use practice theory—in particular, knowledge about cultural production and networks of power—to understand the potential and limits of the Active Physics curriculum in challenging sociohistorical legacies of prototypical physics education. The strength of the practice theory lens is the attention to micro- and macropractices. One cannot examine the local practices of science without also considering how those practices interact with larger, more powerful meanings of science. Thus, my research question is: how do the meanings of Active Physics in various local contexts (*outside* of the classroom) shape the eventual meanings of Active Physics *within* the classroom?

SCHOOL AND CLASSROOM CONTEXT

Sunnyglen High School[2]

Located within a largely upper middle class suburb of a major metropolitan area, Sunnyglen High School served some of the wealthier students in the district. The school's population was mostly White (84%) with 4% Hispanic, 4% Black, and 9% Asian students. Approximately 3,400 juniors and seniors attended Sunnyglen High School, with 97% of the school's 1998 graduates attending college (4-year college 84%; 2-year college 13%). 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., 24.4% of all high-school students took physics in 1994 according to NSF, 1998). 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 (2nd year physics with calculus), (2) AP Physics B (2nd year physics without calculus), (3) Honors Physics I (1st year physics), (4) Regular Physics I (1st year physics), and (5) Physics I- Active Physics (1st year physics). The focus of this study is on Active Physics, which, with "Regular Physics I," was considered to be the lowest level physics.

The Active Physics Classroom

Mr. Stewart, the primary Active Physics teacher at Sunnyglen High School, had a disciplinary background in chemistry (he had a master's degree and an undergraduate degree in chemistry). He taught chemistry for 10 years before switching over to physics. After teaching a traditional physics course for 2 years, he decided to pursue training with the Active Physics curriculum. 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 activity-based, student-centered learning, and includes students' interests and social issues as legitimate aspects of the physics curriculum.

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 two Asian American students). There was one other Active Physics teacher in the school—Ms. Carpenter.[3]

METHODS

The findings reported here are part of a larger ethnographic examination (Carlone, 2000). As Spradley (1980) explains, an ethnographic study aims to capture what the group knows and can communicate explicitly (i.e., explicit cultural knowledge) as well as tacit cultural knowledge that is outside of the group's awareness. I wanted to understand both explicit and tacit cultural knowledge that guided the participants' actions and beliefs.

Spradley's model (Spradley, 1980) for understanding meanings produced by people in their daily activities allowed me to make cultural inferences about the research participants by using three types of information: (1) cultural behavior (what people did), (2) cultural artifacts (e.g., tools and products used), and (3) speech messages (what people said).

Data Collection

I collected data as a participant observer for a total of 6 weeks from December 1998 until May 1999. My participation involved helping the teacher with grading, setting up equipment, handing out equipment to student groups, answering students' questions about the nature of the tasks, and being a chaperone on a field trip to an amusement park. During class activities, I took fieldnotes, which were expanded later the night of the data collection. 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.

Audiotaped interactions of small groups, artifacts from the classroom (e.g., student work, sample handouts), e-mail correspondence (with students and the teacher), and survey data were other sources of data used to triangulate data generated in my fieldnotes. In addition, I conducted informal and formal interviews with Active Physics teachers and students, Regular Physics teachers and students, guidance counselors, and the Assistant Principal of Curriculum and Instruction.

Data Analysis

My primary method of data analysis was Spradley's method of semantic structure analysis (Spradley, 1980). The first stage of analysis involved the search for categories of cultural meaning or "domains."4 Each domain includes a cover term (the name of the domain), included terms (names for the smaller categories within the domain), and a semantic relationship (that describes the relationship between the cover term and the domain). Thus, I searched my data for domains and associated semantic relationships by using my conceptual framework as a loose guide to focus my analysis. To keep track of, organize, collapse, and mobilize the domains and included terms, I used QSR NUD*IST_R qualitative data analysis software.

The second stage of analysis, called taxonomic analysis, involved looking for relationships among the included terms. This stage helped define how the cultural domains were organized. Because I was working with a lot of dialogue, this step often involved categorizing the talk of each included term before I looked for relationships among the included terms. So, for example, in Active Physics, I had a domain labeled "kinds of teacher questions." The included "terms" were actual questions, e.g., "How many waves do you see here?" "Why do you believe that?" "What color is this chair?" and "If short wavelengths bend a lot, which color's gonna come out at the same angle it came in at?" I then categorized these questions as observational, request for more information, obvious or hint-laden, and if/then, respectively. Then, I was able to look for relationships among the categories and included terms.

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., hopes of the administration for the curriculum vs. hopes of the teachers for the curriculum) and the included terms drawn from each domain list. This helped me make sense of the different meanings of Active Physics within and outside of the classroom.

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 information, 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.

FINDINGS

This section describes the various meanings of Active Physics as it traveled through space and time. I begin by describing the micro (classroom) meanings of Active Physics. What were the everyday activities of Active Physics and what did that imply about what it meant to “do” science and “be a scientist” for the students in Active Physics? How did these meanings reproduce and/or contest prototypical meanings of science education? After addressing these questions, I then provide an explanation of how the meanings of Active Physics produced in various outside of the classroom shaped its meaning within the classroom.

The Classroom Meanings of Active Physics at Sunnyglen High School

The written curriculum of Active Physics lends itself to doing the work of school science in ways that counter prototypical school science work—in ways that broaden prototypical meanings of science and scientist. Some of the promise of the curriculum translated into new kinds of activities, new ways of participating in physics, and new ways of being a physics student in the classroom at Sunnyglen High School. I label these challenges to prototypical school science “spaces of possibility,” spaces that not only challenged, but broadened meanings of science and scientist. Yet, the potential of these spaces of possibility in truly challenging prototypical meanings of science was pushed to the margins by traditional practices of science that ultimately buttressed and reinforced prototypical meanings. In this section, I briefly describe the contestations and reproductions of prototypical science.

