

### **Transforming the Classroom Power Structure to Impact Physics Learning**

Among the problems facing public education today, the racial achievement gap is perhaps the most persistent, perplexing, and resistant to positive change. The statistics paint an overwhelmingly conclusive picture; in the U. S., African American and Latino students consistently underperform relative to Whites and Asians (Lee, 2002). There is no question that this is a complex problem for which large scale solutions have been elusive, if not absent. Research has shown that the underperformance of certain racial and ethnic groups can be attributed, at least in part, to classroom practices that function to disadvantage students from backgrounds that are dissimilar to those of the teachers and staff (Bourdieu, 1990; Ladson-Billings, 1995; McAllister & Irvine, 2000). Given a teaching corps that is homogenous relative to the populations that it serves, the incongruity between the culture of school performance and the cultural practices of students from diverse racial and ethnic groups and economic strata is not surprising. However, this incongruity too often contributes to the marginalization and underperformance of these students.

We as educators are faced with the question of what can be done to improve the outlook of children who are just as likely to drop out of high school as to graduate. Should our schools provide meaningful opportunities for all who pass through their doors? Or should the culture of school performance and the means for success in American public schools hold unyieldingly to the traditional practices that clearly function to provide greater opportunities to some than to others? I believe the opportunity for successful educational outcomes can be expanded to the benefit of all stakeholders, and that we must consider fundamental changes in the ways that we educate our nation's youth.

Over the past decade, the very notions of what it means to learn science have been re-conceptualized to emphasize the importance of student engagement in authentic scientific inquiry (Olson & Loucks-Horsley, 2000) and participation in the practices and discourse of the scientific community (Duschl, Schweingruber, & Shouse, 2007). The dissolution of the perceived dichotomy between science content and scientific process is central to this re-defining of the goals of science education and compels dramatic changes in the way we teach and learn science. Traditional modes of science instruction must be reconsidered and modified to encourage the participation of all students in authentic scientific practices and the opportunity to develop a deep understanding of how scientific knowledge is constructed. Further, curriculum and instructional practices in science must be evaluated for their potential effectiveness in educating students from historically underperforming groups.

Innovative curricula offer a means to change the ways in which K-12 science is learned, and my research focuses on the potential of a National Science Foundation funded curriculum, *Physics and Everyday Thinking* (Goldberg, Robinson, & Otero, 2006), to empower students through engagement in authentic scientific practices. *Physics and Everyday Thinking* (PET) is an undergraduate level curriculum designed to prepare pre-service or practicing elementary teachers for physics teaching, though it is currently being used in some high school physics classrooms. This curriculum is innovative in its central focus on students' engagement in scientific practices and discourse through which they may develop a deep understanding of both physics concepts and the development of scientific knowledge. This curriculum was designed to engage students' prior knowledge as an entry point into the testing and iterative modification of students' conceptions using experimental evidence and reasoning. Students then engage in collaborative evidence-based consensus building in which they are encouraged to both challenge and defend scientific assertions. Through these processes, the PET curriculum creates a micro-scale scientific community in the classroom in which the practices and discourse of the greater scientific community are learned and refined. The vision of physics learning realized by PET is consistent with modern goals for science education and the inherently integrated nature of scientific knowledge and the processes through which that knowledge is developed.

I believe that the nature of this curriculum warrants evaluation of its capacity to empower students and their ideas as valuable contributors to the learning experience. Given the vast numbers of students who are not compelled to engage in science learning and the clear relationships to demographic indicators such as race, it is important that the potential of curriculum like PET be considered and evaluated as one means to narrow the achievement gap. The research questions that I will address in this study are:

- What are the effects of the implementation of the *Physics and Everyday Thinking* curriculum on students' engagement in scientific discourse and practices?
- Do the structures and enacted practices of the *Physics and Everyday Thinking* curriculum encourage students from historically underperforming groups toward greater participation in classroom activities?

