AN ABSTRACT OF THE DISSERTATION OF

Sissi L. Li for the degree of Doctor of Philosophy in Science Education presented on September 16, 2011.

Title: Learning in a Physics Classroom Community: Physics Learning Identity Construct Development, Measurement and Validation

Abstract approved:

Larry G. Enochs Dedra N. Demaree

At the university level, introductory science courses usually have high student to teacher ratios which increases the challenge to meaningfully connect with students. Various curricula have been developed in physics education to actively engage students in learning through social interactions with peers and instructors in class. This learning environment demands not only conceptual understanding but also learning to be a scientist. However, the success of student learning is typically measured in test performance and course grades while assessment of student development as science learners is largely ignored. This dissertation addresses this issue with the development of an instrument towards a measure of physics learning identity (PLI) which is used to guide and complement case studies through student interviews and in class observations.

Using the conceptual framework based on Etienne Wenger's communities of practice (1998), I examine the relationship between science learning and learning identity from a situated perspective in the context of a large enrollment science class as a community of practice. This conceptual framework emphasizes the central role of identity in the practices negotiated in the classroom community and in the way students figure out their trajectory as members. Using this framework, I seek to understand how the changes in student learning identity are supported by active engagement based instruction. In turn, this understanding can better facilitate the building of a productive learning community and provide a measure for achievement of the curricular learning goals in active engagement strategies.

Based on the conceptual framework, I developed and validated an instrument for measuring physics learning identity in terms of student learning preferences, self-efficacy for learning physics, and self-image as a physics learner. The instrument was pilot tested with a population of Oregon State University students taking calculus based introductory physics. The responses were analyzed using principal component exploratory factor analysis. The emergent factors were analyzed to create reliable subscales to measure PLI in terms of physics learning self-efficacy and social expectations about learning. Using these subscales, I present a case study of a student who performed well in the course but resisted the identity learning goals of the curriculum.

These findings are used to support the factors that emerged from the statistical analysis and suggest a potential model of the relationships between the factors describing science learning and learning identity in large enrollment college science classes. This study offers an instrument with which to measure aspects of physics learning identity and insights on how PLI might develop in a classroom community of practice.

Learning in a Physics Classroom Community: Physics Learning Identity Construct Development, Measurement and Validation

by
Sissi L. Li

A DISSERTATION

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Presented September 16, 2011
Commencement June 2012

Doctor of Philosophy dissertation of Sissi L. Li presented on September 16, 2011.

APPROVED:

____

Major Professor, representing Science Education

____

Chair of the Department of Science and Mathematics Education

____

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

____

Sissi L. Li, Author

ACKNOWLEDGEMENTS

This was not just the achievement of three uniquely arranged letters; rather it was the growing (bleeding), shaping (sweating) and strengthening (bruising) of a person I hadn't imagined possible and I couldn't have done so alone.

Dedra Demaree, my research adviser, has taken on so many other roles in my life that she is friend, family and mentor all at once. Thank you for allowing, helping and pushing me to grow. I must fly off, but I promise to fly well. Larry Enochs, thank you for your constant faith in me especially on days when I question myself. I also want to thank my cohort (and semi-cohort) of graduate students: Kristin Lesseig, Sue Ellen DeChenne, Shawn Anderson, Nancy Staus, Henry Gillow-Wiles, and Teresa Wolfe. Thank you for cajoling me into being social, sharing your experiences and wisdom, and keeping me sane. And feeding me, each and every one of you has made sure I ate; I'm sure there is a conspiracy.

I want to thank Robert Wei for being my partner for over eleven years. Thank you for teaching me about life and challenging me to grow to be more than I thought possible. I also want to thank Mary Smeller who has been my friend through not one but two attempts at a PhD. Thank you for keeping me grounded and reminding me I can pick myself up after falling on my face. I want to thank Whitney Shepherd for insisting I remember to play despite all the work. I will remember to enjoy the whooshing of deadlines. Josephine Fosdick is, without a doubt, the least likely person

I would have befriended in these years of graduate school. I am incredibly glad and lucky that we are friends. Thank you for supporting and accepting me in all my capacity to be sugar and spice, and possibly nice despite my insistence that I'm mean.

I would like to thank my family for loving me just the way I am. Thank you, Mom for giving me room to grow and teaching me that it's not about being the best but being my best. Thank you Priscilla letting me share and vent in a way I cannot with anyone else. We may be sisters by birth, but we're definitely friends by choice.

I want to thank Brigid Backus for encouraging me to pursue this degree when I thought I was not strong or smart enough for a PhD. Thank you for your vision and for helping me discover that this is what I love to do. I would like to thank Greg Mulder for teaching me to play ultimate Frisbee and showing me what it is like to love to teach. I would also like to thank Dennis Gilbert for our many, many talks about teaching and life. I don't know anyone else who is as good at talking as well as at listening.