One of the most significant contestations of prototypical science was the active meaning of science. Students were produced as active participants in the creation of knowledge. They worked on activities in small groups (of three or four) approximately three or four days per week. Mr. Stewart defined this as a major goal of his classroom:

> It’s kind of the goal I’m getting across here is more just doing science, rather than being told that this was the law that was discovered and this is the person that discovered it and, uh, that sort of thing. So, it’s actually doing it themselves. (Mr. Stewart, Interview, 3/1/99)

Students also noted the active nature of this class as a change from their traditional science classes. The active nature of the class demanded that those enrolled in the class be different kinds of students. One could not be passive and do well in this class. Being “active” did not mean simply “playing around” with tools. It meant struggling through problems that were ambiguous, difficult, and required persistence to solve. While prototypical school science laboratories often place low-cognitive demands on students (Roth, McGinn, & Bowen, 1996), the laboratory activities in this setting encouraged students to think through possible solutions, troubleshoot, and work to make meaning of data. Amy and Max's descriptions of the "active" nature of this class highlight the different meanings of being a science student that emerged in this class:

> 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, Lunch interview, 3/3/99)

> You just 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. So, to really learn [and do well] you have to kind of *want* to understand. (Max, Interview, 5/6/99)

In Active Physics, students learned about physics that was connected to their lives. Subjects that might be considered "extrascientific" (i.e., beyond the scope of science study) in prototypical settings were topics of serious study. For example, students engaged in lessons and problems that involved social issues (e.g., design an energy plan for a house in a developing country with few energy resources), students' interests (e.g., collect data on various amusement park rides and analyze the forces experienced on the ride), and/or topics that related to real life (e.g., design the best car bumper). Further, some activities in the class promoted "extra-scientific" identities that encouraged students to employ logic and reasoning (i.e., as in prototypical science education) *and* use creativity, intuition, and trial and error to solve problems (i.e., things that are normally considered extra-scientific). For example, in one unit, students had to develop a sport to play on the moon. The assignment demanded that the students be creative in their design of a sport and apply knowledge of acceleration, projectile motion, and gravity to demonstrate the logic of their designs.

These extra-scientific activities and ways of thinking about and doing physics pushed the boundaries of physics further than is the norm in prototypical physics classrooms. As well, these activities posed major challenges to prototypical school science that promotes a narrow disciplinary view of science and often relegates "applications of science" to footnotes and diversions (Carlsen, 1998; Eisenhart & Finkel, 1998).

Further, in Active Physics students experienced science as a social endeavor. As Henry explained,

> Solving problems by talking through your ideas with others (reading off a card from the card sort) . . . [that's] pretty much the idea of Active Physics. You talk with your group

> members, see what they think and you think. That's pretty important when it comes to science. Everyone always had something to add, and you're surprised that you didn't think of that. (Interview, 5/5/99)

The students often worked in groups to collaborate and were able to collaborate with one another to socially construct knowledge about physics. This contrasts with practices in prototypical settings, where students may work in groups (or pairs) to collect data, but are left to make meaning of the data individually.

Further, in prototypical settings, labs and/or group work are not prominent features of regular classroom practice. In Active Physics, group problem-solving, peer teaching, and negotiation of the meanings of physics were common group practices.

A final aspect of Active Physics that challenged prototypical meanings of science was its connection to tool use. Students learned that doing physics meant working with tools. As suggested by the meanings of science described above, many activities in Active Physics involved working with tools; e.g., getting equipment ready, gathering data with tools, interpreting information that tools provided, building and testing the efficacy of models, troubleshooting with tools, and learning about the strengths and limitations of tool use in producing the "knowledge" of science. This classroom was filled with computers (desktops and laptops), probeware, software, pulleys, inclined planes, weights, carts, graphing calculators, and many other physics "gadgets" used on a regular basis. I consider the inextricable connection between tool use and physics to be a way to broaden the meaning of prototypical science; that is, while prototypical school science emphasizes the disciplinary knowledge of science and uses tools to reinforce this knowledge, the work with tools in Active Physics was so inextricably linked with the learning of physics that the boundary between science and technology became fuzzy.

Students recognized the tool-centric nature of Active Physics as a significant part of their experience. The meaning of prototypical school science expanded to include elements of "real" scientists' work that involved using tools of the discipline. When asked to describe how this class was similar to the work of "real" science on the survey, students mentioned experiments, labs, hands-on learning, tool use, and trial and error methods, all things that imply a meaning of science that involves tools.[5]

The prototypical physics teacher would label the work done with tools a necessary (but separate) aspect of learning physics; the Active Physics teachers considered the work done with tools *as* "physics." The following excerpt from my fieldnotes illustrates this distinction:

> As I was familiarizing myself with an activity that was a review of how to use and analyze data from the CBL's, graphing calculators, and vertical accelerometers, I had a question.

> One of the problems asked students to set up an experiment to measure the force factor when the accelerometer was swinging in a vertical circle. I was having trouble getting good data as I practiced with the equipment.
>
> I asked Mr. Stewart, Ms. Carpenter, and Mr. Baird (who was a Regular Physics teacher accompanying us on the field trip) what I was doing wrong, and Mr. Stewart showed me how to swing the accelerometer so I got better data.
>
> "Oh!" I said something along the lines of, "I was getting so confused about this question because I couldn't get good data."
>
> Mr. Baird, I think in an attempt to make me feel better, said, "Well, it's not the *physics* you didn't understand, it was just getting the equipment to work right."
>
> Ms. Carpenter, the other Active Physics teacher erupted. "That IS physics! Doing physics and collecting data is part of physics."
>
> Mr. Baird hedged, "Well, I don't know about *that*."
>
> When he walked out of the room, Ms. Carpenter turned to me with a look of exasperation.
>
> "See? This is part of the problem. They don't think that this [working with equipment] is real physics." (Fieldnotes, 4/16/99)

Because learning physics in Active Physics was so tightly linked with working with tools, tool use, in this class, became a legitimate aspect of "physics."