### *Conceptual Framework*

Research on learning in physics has strong roots in the cognitive learning perspectives which are characterized by a focus on changes in students' conceptual understanding of physics content. In these lines of research, learning has been conceptualized as a cognitive process which is often represented by students' content-related conceptions as evidenced by responses to conceptual test questions or interviews. Much of this research has focused on the nature of students' conceptions, students' epistemologies, and characterizes physics learning through abstract representations of cognitive structures or mental schema (diSessa, 1993; diSessa & Sherin, 1998; Hammer, 1994, 1995, 1996; Hammer & Elby, 2003; Smith, diSessa, & Roschelle, 1993-1994). This research has proven extremely valuable in understanding students' physics knowledge and learning of physics, but appears limited in its capacity to inform research questions about engagement in the practices and discourse of science. Other lines of research in science education have focused on the practices and discourse that occur in science classrooms and their roles in the learning process (Driver, et al., 2000; Moje, 2002). The sociocultural perspectives often used to support this research bear a central focus on the social interactions that make up the learning process and conceptualize learning as embedded in these interactions. In this study, I will use a particular sociocultural perspective on learning, that of *legitimate peripheral participation*, to inform and support the investigation of these research questions (Lave & Wenger, 2001). Here, I will briefly describe sociocultural perspectives in general and follow with an explanation of why this particular model of learning was chosen to inform my research.

Sociocultural perspectives are unique in that they characterize learning as a social process that is contextually bound, focusing on the interaction of learners with others and the role of tools as mediators of learning. Several essential elements are common to sociocultural theories. The first is that the focus of analysis is the activity or interaction that occurs between subjects rather than the latent traits that belong to individuals. This activity can be conceptualized as enacted cultural practices or more simply as all manner of ways of communicating and interacting that are germane to a particular community. The second is an emphasis on activity at multiple levels. These levels may take the form of levels of social structure, such as the interpersonal, classroom, and community structures, or may be characterized using various temporal domains. Third, tools and artifacts function to mediate, and are thus inseparable from, all activity. The most obvious tool mediating social interactions is language, but mediating tools include all of the means by which we communicate our ideas and interpret the world around us. Finally, from this perspective, social activity and the changes in social relations that occur as a result of social interactions constitute learning or, at the very least, play a critical role in the learning process.

Legitimate peripheral participation is a sociocultural perspective in which learning is embedded in the cultural practices of communities. Each of us are members of a vast number of communities of practice, some of which we participate in peripherally and some in which we play roles characterized by greater participation. Increasing levels of participation are not unlike the phenomenon of apprenticeship in

which the successful apprentice follows a trajectory that leads to full membership in the community of experts of their given trade or practice. Following from peripheral participation is what Lave and Wenger call *full participation* (1991, p. 37). As we move from peripheral to full participation, we engage more fully in the practices of a particular community. This model, like all sociocultural conceptualizations of learning, views learning as embedded in social interaction. However, the notion of individual acquisition or internalization of “knowledge” does not appear in this model. Rather, learning is an integral and necessary part of greater participation. Learning in this case takes on a much less intentional, goal-directed character, and appears more as a natural and unavoidable consequence of social interaction.

Though this conceptualization of learning is clearly unique from the cognitive models of learning that have dominated physics education research, I argue that it is a necessary expansion of our notions of learning when considering the importance of the participation of students in the discourse and practices of the scientific community. As mentioned above, the educational goals for proficiency in science have been re-conceptualized by some researchers to place a greater emphasis on cultural practices. Duschl et al. (2007) have described four strands of science learning to be taken as goals for science proficiency:

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.

Though we see that conceptual understanding and application of scientific explanations is a priority, there is a clear emphasis on students’ proficiency in participation in the practices and discourse of the scientific community. Legitimate peripheral participation is a model of learning that offers the analytic power to examine the complex processes of increasing participation in a community of scientific practice. Further, it offers a means to examine the ways in which students are encouraged to greater or lesser levels of participation in the practices of the science classroom and what role the PET curriculum may play in increasing equity and access for historically underperforming groups.