I would like to thank the Science and Math Education department and the Physics department for their support through my years at Oregon State University. I would also like to thank the Education Opportunities Program and Chemistry department for the chance to teach some amazing students who easily taught me more than I taught them. It is because of all these departments and programs that no one can quite remember what subject I teach; and for that reminder that learning is multidisciplinary and boundless, I shall always be grateful.

And for all the graduate students who walk this road after me, I leave you with words that I looked to when I fell and there was no one to pick me up.

> *"Nothing in the world is worth having or worth doing unless it means effort, pain, difficulty... I have never in my life envied a human being who led an easy life. I have envied a great many people who led difficult lives and led them well."*
>
> *Theodore Roosevelt*

CONTRIBUTION OF AUTHORS

Dr. Dedra Demaree contributed to the design and validation of the Physics Learning Identity Instrument. Dr. Mark Needham contributed to the statistical data analysis of the Physics Learning Identity Instrument.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF TABLES

LEARNING IN A PHYSICS CLASSROOM COMMUNITY: PHYSICS LEARNING IDENTITY CONSTRUCT MEASUREMENT, DEVELOPMENT, AND VALIDATION

CHAPTER I

INTRODUCTION

INTRODUCTION

At the university level, introductory science courses are usually part of the core requirements for all majors to provide a broad base of knowledge and learning tools on which students can build advanced understanding in their chosen majors. In order to accommodate such a large population of students with limited faculty and physical resources, introductory science courses tend to have high student to teacher ratios. These classes with hundreds of students are frequently taught with traditional direct instruction with the lone instructor giving a speech behind a podium at the front of the class while the students listen quietly as passive observers. Not only do teachers and students commonly expect this model of teaching at school, it is the model in which many teachers succeeded as students. Consequently, teachers are likely to continue to follow this default mode even when they find many flaws in this system.

There are many reasons that lecture is not sufficiently effective or productive for the learning we want. Anecdotal teacher complaints commonly include students forgetting all the new knowledge as soon as they walk out of class, and teacher being unable to connect with individual students; students complain that their classes are boring or they learn more from the book. However, students entering universities in the last decade are very different from the population of learners for which the "traditional" curriculum with direct instruction was designed. According to the 2006

US census, enrollment in college and graduate school has increased from 15.3 million to 17.2 million from 2000 to 2006. This is a significant change compared to college and graduate school enrollment from 1994 to 2000 (2000 US census) which had remained relatively steady at approximately 15 million.

The prevalence of the internet and other media allows for highly interactive and customizable learning outside of the classroom. Additionally, the students are entering a quickly growing work force with changing demands. As a result, it is not realistic to teach students what they need to do their job; rather we need to teach students how to *learn* to do their job. While direct instruction worked adequately for smaller populations of students in a time with more constant work demands, it is a poor design for today's students in large lectures classes. While traditional direct instruction does still help students learn some specific facts and skills, it is not longer adequate for addressing the learning needs for students today.

An examination of large enrollment classes reveals the largely negative effects on student learning. Large enrollment lecture courses are often plagued by low and declining attendance (Gardiner, 1994), high course drop out and failure rate (Hewitt & Seymour, 1999; Kopeika, 1992), low graduate rate (Kopeika, 1992), and low interest and motivation (Lord, 1999). Borden & Burton (1999) showed that large classes of over 100 students had negative effects on student performance compared to smaller classes of 3-90 students. In contrast, Hou (1994) found that larger class size (n=54) performed better than a smaller class (n=25) a study of college economics courses. Some studies observed no correlations between class size and student achievement in terms of standardized test scores (Kennedy & Siegfried, 1997). These studies with mixed results indicate that while large classes can reduce student learning, there appear to be factors that can lessen or even counter those effects. Additionally, measures of learning are inconsistent across the studies which lead to difficulty in comparing the effect of large lectures to smaller classes.

Using the force concept inventory (Hestenes et al., 1992) as a standardized tool for comparing conceptual understanding of Newtonian physics, R.R. Hake showed that students in introductory physics classes using direct instruction learned less than 20% of what they did not know prior to the course regardless of class size (1998). In classes where teachers reported using some form of active engagement instruction, the force concept inventory showed that students learned 30-70% of what they did not know prior to the course regardless of class size (Hake, 1998). This finding supports the claim that the negative effect on learning observed in large classes can be reversed, and that active engagement is one factor that contributes to the reversal. However, there are many types of active engagement learning environments with myriad contributing factors. Furthermore a learning environment impacts not only student learning but also student identity as a learner of the particular discipline (Boaler, 1998; Brahmia & Etkina, 2001). In this dissertation, I begin to explore specific elements of active engagement learning environments through the development of an instrument to measure learning identity and its evolution in the classroom.