Though these challenges had their limits, they did indeed promote new kinds of participation, new kinds of activities, and new ways of using tools. Yet, unfortunately, these spaces of possibility were overshadowed by practices that reproduced narrow meanings of school science. For example, though the tool-centric nature of Active Physics was influential in shaping rich interactions among students and gave students opportunities to use tools in meaningful ways to construct knowledge of physics, the potential of tool use was somewhat diminished because of the promotion of other, more prototypical meanings of science. In Active Physics, a dual meaning of tools was present; tools as ways of accessing information and tools as toys or gadgets. There was a sense in which tools were sometimes emphasized *over* the ideas and information the tools enabled. According to Ms. Carpenter, this aspect of Active Physics seemed to get more pronounced over the five years that Mr. Stewart and Ms. Carpenter enacted the curriculum.

> Over time, the class has become more rigorous, more technological. It's become a more inhuman curriculum . . . It's become more about getting the right data and interpreting the data correctly than applying it to real life situations.

> The [tools used in Active Physics] are big boys' toys. (Ms. Carpenter, phone conversation, 3/17/00)

This perceived inhuman aspect of physics was reinforced by the expectations of the teacher that tools provide unambiguous, objective information that can be interpreted one way. Doing well in the class hinged upon getting "good data" and interpreting that data correctly.

> Labs are frustrating because I feel like I have a 50/50 shot of getting a good grade . . . If we don't get good data, and there's no guarantee we will, then we get points taken off. (Frank, Fieldnotes, 4/12/99).

And, it was expected that all students would have some measure of control over getting good data.

> . . . I guess maybe if we had done the experiment like more precisely, paid more attention to what we were doing, the results would have been better and we wouldn't have drawn false conclusions. You know there's always error in experiment, [Mr. Stewart] would say. You can avoid much of that error if you do it right, instead of slopping it down. (Tanya, Interview, 5/6/99).

Generally, the students did not have a good understanding of the ways in which tool-based practices put limits on the authority of science (Collins & Pinch, 1998).

> I do think that in science you have to come up with the completely right answer. But that is true in all aspects of science. You have to be able to collect specific, correct data, and so does the next person. That makes life a little more difficult, but it's something that needs to be expected. I am a person who can see more than one aspect of something, and I completely agree that there is almost always a different way to interpret something. But what I think and what science expects are two different things. If science weren't so rigid, there would be experiments with completely different data that could never be duplicated, and therefore inconclusive. So, basically I see why there is the need for the one correct answer. (Brenda, e-mail correspondence)

Partly, not only because of the difficulty of tool use and getting good data, but also because of many other messages conveyed through the activities of the classroom, Active Physics reproduced the sociohistorical legacy of physics as difficult and hierarchical. Historically, physics has been constructed as "hard"—in what it studies, how it studies it, the degree of difficulty attributed to it, and the emotional attachment involved (Schiebinger, 1997).

Students in Active Physics came to understand that aspects of physics were difficult, and not everyone would be able to do and understand every aspect of the class. The sociohistorical legacy of "physics as hard"was not necessarily challenged within thewalls of the classroom.

There were ways that this “difficulty” was operationalized in the spirit of science education reform; e.g., stressing conceptual understanding vs. memorization of facts. However, Mr. Stewart often emphasized the difficulty of problems, got excited about “sophisticated concepts,” and infused “rigor” into activities in seemingly arbitrary ways (e.g., by implementing a scoring system on certain tasks that was based on how quickly students were able to solve a problem). In whole group “discussions,” Mr. Stewart dominated the talk, promoting a meaning of science that implied that physics knowledge “belonged” to the expert (i.e., himself) and that it was his duty to impart it to the students. Despite the fact that students had spent days collecting and making sense of data, he elicited their participation in limited ways; e.g., by asking questions that demanded one or two word answers. This established the difficulty and sophistication of science and students’ naiveté.

The construction of physics as “hard” implied a hierarchy among the students. As Amy described:

This 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 the classroom hierarchy more explicit. For example, Mr. Stewart differentiated between the kids who worked hard and the kids 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 fewwill 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)

This promoted meaning of “scientist” (as males with natural ability) surely reproduced prototypical meanings of scientist.

Summary. In this Active Physics class, physics was constructed in ways that both contested and reproduced prototypical meanings of science. While its active, extra-scientific, social, and tool-centric nature contested prototypical meanings, its promotion of using tools to collect unambiguous information and its construction as difficult and hierarchical reproduced the status quo and may have undermined its potential as a transformative science. The ways in which prototypical meanings of science intertwined with and constrained the potential of broader meanings of science in Active Physics complicate notions of the possibilities of a broader meaning of physics in a prototypical setting (i.e., a public high school).

So, what happened to Active Physics? Some might argue that Mr. Stewart's lack of disciplinary knowledge or pedagogical content knowledge limited his ability to enact a truly reform-based curriculum. While this may or may not be true, this explanation stems from a psychological perspective, while I was more interested in using an anthropological lens (by focusing on cultural meanings of the course).

Despite the purpose of the Active Physics curriculum—to make physics more accessible to a wider range of students—physics in this setting was constructed as difficult and only fully understandable to the "smartest" students. In this sense, the idea of an "inclusive" physics becomes somewhat paradoxical. If physics is "hard," then by its very nature, it is not accessible to everyone and some will be able to do it and understand it better than others. Historically, physics teachers have benefited from this construction of physics (Cross & Ormiston-Smith, 1996). If physics is the most difficult subject matter, then surely, physics teachers must be among the "smartest" teachers in the school. Conversely, if physics teachers try to make physics accessible to everyone, their status is threatened. If everyone can do and understand physics, then its special status is no longer warranted, and it becomes another course for the masses.