### *Methodology*

Given my research interest in addressing the achievement gap, I have gained access to a racially diverse urban high school with a high proportion of students with low socioeconomic status. A physics teacher and former Noyce Fellow and Learning Assistant is currently implementing the PET curriculum in her classes. I intend to teach two of her five sections as the primary instructor for the third trimester of the current school year. This will allow me to observe and collect data in her PET classes as a “fly on the wall” observer, as well as to collect data and gain additional insights as the instructor in my own class as a participant observer. The data collection will occur during a yet to be determined unit during the third trimester.

Given the sociocultural model of learning I intend to employ, the appropriate unit of analysis is *the interaction*. That is, the interactions between students, of students with mediating tools, between teacher and students, and of the teacher and mediating tools will be the central focus of data collection and analysis. More specifically, the interactions that embody the cultural practices of the scientific community as well as those that function to encourage greater or lesser participation in that community will be of primary concern. Here, I will describe the types of data I intend to collect and how these data will be used to capture the scientific practices of interest.

One primary data source will be video of classroom interactions. This type of data will allow for careful examination of the nature of the interactions that occur as the curriculum is enacted, frequency counts that may indicate changing levels of participation, and interactions and structures (curricular or

otherwise) that function to mediate the participation of students in scientific practices. Legitimate peripheral participation takes learning to be increasing levels of participation in a community, and in this case, participation is manifested as engagement in the cultural practices of the scientific community. Thus, practices may take an overwhelming number of forms in the science classroom. This will necessitate the development of categories a priori to facilitate data collection in the early stages as is shown in Table 1. The primary community of interest regarding the goals of science education is a community of scientific practices. Thus, I have developed categories based on the scientific practices represented in the essential elements of scientific inquiry (Level 1) (Olson & Loucks-Horsley, 2000). I further differentiated within these categories by drawing from the strands of scientific proficiency (Level 2) (Duschl, H., Schweingruber, H. & Shouse, A., 2007). These a priori categories represent an array of practices accepted and valued within the scientific community, but they clearly do not comprise a comprehensive list. Thus, I intend to modify and expand or collapse many of these categories as video and other data are analyzed. The final column in Table 1 is for recording any mediating tools associated with recognized practices. For example, it may be that a student uses a force-diagram or other representational means to construct and communicate an explanation, and therefore, it will likely be useful to record the use of this mediating tool along with the identified practice.

Table 1. Categories of scientific practices

Scientific Practices		Mediating Tool(s)
<u>Level 1</u>	<u>Level 2</u>	
Scientific Questions	Engage Create	
Prioritize Evidence	Use Generate Evaluate	
Explanations	Interpret Evaluate Generate Communicate*	(eg., graphical representation)
Scientific Knowledge	Theory to explain Explanation to build theory	

\*Communication of explanations appears as one of the five essential elements of classroom scientific inquiry.

Classroom artifacts such as assessments and other student work will comprise another primary data source and will be analyzed to provide evidence of scientific practices that will complement the video data and facilitate multiple source data triangulation of any findings. For example, open-ended assessment items will provide opportunities for students to engage in the practices of science. These practices may appear as using scientific terminology in developing explanations, using evidence to support claims, using various representational tools in formulating and communicating explanations, and using conceptual tools such as force diagrams to conceptualize and analyze natural phenomena.

The final source of data will be student interviews and students' written reflection data. These are intended to give voice to students and their perceptions of the experience of working with the PET curriculum. These data may offer insights into what students perceive as curricular structures and classroom practices that have positive or negative effects on their own participation or that facilitated greater conceptual understanding. These data may also offer insight into student perspectives concerning how the enactment of the PET curriculum may differ from more typical or traditional science learning experiences.

### *Project Timeframe*

Figure 1 shows a proposed timeframe for the implementation of this study. I intend to defend my dissertation prospectus in the early spring of 2011 and to begin teaching the PET classes at the beginning of the third trimester of the research site. Data collection will occur during a unit to be determined by the physics teacher of record at the site, my faculty advisor, and myself. Data collection will be complete by the end of the spring semester and data collection will begin in earnest during the summer of 2011. It will most likely become intertwined with the writing of the dissertation and continue through the fall of 2011 and perhaps into the spring of 2012. The projected completion of the project is May 2012.