Studying Learning Identity Development

Active engagement is broadly defined in this study to include collaborative learning (Beichner et al., 2000, 2007; Christensen, 2005), peer learning (Crouch & Mazur, 2001; Krych et al, 2005), and other pedagogy that support learners in real time exploration of concepts and ideas for themselves (Etkina & Van Heuvelen, 2007). These curricula have been developed with deliberate use of active engagement in science learning with opportunities for instructors to connect with students and attend to the factors that mediate student's development. According to Vygotsky, social interaction is considered "central and necessary to learning and not merely ancillary" (Lemke, 2001, p296). Thus supporting student learning means both helping students make productive use of social interactions and promoting learning through social interactions beyond the course. Proponents of social learning have found improved student learning in test performance and grades as well as attitude and interest in science including:

1. students are able to ask higher-level question (Marbach-Ad & Sokolove, 2000),
2. students perceive that group activities help their learning (Christensen, 2005),

3. students are engaged in deeper thinking process and are more likely to remember those ideas and concepts when they need to be applied (McKeachie & Svinicki, 2006),
4. students are able to make more diverse and deeper connections and meanings with discussion in groups compared to individually (Hatano & Inagaki, 1993), and
5. students develop positive affect towards the subject (Yazedjian & Kolkhorst, 2007).

In the calculus-based introductory physics courses at Oregon State University, we have adopted the investigative science learning environment (ISLE) developed by Ektina and Van Heuvelen (2007) as a curriculum with the goal to help learners develop skills of authentic scientists. ISLE teachers support this development by using a learning cycle to scaffold students' development of their own ideas and encouraging the use of specific skills such as multiple representations of physical processes in productive problem solving (Etkina & Van Heuvelen, 2007).

Development of these skills is facilitated through social interactions with members of the classroom as opportunities for students to refine their ideas about science. However, most students expect to be passive observers in a large enrollment course held in a lecture hall with stadium seating. This is consistent with anecdotal reports from ISLE practitioners in smaller classes that students typically need nine weeks of exposure to the learning environment to adjust so they can productively participate in class (E. Etkina, personal communitcation, 2009). In larger classes, students potentially have to make even larger adjustments. Woods reported students in “nontraditional” classes going through eight steps similar to those associated with trauma and grief ranging from shock and denial to integration and success (1994). I hypothesize that students are driven to make changes in order to adapt to the active engagement learning environment. A mechanism for change is to redefine their student role along a trajectory from passive observers to active and social learners. This redefinition includes feeling allowed to engage with the community, becoming able to engage in the practices of the classroom community, valuing the practices for achieving their goals, and believing that one is becoming more competent in that community.

I propose that this is a mechanism by which students can become successful in the science course and in their future careers. However, there are two major challenges to understanding this change. First there are multiple trajectories each individual can take to arrive at being active learners and no single way is the best for all students. Second the changes on the individual level have a reciprocal relationship rather than a direct casual relationship with the collective changes in the classroom community. I use Wenger’s (1998) community of practice as a conceptual framework which provides a systematic way to look at the complex ways in which a group of people such as teacher and students work together on the common goal of learning in a classroom. Wenger describes ways of participating which impact how the people and the group shape each other. By interacting with a community of practice, members develop an identity as the way they understand how to be a part of that community. As result of the interplay between the individual and collective changes in the classroom, students can become more competent at the conceptual understanding as well as function as a member of the group. This change is the process of learning identity development, and it is the focus of study in this dissertation.

Research questions

This study is guided by a specific overarching research question: how is student identity as learners in our physics classroom community related to their learning. Specifically, I address the following questions.

1) What are the student learning identities as they enter our classroom community in terms of their expectations of roles and social norms, their attitudes towards social learning, and their self efficacy in their ability to learn this way?
2) In what ways are environmental and social factors in the classroom CoP brought to bear on identity development?

3) How are these aspects of learning identity related to student learning (as measured by standard conceptual assessments, and as participation during lecture) in terms of correlated changes over time?

The relationship between science learning and learning identity is examined from a situated perspective in the context of a large enrollment science class as a community of practice.

In chapter two, a review of the literature on large enrollment classes and active engagement provides a basis to situate the research questions. The conceptual framework for this study is based on Wenger's (1998) communities of practice with a situative perspective, Bandura's (1997) notions of self-efficacy, and about the components of identity (Boaler, 1998; Wenger, 1998). The conceptual framework generated from the literature emphasizes the central role of identity in the practices negotiated in the classroom community and in the way students figure out their trajectory as members. Using this framework, I want to understand how the changes in student learning identity are supported by active engagement based instruction. In turn, this understanding can better facilitate the building of a productive learning community and provide a measure for achievement of the curricular learning goals.