This paradox of inclusive physics seemed to be especially problematic for Mr. Stewart, who was using a curriculum aimed at making physics more accessible and was constructed by many as a "pseudo-physics" at the bottom of the physics hierarchy. As will become more clear in the next section, Mr. Stewart had to negotiate the accessibility of the written curriculum, the perception of the legitimacy of the course among counselors, other teachers and students, and his reputation as an "academic" and strong physics teacher.

In the next sections, I examine the possible reasons why this enacted curriculum ultimately reproduced prototypical meanings of science by examining how the meanings of the course were socially constructed in various contexts and the influence of these concepts in shaping the meanings of Active Physics described earlier.

Meanings of Active Physics for Curriculum Developers and Science Education Reformers

Active Physics was designed as an innovative, reform-based curriculum in response to the low physics enrollment in high schools around the country. It was developed by major stakeholders of physics (American Association of Physics Teachers and American Institute of Physics) explicitly to make physics more accessible, relevant, and interesting to a broader range of students. Eisenkraft (1998), in the introduction to the Active Physics texts, writes that Active Physics was developed *in response* to the "usual physics course," which

> 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. Physics should be experienced to make sense to [students.] (Introduction).

Each unit of Active Physics opened with a realistic event that students might have experienced or could imagine happening in “real” life. The unit is framed by a problem that students are expected to solve by the end of the unit. So, for example, in one unit in the “Sports” module, students are expected to develop a sport to play on the moon. All of the activities in the unit are designed to facilitate students’ understanding of the physics concepts that will help them meet the challenge successfully. Rather than learn physics concepts such as “force” and “acceleration” in discrete units, these (and other) concepts are revisited in different units, giving students an idea of how these concepts apply to various contexts. For example, students studied force and acceleration in both the “Sports on the Moon” unit in the fall and the “Roller Coaster” unit later in the spring.[6]

Thus, the meaning of Active Physics for curriculum developers and science education reformers was as an alternative physics course. It was developed in specific reaction to the “usual” (prototypical) physics course with hopes that it would attract more students to physics.

Meanings of Active Physics for Me----the Science Education Researcher

I chose to study an Active Physics classroom because of the potential I saw in the curriculum to challenge and broaden prototypical meanings of science. The activity-based, group-oriented curriculum that placed the study of physics within contexts of students’ interests and the real world certainly seemed to be a different kind of physics. This curriculum did not sound like the physics *I* studied in high school! Although it lacked an overtly political examination of the nature of science, its potential piqued my interest.

Though there seemed to be possibilities and limitations in the Active Physics curriculum, this is true of any curriculum, and I was surprised and impressed by its potential to challenge prototypical meanings of physics and its consistencies with some of the calls for a more inclusive school science. Its hands-on, activity-based nature, its potential to bring students’ voices and ideas to the fore, its emphasis on interesting, relevant, real world themes, and its possibility for exploring microsociological and macrosociological issues of science (Cunningham, 1997) were challenges to prototypical school science.

Meanings of Active Physics for Physics Teachers

Across the Nation

I did a national search for classrooms using the curriculum and found a lot of resistance to the notion of using Active Physics in lieu of a traditional physics curriculum. Many physics teachers I contacted perceived the curriculum as “soft,” “not rigorous enough,” and “not real physics.” I received the following responses (among other similar responses) when I asked physics teachers about the curriculum:

> You can mess with other sciences, but don’t mess with my physics.

> No, I don't use that curriculum. I like to protect the sanctity of physics.

> That's not really physics. It's really physical science for ninth graders.

Despite the fact that this curriculum was developed in association with the American Association of Physics teachers and the American Institute of Physics (i.e., major stakeholders in protecting the legitimacy of physics), many high-school teachers rejected it. Many who had piloted the curriculum used some of the activities or units, but used them to support their traditional physics curriculum. Others used the curriculum at the ninth-grade level in support of a recent "physics first" movement wherein students learn physics, instead of biology, at the ninth-grade level. Still others thought the curriculum was appropriate for the middle-school level. My search was a testament to the well-guarded boundaries of prototypical high-school physics.

Historical Meanings of Active Physics at Sunnyglen High School

The course was born out of Mr. Stewart and Ms. Carpenter's dissatisfaction with the way that Physics I (Regular Physics) was being taught. They felt as though Regular Physics did not really teach students physics. Instead, they believed it taught students "little boxes of information with no real understanding or learning" (Ms. Carpenter, Fieldnotes, 5/6/99).When Ms. Carpenter saw an advertisement for a field testing opportunity with the Active Physics curriculum in her professional journal, she showed it to Mr. Stewart, who was very interested.

Their decision to apply for the field testing program was supported by the administration that had some concerns that the Physics I program did not meet all students' needs. In addition, the administration "wanted to keep up with the latest research that said it is best to connect emotions, physics, math, art, creativity, and visual activities to learn a concept" (Ms. Carpenter, Fieldnotes, 5/6/99). The administration provided Active Physics with one of the largest, most prominent, and best-equipped classrooms in the physics department (with regard to technology, lab space, and lab materials). This classroom, with large windows and a large sign above the windows that read "Active Physics," was the first classroom visible as one walked down the hall toward the physics department and contained over $60,000 worth of equipment. Mr. Stewart and Ms. Carpenter had the only permanent classroom in the department while every other teacher "floated" from classroom to classroom. While this space was prestigious, its prominence in the school promoted a dual meaning—as a "showcase" and as a "fishbowl."

Though the program was supported financially and ideologically by the administration, there was pressure to perform. Active Physics became a kind of bragging right for the administration. As Ms. Carpenter explained, "[Active Physics] brought out the idealism of teaching. The administration wanted to promote this teaching approach" (Phone conversation, 3/17/00). During the first year of its implementation, Mr. Stewart and Ms. Carpenter were asked to demonstrate the "Design a Car Bumper" assessment (along with sample student projects) to the Sunnyglen District School Board. Members of the central office visited their classroom quite often.