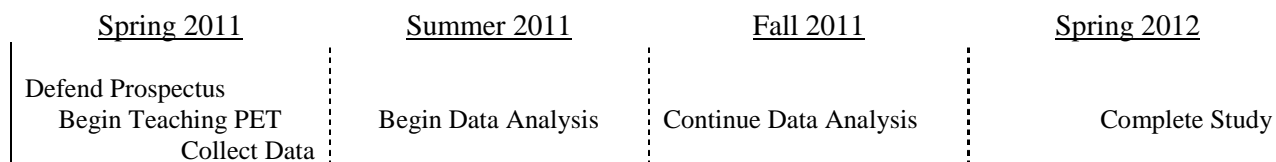


Figure 1. Proposed research timeframe.

### *Study Impact*

The prospective financial support of this project by iSTEM will allow me to complete my doctoral research in a timely manner by freeing up 25% time that would otherwise be committed to an unrelated teaching or research assistantship. This will provide a critical increase in the time available for me to prepare for and teach the PET curriculum, perform data collection and analysis, and to write the dissertation. Most importantly, this support will allow me to sustain a greater commitment of time and energy to addressing the problems and questions that brought me from teaching high school physics to graduate school in the search for answers to one of the more daunting problems facing American public education.

The support of this project will also benefit the School of Education and its commitment to social justice. The achievement gap and the greater social ramifications of this phenomenon are issues of equity and educational opportunity that are aligned with the mission of our school as well as the views of department faculty and doctoral students. Further, the support of research on NSF funded curriculum and its potential impact on issues of equity and access in the physics classroom by the Physics Education Research Group or other discipline-based education research faculty will likely have positive effects. These benefits include an expansion in the focus of local physics education research into the K-12 realm, increased diversity in the models of learning and methodology employed in conducting physics education research, and the moral renown associated with addressing one of the more complex, pervasive, and deleterious problems facing public education today.

The CU community is rapidly gaining national recognition for its innovative and effective STEM education programs. It is a great privilege for me to work with such elite intellectual pioneers and engineers of institutional change. However, it is my opinion that this well-deserved prestige grows in the shadow of an obstinate perception that this university lacks, and, therefore does not value, diversity. I believe that the university STEM community and the university as a whole can benefit from supporting research into issues of equity and educational access within the context of physics and, more generally, science education.

## References

- Bourdieu, P. & Passeron, J. (1990). *Reproduction in Education, Society, and Culture*. London: Sage.
- diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction*, 10(2&3), 105-225.
- diSessa, A. A., & Sherin, B. (1998). What changes in conceptual change? *International Journal of Science Education*, 20(10), 1155-1191.
- Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287-312.
- Duschl, H., Schweingruber, H. & Shouse, A. (2007). *Taking Science to School*. Washington D.C.: National Academies Press.
- F. Goldberg, F., Robinson, S., & Otero, V. (2006) *Physics and Everyday Thinking*. Armonk, NY: It's About Time.
- Hammer, D. (1994). Epistemological beliefs in introductory physics. *Cognition and Instruction*, 12(2), 151-183.
- Hammer, D. (1995). Epistemological considerations in teaching introductory physics. *Science Education*, 79(4), 393-413.
- Hammer, D. (1996). Misconceptions or P-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions. *Journal of the Learning Sciences*, 5(2), 97-127.
- Hammer, D., & Elby, A. (2003). Tapping epistemological resources for learning physics. *The Journal of the Learning Sciences*, 12(1), 53-90.
- Ladson-Billings, G. (1995). But That's Just Good Teaching! The Case for Culturally Relevant Pedagogy. *Theory into Practice*, 34(3), 159-165.
- Lee, J. (2002). Racial and ethnic achievement gap trends: Reversing the progress toward equity? *Educational Researcher*, 31(1), 3-12.
- McAllister, G. & Irvine, J. (2000). Cultural competency and multicultural teacher education. *Review of Educational Research*, 70, 3-24.
- Olson, S. & Loucks-Horsley, S. (2000). *Inquiry and the National Science Education Standards*. Washington D.C.: National Academies Press.
- Smith, J. P., diSessa, A. A., & Roschelle, J. (1993-1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences*, 3(2), 115-163.