In chapter three, I use the conceptual framework and physics learning identity construct to develop an instrument that can measure large numbers of students at multiple points in time, target components of learning identity, and be specific to the

ISLE learning goals. A survey is suited for large populations, but the existing surveys in the literature do not address all of the requirements. Therefore chapter three describes the development and validation of a survey instrument to measure physics learning identity in terms of student learning preferences, self-efficacy for learning physics, and self-image as a physics learner.

In chapter four I present a case study of a student through the lens of this framework to provide a rich context for the type of quantitative analysis that can be obtained from the survey results. The case study includes data from recorded class observations, a semi-structured student interview and written responses to open-ended questions. These data are used to support the factors that emerged from the statistical analysis of the survey development and suggest a potential model of the relationships between the factors describing science learning and learning identity in large enrollment college science classes. These data are also used to demonstrate the use of analytical tools to examine learning identity in a way that is more comprehensive and realistic than qualitative or quantitative data alone.

Extending the Field of Science Education Research

This dissertation extends the field of learning identity research in two important ways. First, this project aims to fill a knowledge void with a set of mixed method tools to measure and analyze aspects of student learning identity. The survey instrument can be used as a means to characterize students individually or into groups to guide more fine grained research in understanding how particular students adjust to an active engagement learning environment like ISLE. The case study is shown to enrich the quantitative data to provide a meaningful description of the classroom community. Second, this study emphasizes the importance of considering classroom learning as collaborative and social interactions. Learners are connected to the other community members though practice rather than being disjoint entities that are independent of the learning environment. Supporting and sharing this way of viewing classroom learning adds to the existing research in physics education which has historically focused on specific teaching strategies where student learning was examined with little or no consideration of the classroom social context. Innovations in curricular reform for teaching physics is a rapidly growing field, and it is important to study the effects of the reform efforts in helping students develop conceptual understanding and identities of physics learners that will have implications for the quality of science learners that leave our classrooms.

References

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Worth Publishers.

Beichner, R. J., Saul, J. M., Allain, R. J., Deardorff, D. L., & Abbott, D. S. (2000). Introduction to SCALE-UP: Student-centered activities for large enrollment university physics. In *Proceedings of the 2000 Annual meeting of the American Society for Engineering Education,* 18–21.

Boaler, J. (1998). Open and closed mathematics: student experiences and understandings. *Journal for Research in Mathematics Education,* 29(1), 41-62.

Brahmia, S., & Etkina, E. (2001). Switching Students on to Science: An Innovative Course Design for Physics Students. *Journal of College Science Teaching*, *31*(3), 183–187.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small. *New Directions for Teaching and Learning*, *2000*(81), 5–16.

Christensen, T. (2005). Changing the Learning Environment in Large General Education Astronomy Classes. Journal of College Science Teaching, 35(3), 5.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, *69*, 970.

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer Instruction: Engaging Students One-on-One, All at Once. *Reviews in Physics Education Research*, *1*.

Etkina, E., Personal communication (2009)

Etkina, E., & Van Heuvelen, A. (2007). Investigative Science Learning Environment–A Science Process Approach to Learning Physics. PER-based reforms in calculus-based physics. College Park, MD: AAPT.

Gardiner, L. F. (1994). *Redesigning higher education: producing dramatic gains in student learning*. Graduate School of Education and Human Development, George Washington University.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64–74.

Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. *Perspectives on socially shared cognition*, 331–348.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 20*, 141-158.

Hewitt, N. M., & Seymour, E. (1991). Factors contributing to high attrition rates among science and engineering undergraduate majors, *Unpublished report to the Alfred P. Sloan Foundation*.

Ishak, M., & others. (2008). Improving the Training of Pre-Service Physics Teachers in Malaysia using Didaktik Analysis.

Kopeika, N. S. (1992). On the relationship of number of students to academic level. IEEE Transactions on Education, 35(4), 294–295.

Krych, A. J., March, C. N., Bryan, R. E., Peake, B. J., Pawlina, W., & Carmichael, S. W. (2005). Reciprocal peer teaching: students teaching students in the gross anatomy laboratory, *Clinical Anatomy*, 18(4), 296-301.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316.

Marbach-Ad, G. & Sokolove, P.G. (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching,* 37(8), 854-870.

McKeachie, W. J., & Svinicki, M. (2006). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers*. Houghton Mifflin Boston.

Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge University Press.

Woods, D.R. 1994. Problem-based learning: How to gain the most from PBL. Waterdown, Ontario: Donald R. Woods.

Yazedjian, A., & Kolkhorst, B. B. (2007). Implementing Small-Group Activities in Large Lecture Classes. *College Teaching*, *55*(4), 164–169.