Ms. C.: I'd be teaching a lesson and there would be six heads outside my room, with their noses smashed up against the window.

Heidi: Well that presents a certain pressure, doesn't it? You couldn't have students just playing around with equipment. (I'm responding to a comment she made earlier about not feeling pressure from the administration).

Ms. C.: You bet! All those damned observers influenced what we did. No way we could play around. This class had to perform from Day 1. (Phone conversation, 3/17/00)

Not only did the class have to perform, according to Ms. Carpenter, "Active Physics had to be better than Regular Physics to survive and gain legitimacy in the school" (Fieldnotes 5/6/99 & Phone conversation, 3/17/00). "It was not a good idea to put Active and Regular in the same school. It put Active in a bad position, having to prove its worth and always being compared with Regular" (Ms. Carpenter, Fieldnotes, 5/6/99). Yet, the distinctness of Active Physics was both a challenge and an opportunity. This was a chance for Mr. Stewart and Ms. Carpenter to make a difference to improve the Physics I program and to gain some recognition in the process. "[Mr. Stewart's] competitive and so am I," Ms. Carpenter told me (Phone conversation, 3/17/00). As it turns out, their drive was necessary to make it through the first couple of years of teaching Active Physics.

The Active Physics teachers worked tirelessly in the first year. Twelve- to seventeen-hour days were typical, according to Mr. Stewart. They had to be sure to educate those around them about the purpose of the course and its legitimacy. The parents in this upper middle class community had to be convinced that their children were getting a good education. And, the students wanted to make sure that this course would "count" for college admissions.

Active Physics in the Community of ''Achievement''

The administration's expectation that they teach a "new" kind of physics was one kind of pressure for the teachers, but, at the same time, they had to demonstrate that the course was not *too* new—that it was still "real physics." This was especially important for the students and parents within this community.

This school's academic achievement statistics were impressive. The school described itself (and was known to members of the community) as having "a long history of academic excellence and innovative programs" (Sunnyglen High School homepage). Seventy-two percent of the faculty held advanced degrees. Approximately 97% of the school's 1998 graduates attended college (4-year college 84%; 2-year college 13%). The school offered its students a variety of classes, including the choice of 22 different kinds of Advanced Placement (AP) courses for college credit (one of the largest AP programs in the country). In 1998, the mean SAT score was 1129 (550 verbal, 579 math), while the mean composite score for the ACT was 23.7. In addition, in 1998, the school had 34 National Merit finalists.

These statistics demonstrate the need for students and parents to recognize the Active Physics program as strongly academic. Thus, during the first year of implementation, the teachers spent a bit of time educating the local stakeholders (parents, students, counselors, administration) about the curriculum. They held a meeting for students' parents, explaining the rationale behind the curriculum, showing the parents what students were going to learn, how it applied to real life, and how it related to the Advanced Placement curriculum.[7] The parents had to be convinced that this course would prepare their children for the next academic steps.[8] Despite this effort, concerned parents called and students came to the administrators and counselors to complain.

> Ms. W.:[9] The students were worried that they weren't getting real tests, just "assessments." They weren't sure how they were being evaluated if there were just group assessments . . . The students and the parents were worried that [the students] weren't learning real physics.
>
> Heidi: What do you mean by "real physics"?
>
> Ms. W.: They were worried that they weren't being prepared. They were playing with cars, they didn't think they were learning physics theory . . . It helped that two of our best and most academic teachers were teaching it and *chose* to teach it. (Interview, 5/4/99)

After the first year, Mr. Stewart and Mr. Fields (the physics department head) decided to administer a content test called the Force Concept Inventory to all Honors, Active, and Regular Physics students to compare the students' understanding of basic physics concepts. The results showed no significant difference between the achievement of Active Physics students and Regular Physics students. In addition, the results showed that the students' attitudes toward physics were considerably more positive in Active Physics. In that first year, the Active Physics teachers enacted the curriculum in ways consistent with how it was written. By the end of the year, the counselors had quite a few students asking for the course for the next year, despite the fact that it was not being advertised as a separate physics course.[10] The students heard the course was an "easy" and "fun" way to learn physics from students who had taken the course.

Thus, from the beginning, Active Physics struggled a bit to define itself as both an alternative and unique physics course and a course steeped in strong academic tradition. In a sense it had to be a rigorous (for this community of "achievement"), inclusive (for the administration who felt not all students' needs were being met), and fun (for students to buy into the course) alternative to the traditional physics class. Toward the end of the first year, Active Physics' reputation as a "fun" or "easier" alternative to Regular Physics may or may not have bolstered its status in the school, despite the fact that its students performed equally to Regular Students on a traditional academic measure (i.e., the Force Concept Inventory).

Active Physics as ''Blow-up'' Physics

Mr. Stewart and Ms. Carpenter said that others in the school did not necessarily understand what they were trying to do with Active Physics. Some of the counselors were telling students that Active Physics was the "easiest" physics class (i.e., the lowest on the physics hierarchy) despite the fact that it was labeled "Physics I" (as was Regular Physics) on students' transcript. On more than one occasion, Ms. Carpenter said she had to go to the counselors to "straighten out the myth" that Active Physics was less rigorous and hard than Regular Physics.[11] Other Regular Physics teachers also played a part in defining Active Physics as "less than" Regular Physics to their students. For example, Mr. Grant (a Regular Physics teacher) explicitly laid out the physics hierarchy for his students, placing Active Physics at the bottom of the hierarchy.

> Paula: My counselor wanted me to take Honors [physics], and there was *no way* I was going to take Active. I convinced her to let me take Regular. They [the counselors] wouldn't let me take Active. It's like there's Active, then there's Regular, then Honors.
>
> Heidi: Active is seen as the lowest?
>
> Paula: Yes. The lowest. That's what Mr. Grant said. He laid it out on the first day of class. There's Active, Regular, then Honors. Then, there's AP Physics. (Paula, a Regular Physics student, Interview, 5/5/99).

Ms. Carpenter said that when she heard that counselors and Regular Physics teachers were inaccurately defining the hierarchy to students, she "hit the roof." She said that she and Mr. Stewart had been working hard to convince others in the school of the legitimacy of the course (Fieldnotes, 5/6/99). Still, the nickname "blow-up physics" made its way across the student body—a relative death knell in this culture of "achievement."

> I didn't request Active Physics because everyonewas saying it's "blow-up" physics. (Veronica, an AP physics student who took Regular Physics for her first year physics course, Interview, 5/4/99).
>
> I always thought Active Physics was considered easier. I guess I was told by seniors. Taking Active Physicswas taking physics but taking an easier version of it. Not taking it as seriously. . . I would have taken Active Physics if I'd known it was more labs and stuff, but I just thought it was considered a blow-off course. (Brian, a Regular Physics student, Interview, 5/7/99).

Students' choice to avoid a blow-off course is indicative of the pressure to be seen as a serious academic-type in this particular school. It is also noteworthy that this active class was considered to be a "blow-off" course by those not enrolled.[12] I argue that one of the reasons for this is that Active Physics challenged prototypical meanings of active (or hands-on) science classes. Characterizing an active class as "easy" is a notion so entrenched in the sociohistorical legacy of science education that to imagine a challenging, active class seems almost paradoxical. One may have to experience the active class to be convinced of its challenging nature. This certainly seemed to be the case at Sunnyglen High School. Christopher, who had taken Active Physics in the previous year, was enrolled in Advanced Placement Physics and was doing quite well according to his own reports and those of his teacher. Yet his classmates teased him for taking Active Physics:

> Heidi: Do any of your AP classmates say anything about you coming from Active Physics?
>
> Christopher: Yes, I get that a lot. [They say], "Why are you going to AP?" . . . They think because we had more fun with it that we didn't learn as much. That's far from the truth. [They say], "You went to the amusement park. You must not have done anything. How hard could it be?" (Interview, 5/6/99)

Challenging the sociohistorical meanings of an "active" physics classwas difficult. Students came into the class with a certain notion of what an Active Physics class would entail (i.e., that it would be easier) and were surprised when the class turned out to be much harder than they envisioned.

After the first year and over the course of the next few years, Mr. Stewart and Ms. Carpenter infused more elements of traditional physics (and rigor) back into the course. In Mr. Stewart's words, " . . . All of the changes which Ms. Carpenter and I made [to the written Active Physics curriculum] have been in the direction of more demanding" (e-mail correspondence). To ensure individual accountability and evaluate individual students' understandings, they added quizzes, lab practicals, and concept-based tests to the group assessment projects. To make sure students had a grasp of the concepts underlying the labs, they added more lectures. They also added more accountability to "make sure students were able to articulate the ideas that are uncovered in the lab" (Mr. Stewart, Interview, 3/1/99). As Mr. Stewart said,

> The way this particular curriculum is done is to work in groups all the time and then come back and do the assessment that pulls it together. And, I think that does not work at all. And that's what we did the first year, and I don't think they learned anything . . . [the course has] kind of evolved over the course of four years to, well, you can see what it's like . . .We still approach the ideas from a constructivist standpoint, but we don't take it to the intent of the curriculum. (Interview, 3/1/99)

His comment that he did not think the students learned anything the first year is striking, considering the Active students' performance on the Force Concept Inventory (i.e., equivalent to that of the Regular students' performance). Yet, his evaluation may be an indication of Mr. Stewart's competitiveness and the pressure to be "better than" Regular Physics.

The local context described above certainly points to the pressure Active Physics faced to prove itself as a legitimate physics course. And legitimacy, in a large sense, meant proving the course's "difficulty" and "rigor" since that is, after all, what we think of when we think of physics. It is telling that Mr. Stewart adjusted the Active Physics curriculum to be more and more challenging each year. In fact, Ms. Carpenter, who also taught Advanced Placement Physics, felt as though Active Physics "was becoming a college level course" (Phone conversation, 3/17/00). Despite the meaning of science as difficult that emerged from within the Active Physics classroom, students from outside of the course still called it "blow-up physics."

Active Physics as an Island: Cut off from (But Influenced by) Regular Physics

It was striking to see the lack of exchange of ideas between the Active and Regular teachers. Active Physics teachers did not go to the Physics I meetings, where the group of eight teachers met to plan the content they would cover, the labs they would do, and the kinds of tests they would give each unit. I did not once observe any Regular Physics teachers ask Mr. Stewart about any of the lab activities he did.[13] This struck me as odd during each of my visits because I thought many of the labs in Active Physics were so unique and intriguing. When I asked Mr. Stewart if any of the Regular Physics teachers ask about the labs he did, he said, "No" (Fieldnotes, 4/12/99). While the Active and Regular teachers seemed friendly with one another, they did not seem to exchange ideas about teaching physics, despite the fact that many of them shared an office. In many ways, Active Physics was its own little island, seemingly cut off from (but nonetheless influenced by) Regular Physics.

Active Physics, with its six sections to the 31 sections of Regular Physics, was, in some ways, marginalized.[14] And, based on its history and predictions about the future from Active and Regular teachers, it was not going to grow.

> [Active Physics] hasn't been allowed to [grow]. The counselors set up this is how many sections we'll have. Or the principal says we're gonna have seven Active Physics and then the rest will be [Regular Physics]. So, it's not a question, it's not really a question of choice for the students . . .We don't say sign up for Active Physics or Regular Physics because we can't afford to do that . . .We don't have the facilities to house 32 Active Physics sections. So it would be futile to teach Active Physics in the marketing education in the corner of the building. Which is where we are teaching a [Regular Physics] course this year . . . I mean, you have to have a facility where your computers are there all the time and they never move and neither do you. (Mr. Grant, a Regular Physics teacher, Interview, 5/6/99)

While Mr. Grant defined the reasons for the lack of growth of Active Physics in terms of lack of space and resources, when probed, he also noted that none of the Regular Physics teachers would be willing to teach Active Physics.