CHAPTER II

PHYSICS LEARNING IDENTITY: TOWARD DEVELOPMENT OF A MODEL FROM RELATED RESEARCH

PHYSICS LEARNING IDENTITY: TOWARD DEVELOPMENT OF A MODEL FROM RELATED RESEARCH

Abstract

Lecture classes enrolling hundreds of students are becoming the norm in introductory science courses. Many studies indicate that learning in large population enrollment traditional lecture courses correlates with lower course performance, reduced retention in the course (Gardiner, 1994; Borden and Burton, 1999) and as science majors (Kopeika, 1992; Hewitt & Seymour, 1999), reduced interest and motivation (Lord, 1999), and weaker grasp of meta learning goals such as critical thinking skills (Kennedy and Siegfried, 1997). However, the negative effects of large enrollment courses appear to be reduced by implementing some form of active engagement curriculum in place of the passive traditional lecture (Hake, 1998; Powell, 2003). Further examination of learning in active engagement classrooms suggests that the learning environment mediates the quality of knowledge built because the learning environment facilitates students in developing identities in relation to the discipline (Boaler, 2002). Therefore we must study student learning as identity development in addition to conceptual knowledge building. The purpose of this chapter is to build a model of social learning to frame the construct of physics learning identity. This will enable further development of analytical tools to measure and examine students' learning identity as they engage with the classroom community of practice.

Introduction

Students and teachers face multiple challenges in large lecture classes. Enrollment of over 100 students makes it *large*, and the instructor at the front of the class talking to passive students quietly taking notes makes it *lecture*. The studies on the effect of large enrollment courses on student achievement show mixed results. Kennedy and Siegfried (1997) observed no difference in student in achievement terms of acquisition of knowledge in introductory economics. On the other hand, Borden and Burton (1999) conducted studies across disciplines that showed that large classes (over 100 students) had a negative effect on student performance compared to smaller classes (3- 90 students). Kopeika (1992) found that reducing class size from 200 down to 70 students contributed to increased graduation rate as well as improved academic level as reported by industry and graduate schools. While Kopeika's findings seem contradictory to the other studies, closer inspection shows that measured variables to represent student learning for the studies are not uniform across the studies. For example, Kopeika (1992) measured graduation rates, while Kennedy and Siegfried (1997) measured knowledge acquired. In addition, the instructional methods in the classes studied were not consistent from one study to the next which added another confounding variable making the results difficult to compare. However, the results indicate that large classes have the potential to reduce student achievement, but the negative effect may be offset by other factors in the classroom.

The identifying feature of a lecture class is students passively listening to the professor speak. This model frequently results in low interest and motivation (Lord, 1999), low and declining attendance over time (Gardiner, 1994), and high dropout rate for the course as well as for the program (Cooper & Robinson, 2000; Hewitt & Seymour, 1999; Kopeika, 1992). However lecture has its place—it is suited for tasks such as providing relevant context for an otherwise abstract concept, demonstrating a problem solving technique as an advanced practitioner, or showing enthusiasm for the subject (Cuseo, 1998; McKeachie, 1999). Particularly illuminating is that Kennedy and Siegfried (1997), comparing large classes and in small group discussion teaching modes, found that students learned content knowledge equally well. However, students in small class discussion settings were better able to gain deeper understanding such as critical thinking, problem solving and transferable skills. Furthermore, Powell (2003) reports that some college professors are adapting their teaching methods with peer instruction (Mazur, 1997; Crouch et al., 2007) to reduce monolog time and counter the impersonal effects of large-enrollment. One professor incorporated simple hands-on experiments that can be done in small groups in class so that the students can experience physics phenomena the way a real physicist does (Powell, 2003). This research suggests that lecture can be supplemented or replaced with alternate instructional modes that use active engagement to optimize the learning experience. Lecture has its purposes but incorporating instruction supporting having students actively engaged in learning is key to a successful learning experience.

Although large lecture classes can have negative effects on the quality of education, they are typically how introductory science classes are taught at the university level. Given that this trend is largely an institutional choice, individual departments and instructors often have little control over class size. Instructors do have control in how they teach, and many have incorporated teaching methods such as peer instruction (Mazur, 1997; McKeachie, 1999; Nichol & Boyle, 2003, Crouch et al, 2007), cooperative learning (Johnson & Johnson, 2001; McKeachie, 1999), investigative science learning environment (Etkina et al, 2006), and student-centered active learning environment for undergraduate programs (Beichner et al., 2007) to improve student learning through active engagement.