Heidi: Would there be other teachers interested in teaching Active?

Mr. Grant: No. (definitive answer) . . . No one has expressed an interest in going wholesale to an Active Physics curriculum . . . I think one of the reasons that they would give you is because we don’t have the facilities and it would be a big, big headache. Some of the teachers would probably answer that it would take way too much work. And they’re not willing to do that. And in some ways, I don’t blame them. I mean, I work pretty hard, but I saw what [Mr. Stewart] went through for two or three years building all that equipment. Now [Mr. Stewart] is obsessive when it comes to building equipment, and I’m not saying that’s a bad thing, I’m just saying most teachers are not willing to spend 20 hours a day doing what he did. And he did a great job with it. But, in my opinion, well, I can’t speak for him, but it would be too much of a sacrifice for me. (Mr. Grant, Interview, 5/6/99).

Mr. Grant’s comments illustrate a particular conundrum for the position of Active Physics in the school. If Active Physics was never going to be allowed to grow and none of the other Regular Physics teachers were interested in teaching it, then Active Physics was never going to gain the status (and perhaps the legitimacy) that Mr. Stewart and Ms. Carpenter were hoping for. While the separation from Regular Physics gave Mr. Stewart and Ms. Carpenter a lot of freedom to try different kinds of activities, to establish the uniqueness of their class, and to enact the curriculum in their vision of “good” physics instruction, some of the products of their hard work may have gone unrecognized by their physics teacher peers. This situation, in some ways, may have permanently relegated Active Physics to a fringy alternative to “real” (and rigorous) physics.

INTERPRETATIONS AND CONCLUSIONS

The boundaries of science (and especially physics) are tightly guarded, making change at any level difficult. Yet, understanding that school science has been socially constructed in alienating ways reminds us that it can be socially constructed differently. In this paper, I attempt to understand how the contexts enveloping Active Physics enabled and constrained what it eventually became.

Active Physics made some fairly significant challenges to prototypical science education. Its active, social, and tool-centric nature, coupled with its connection to topics normally considered extra-scientific, promoted new ways of participating in physics and being a physics student. Indeed, in some ways, it was a different kind of physics class. This new kind of physics class did not evolve in a vacuum. One can examine how the meanings held by various stakeholders outside of the classroom enabled the new meanings within the classroom.

The curriculum itself enabled a new kind of physics. The developers’ promotion of the curriculum as a response to the “traditional physics curriculum” enabled Mr. Stewart’s enactment of a new kind of physics. Further, in examining the birth of Active Physics at Sunnyglen High School, the Active Physics teachers and the administration were supportive and enthusiastic about Active Physics because of its uniqueness and their dissatisfaction with the traditional physics curriculum. They perceived a need to create a different kind of physics course. The “pressure to perform” enabled innovative practice, as the Active Physics teachers taught for observers in their “showcase”/”fishbowl” of a classroom. Interestingly, the isolation of

Active Physics from Regular Physics may have also facilitated its innovation—Mr. Stewart and Ms. Carpenter had the freedom to enact their visions of good science education without having to coordinate their curriculum's content and methods with other teachers who may have had different ideologies. And, finally, my presence as a researcher in the classroom may have influenced the "new" meanings produced within the classroom. Mr. Stewart knew I was interested in learning more about students' participation in this "new" kind of physics. As a self-described "perfectionist" and "competitor," he may have felt obligated to allow me to see the "best" activities and the most innovative practice, thus perhaps skewing the meanings of science I captured during my data collection trips.[15]

Yet, there were other contextual meanings of Active Physics that constrained its potential to become a truly transformative physics course. In examining the meanings of Active Physics produced within the physics department, in the administration, and among students in and out of the class, I found compelling reasons why "difficult" and "rigorous" became defining characteristics of Active Physics. Active Physics was put in a precarious position within the school context—it had to prove itself as a new, innovative, and inclusive course as well as a course that was recognizable as "real physics." This latter meaning was especially important in this community of "achievement." With 97% of the school's population attending college, it was especially important that this course was perceived (by parents, administrators, counselors, students, other physics teachers) as a good preparation for future study in science, that it would count as a legitimate science course on college transcripts, and that it would be enacted in the "rigorous" academic tradition that was the cornerstone of this school's reputation. Active Physics struggled with its reputation as "blow-up" physics and, in response, became a more difficult and traditional course over the five years it was enacted at Sunnyglen High School.

Thus, its hierarchical nature and the infusing of "difficulty" into the course in seemingly arbitrary ways could be seen as responses to the pressure Active Physics was under to demonstrate its legitimacy. Interestingly, this demonstration of legitimacy was enough to ensure the survival of Active Physics, but not enough to ensure its growth and Mr. Stewart and Ms. Carpenter's prestige within the department. In essence, the Active Physics teachers were disconnected from the local and broader established actor network of physics.

The difficulty of Active Physics in connecting to the established actor network of physics speaks to the difficulty of "broadening" the meaning of physics in high school classrooms. In opening up the boundaries of what counts as physics, one effectively ceases to be enrolled in the network of physics. Interestingly, in examining Mr. Stewart's and Ms. Carpenter's positions within the school (as isolated from the other physics teachers), it was clear that neither they nor their Active Physics class were enrolled in the established actor-network of physics. While I am not abandoning the potential and possibilities of a broadened meaning of science, this paper demonstrates the complexities that such a vision evokes.