The goal of active engagement is to facilitate the students in developing their understanding through interaction with the scientific phenomena and social negotiation of the meaning of scientific concepts. However, development as science learners includes both the students' cognitive growth and shaping of an identity as the kind of science practitioner they want to be. The teacher's role then is to support student identities of interested and motivated practitioners of authentic scientist skills. To facilitate this process, students are provided with opportunities to communication through scientific argumentation, divergent thinking in considering multiple explanations and solutions, robust problem solving, and metacognition through reflection. In order to help students learn in this environment, teachers need to be sensitive to students' cognitive development, emotional and motivational state, and social orientation to the classroom community. In other words, teachers must attend to the student as a whole learner.

Why study identity?

Using the communities of practice as a model for how groups of people with a common goal interact, Wenger (1998) describes identity as the way people understand how to be a part of a community. It can be an identity of inclusion with various levels of participation or exclusion with resisted attempts to participate (marginalization) or a decision to refrain from participating (non-participation). Wenger (1998) further asserts that "we accumulate skills and information, not in the abstract as ends in themselves, but in the service of an identity" (p215). In a classroom community, participation shapes the students' identity as learners as a result of the interactions designed to build conceptual understanding.

Not only do interactions shape identity, but the type of interactions with the community can impact the quality of learning through the development of disciplinary relationship as part of identity. Boaler (2002) has observed that students in different learning environments developed different relationships to the discipline because the learning environment engages them differently. Students in classes where they were passive receivers of knowledge developed a dislike and detachment from mathematics; students in classes where they were asked to actively contribute and make personal meaning regarded mathematics as a desirable and integral part of their lives (Boaler, 2002). Participation allows for the development of disciplinary relationships that impact if and how students become part of the community.

Given that interactions shape identity through disciplinary relationship and this development impacts the quality of learning, then it follows that we need to examine student learning identities and how they change in order to understand how the active learning environment influences student learning. Because student learning identity and the community mutually transform each other, taking this research lens allows for shifting the focus from single students, small groups of students, and to the whole classroom community. This malleability in the research model is essential and well suited to examining active engagement learning environments where interactions happen at multiple levels at the same time or shifting quickly over a short time.

In order to examine student learning identity, I will first define the context for learning and knowledge in this study. I will then examine what has been studied about the active engagement learning environment and situate learning identity in context specific, socially interactive models of learning. Using these models, I will synthesize the construct of *physics learning identity* that will be central to addressing the following research questions.

1) What are the students' learning identities as they enter and then experience the classroom community?
2) In what ways are environmental and social factors in the classroom community of practice related to identity development?
3) How are these aspects of learning identity related to student learning in terms of curricular learning goals?

Learning and identity literature

Learning and knowledge in communities of practice

Not only is the nature of learning constructed by each individual, it is also shaped by the environment and community in which learning is socially constructed (Doolittle, 1999; von Glasersfeld, 1995). Our understanding of the world is constructed from our interactions with and perceptions of the world. Wenger proposes that by engaging in social interactions, people develop ways to do things and make sense of their experiences to help deal with the world around them (1998). Developed as a model for describing how people work together on shared tasks and goals in the work place, a community of practice (CoP) is a group of people engaged in a common endeavor through social interactions in meaningful experiences (1998). This notion of a CoP is also useful in the school setting where the common goal is to learn through social interactions with others. As members interact in the CoP, they shape practices, or ways of doing things. The practices of a community are not merely adopted and assimilated by members of the community. Rather, the members mutually engage in negotiation to develop a common set of meanings of participation that characterize the community of practice. This does not mean everyone in the community engages in identical practices but that the practices are shared common ground from which new meanings and practices may be developed. Wenger makes a clear example of the idea of common sense which "is only common-sensical because it is sense held in common" (1998, p. 47). The practices of a community of practice are specific to that community because the members have a history of practice developed as a collective which becomes a shared repertoire that continues to be negotiated and evolve. This repertoire need not be unique to the community; it only need be shared understanding of meaning within the community. Wenger describes knowledge as competence in dealing with the world and thus the act of learning is the process of gaining competence through participation in making sense of experiences in the world (1998). This is an apt perspective to consider student learning because they are making sense of science ideas by thinking and behaving like scientists.

In addition, the nature of social interaction means that students will have a say in shaping the practices of the classroom community. In other words, knowledge and practices are developed and negotiated in a shared manner so that members become authors and defenders of knowledge. This notion of shared contributions is aligned with goals in many active engagement teaching strategies so that it is one indicator of how competent the students are becoming. The CoP is also fluidly evolving over time where “persons and practices change, re-produce, and transform each other” (Lave, 1993, p68). This temporal nature of the CoP means the relationships between variables such as facilitation of learning, classroom practices, and assessment of conceptual understanding must also be studied over time with a developing history rather than at a single point in time. For individual members, this history is the trajectory along which members become more or less involved in shaping knowledge and practices of the community. By studying change along trajectories, we can gain insight into how to support students being more involved and in control of their classroom learning.

Learning and identity development

The students’ identity is the result of engaging in a CoP “because learning transforms who we are and what we can do” (Wenger, 1998, p215). The type of identity and how it develops can influence the quality of learning that result. Additionally, people interact in multiple CoP’s throughout their daily lives and form identities that shift as they move between each CoP. The incorporation of these multiple identities is the concept of a nexus of multimembership (NoM). While this is beyond the scope of this study, there are factors beyond a single CoP such as a physics class that can significantly impact identity development. Knowledge of the learning identity that students bring into class and understanding of how this identity interacts with the learning environment are crucial for successful facilitation of learning through active engagement. For the purpose of this study, I will focus on examining aspects identity relevant to engaging in a classroom learning environment.

A first step to examining identity is the individual's self-image. While self-image is only a part of identity, it can be highly influential in how we decide to interact with others. Studies show that how you think others see you (perceived other appraisal) depends more strongly on how you see yourself (self-image) rather than how others actually see you (actual appraisal) (Tice & Wallace, 2003). Therefore, how people think of themselves will strongly influence their choices as they interact with others. However, considering learning as social interaction means identity also encompasses perceived role, relationship with others, day to day interactions with others and experiences in other CoP. Identity also includes the individual's past experiences which inform about the roles played and interactions in the classroom CoP. Additionally, identity includes an aspect of alignment in which the individual believes the practices and how they are done are valuable. Thus an identity of a central member of the CoP includes actively participating in social interactions with others, perceiving and being treated as a valued member who can affect change in the practices, and believing that engaging in these practices will achieve the common endeavor.

Lastly, self-efficacy theory indicates that people are most likely to persist and improve at a task if they believe that they are capable of succeeding (Bandura, 1997). Self-efficacy is a person's belief that he/she is capable of succeeding at a specific task. This belief is influenced by four sources: (a) mastery experience of personal success, (b) vicarious experience of seeing others succeed, (c) social persuasion, and (d) physiological and affective states (Bandura, 1997). The advantage of an active engagement classroom is the increased opportunities for mastery experience which is the strongest factor for improving self-efficacy. In addition, this learning environment makes vicarious experiences more visible through social interactions with peers. In comparison, a traditional lecture classroom primarily supports vicarious experience of seeing the teacher succeed and social persuasion from the teacher that students are able to succeed in the class.

In sum, an identity of a central member of the CoP includes actively participating in social interactions, perception of being treated as a valued member who can affect change in the practices, belief in the ability to engaging meaningfully with the community, and belief that these practices will achieve the common endeavor. This identity development informs the students' attitudes and affect for the common endeavor of learning science. For example, the interactions specific to science can be very different from everyday interactions; it is perfectly acceptable and encouraged to engage in argumentation in science whereas most everyday interactions aim to avoid conflict and confrontation because it is seen as hostile or impolite (Belenky et al., 1986). Therefore learning to be a member of the science community is not only to acquire the ways of interacting and thinking, but also how to accommodate those ways into the member's existing ways of interacting. The socially interactive curriculum thus both requires knowledge of theses ways of interacting and provides opportunities for students to make sense of and contribute to these practices.

Learning is situated

Just as learning in each individual is different, the setting in which learning occurs also play a significant role in enhancing or impeding one's ability to construct meaningful understanding (Greeno, 1998). In this view, learning is the attunement of the student to the constraints and affordances in the learning environment in order to participate in the negotiation of meaning through social interactions (Lave & Wenger, 1991). The same idea in different contexts can make the idea seem distinctly different. For example a savvy shopper might be able to figure out how much is saved at the 65% off sale, but that same person in math class might struggle mightily trying to calculate 65% of the speed of the train heading northwest. Differences in context can be much more subtle. Students asked to report a measurement to an instructor, a friend or in a formal report were found to different answers depending on the stated audience (Taylor et al., 2009). In order to achieve the goal of education in supporting students to take what they learn and use it when they leave school. Therefore educators must attend to the details of the learning context to support productive learning in the classroom and connection to contexts beyond the classroom.

The constraints and affordances of the learning environment have many sources. Subtleties in the way learning is verbally facilitated can have considerable impact on how students engage in learning activities (Li & Demaree, 2010). In an analysis of verbal prompts given prior to and during small group activities in an active engagement introductory physics classroom, students appeared to participate more when the instructor (a) provided hints, (b) gave instructions with "I" or "me" (I want you to do this, draw a diagram for me), (c) rated the difficulty of an activity, and (d) made explicit that students are being held accountable (Li & Demaree, 2010). While these prompts increase instances of participation, they do not necessarily affect the sustained duration of participation in the same way. For example, giving hints and asking guiding questions during the activity increases overall participation but lowers continuous participation during the allotted time. Providing hints and asking guiding questions can constrain participation because student conversations are interrupted to listen to the instructor. However, providing this help can also afford lost or confused students the scaffolding needed to become comfortable enough to share their understanding with their peers. These findings warrant the need to closely examine the classroom discourse and the quality of participation facilitated.