This study shows the influence of context and agency in shaping innovative science practice. Previous studies may have shown the effects of the powerful sociohistorical legacies of science on the local context. This study shows the potential of a less deterministic framework. Rather than viewing the powerful sociohistorical legacy of science as an oppressive structure that limits the potential of reform, we can view the meanings of science in local settings as partially fluid entities, sometimes reproducing and sometimes contesting sociohistorical legacies.

Thanks to Ronald Anderson, Julie Bianchini, and Margaret Eisenhart for comments on earlier drafts of this paper.

Notes

1 I use "prototypical" here to denote the traditional practices of science education and kinds of students produced in such settings that have prevailed for decades. Thus, "prototypical" science education is "an original thing . . . of which . . . copies, imitations, improved forms, representations, etc. are made" (Weiner & Simpson, 1991). Prototypical science education is what any science educator contends with in trying to enact any model of reform-based instruction.

2 All names used in this paper are pseudonyms to protect the anonymity of the participants.

3 I collected data in Mr. Stewart's classroom because he taught more sections of Active Physics and was considered the "lead" teacher of this team. That is, he did most of the planning, curriculum adaptation, and equipment building.

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

5 Incidentally, these things also imply an "active" meaning of science.

6 The roller coaster unit was in the field test version of the curriculum, but not in the final, published version.

7 Ms. Carpenter said that it was important that the Active Physics course prepare students for AP Physics (or college physics) since it was labeled "Physics I" on students' transcripts.

8 Indeed, this pressure on Active Physics cannot be underestimated. For a more extensive discussion of the ways the historical goals of schooling might influence reform efforts, see Labaree (1997). Thanks to an anonymous reviewer for directing me to this reference.

9 Ms. W was the assistant principal in charge of curriculum and instruction. She was a big supporter of the curriculum.

10 Though I asked many people, no one had a good explanation for why the Active Physics course was not advertised. There were concerns about it growing too much because there were

not enough Physics I teachers who were willing to teach it, nor was there enough equipment to teach more than 6 sections. Further, there was a general feeling that Active Physics had to have the same course number as Regular Physics in order to be seen as legitimate.

11 Ms. Carpenter said that she thought she had a large role in maintaining the survival of Active Physics because she was more “political” than Mr. Stewart. She did more of the public relations work with Active Physics in that she spent more time trying to convince others of its legitimacy.

12 None of the Active Physics students characterized Active Physics as a “blow-off” course.

13 The only advice, I saw, sought from Mr. Stewart was technological advice. He was the designated “technology advisor” for the department.

14 The notion of Active Physics as marginalized is an interesting contradiction. In one sense, it was the “star” of the physics department (for the administration), but in another sense, it was marginalized from the more traditional physics classes.

15 See Wolcott (1999) for an explanation of why this “observer effect” is unlikely (because one can only keep up appearances for so long) and/or informative (because a performance gives clues about what participants think comprises “good” practice).

REFERENCES

American Association for the Advancement of Science (AAAS). (1989). Science for all Americans. Washington, DC.

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

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(1), 3–16.

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.

Carlsen, W. S. (1998). Engineering design in the classroom: Is it good science or is it revolting? Research in Science Education, 28(1), 51–63.

Collins, H.,&Pinch, T. (1998). The golem: What you should knowabout science (2nd ed.). New York: Cambridge University Press.

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

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(2), 24–34.

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

Eisenhart, M. (2001). Changing conceptions of culture and ethnographic methodology: Recent thematic shifts and their implications for research on teaching. In V. Richardson (Ed.), The handbook of research on teaching (4th ed.). Washington, DC: American Educational Research Association.

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

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. American Educational Research Journal, 33(2), 261–295.

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: Routleddge.

Gaskell, J., & Hepburn, G. (1998). The course as token: A construction of/by networks. Research in Science Education, 28(1), 65–76.

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

Keller, E. F. (1985). Reflections on gender and science. New Haven, CT: Yale University Press.

Labaree, D. F. (1997). Public goods, private goods: The American struggle over educational goals. American Educational Research Journal, 34(1), 39–81.

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.

Levinson, B. A., & Holland, D. C. (1996). The cultural production of the educated person: An introduction. In B. A. Levinson, D. F. Foley, & D. C. Holland (Eds.), The cultural production of the educated person: Critical ethnographies of schooling and local practice (pp. 1–54). 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(2), 35–44.

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

National Science Foundation (NSF). (1998). Women, minorities, and persons with disabilities in science and engineering. Arlington, VA. Retrieved January 23, 2000 from http://www.nsf.gov/sbe/srs/nsf99338/start.htm

Nespor, J. (1994). Knowledge in motion: Space, time and curriculum in undergraduate physics and management. Washington, DC: Falmer Press.

Postman, N. (1992). Technopoly: The surrender of culture to technology. New York: Alfred A. Knopf.

Rodriguez, A. J. (1997). The dangerous discourse of invisibility: A critique of the National Research Council's science education standards. Journal of Research in Science Teaching, 34(1), 19–37.

Rosebery, A., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. Journal of the Learning Sciences, 2(1), 61–94.

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

Roth,W.-M., McGinn, M. K.,&Bowen, G. M. (1996). Applications of science and technology studies: Effecting change in science education. Science, Technology, & Human Values, 21(4), 454–484.

Schiebinger, L. (1997). Creating sustainable science. OSIRIS, 12, 201–216.

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

Traweek, S. (1988). Beamtimes and lifetimes: The world of high energy physics. Cambridge, MA: Harvard University Press.

Weiner, E. S., & Simpson, J. A. (Eds.). (1991). The compact Oxford English Dictionary. New York: Oxford University Press.

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

Wolcott, H. F. (1999). Ethnography: A way of seeing. Walnut Creek, CA: Altamira Press.

Ziman, J. (1994). The rationale of STS education is in the approach. In J. Solomon & G. Aikenhead (Eds.), STS Education: International perspectives on reform (pp. 11–20). New York: Teachers College Press.