The physical space in which the class is held is another part of the classroom context that impacts learning. This is an oft overlooked variable because teachers usually have little control over the room assignments. The physical environment can strongly suggest specific student behaviors and roles. Sommer (1967) found that when students can make direct eye contact with ease, they are statistically more likely to engage in discussion; however, this effect may be canceled other factors such as noise or crowdedness leading to the perceived best seats in the room not being optimal for visual contact. For students entering a lecture hall with more than 100 seats in front facing rows, it is likely to suggest that it is not appropriate to turn around to speak to another student. Recall that students often enter a large enrollment class with little experience or expectation of social learning. With these pre-conceived notions about learning and a physical environment that appear to reinforce those notions, it should not be surprising that teachers report a lengthy period of adjustment before student s regularly make productive use of social learning activities in class.

From the teachers' perspective, they need to be aware that physical features of the classroom can support or hinder their instruction, and they need to have flexible classroom features that can be modified to suit their style of instruction (Weinstein, 1981). Gibson's (1986) notion of environmental affordances states people are guided in what to think and how to behave in part by the arrangement and materials that make up the physical features in the classroom. Hence it is natural for teachers assigned to teach in a classroom with stadium seating to feel lecture is the default mode of instruction; similarly, students seated around a conference table may feel more inclined to speak up and contribute because the space suggests collaboration. Graetz and Goliber (2002) caution that using “the classroom in a manner that does not agree with its affordances… may lead to a negative emotional response” (p16). The physical layout of a room can convey the behavioral expectations to participants (Weinstein, 1981). As a result of these expectations, users may react with a negative emotional response to the space being used for the unexpected. For example, asking students to perform small group experiments in a tightly packed traditional lecture classroom may cause the student to feel that the experiment is impossible to perform and not take the lesson seriously. Consequently, it is crucial for teachers as a facilitators of classroom practices to be aware of their own assumptions about the physical features of the learning environment as it is brought to bear upon the quality of engagement and learning in the classroom.

Furthermore, the quality of learning involves both the conceptual learning and productive relationship towards the discipline. Boaler (1998) studied two high school math learning environments which she calls “open” and “closed” classrooms. The open classroom is characterized by the teaching “philosophy that students should encounter a need to use mathematics in situations that were realistic and meaningful to them” (Boaler, 1998, p49). As a result the teacher was a resource for explaining concepts students found they needed as they worked in collaborative groups on open-ended problems. This led to the students being the driving force with some agency in the direction of their learning. The closed classroom utilized a traditional curriculum where the teacher explained new concepts with lecture followed by students passively completing related exercises in class without challenging the tasks or the authority figures.

Boaler (1998) found that students in the closed classroom spent more time on task but they learned math as set rules and equations. Furthermore, their problem solving was “cue-based” where math reasoning was guided by what they perceived the teacher wanted and routines in the exercises such as problems ordered with increasing difficulty. Students in open classrooms more frequently found the math interesting and recognized they had agency and responsibility in learning. Compared to the closed classroom students, those in the open classroom scored higher on standard tests (NFER), were more proficient at an open-ended applied problem solving task, and performed comparably in traditional close-ended math questions. These results indicated that (a) we cannot only look at course grades or test scores as measures of student learning, (b) the expectations in a learning environment can have significant influences on student understanding about the nature of learning in the discipline which has implications on affect, interest and motivation, and (c) student perception and exercise of agency allow them to develop into legitimate members of the classroom and disciplinary community so that they are interested in pursuing the discipline.

Learning occurs across settings

A single community of practice does not stand on its own. Instead it is interconnected with a myriad of other communities of practice in which an individual is a member. This is apparent in the way individuals identify themselves. In the community of physics class a student might consider himself a mediocre student. In the community of the softball team he might view himself an excellent pitcher. In the community of his study group, he might be the one with great insight on 20th century British literature. Communities may overlap anywhere from significantly to hardly at all. As he travels between each community, he adjusts his identity within the community as well as takes a portion of one community to interact with the other community. The example highlights the need for a holistic view of how these communities interact on mutually interacting connections.

Learning cannot be viewed as a single event in time and space, but rather a series of connected experiences in different settings that we bring to bear on our interpretation of our interactions with the world. My scope of research on learning is deliberately focused narrowly on what happens in the classroom in order to start with a manageable analysis. I am aware that the rest of the students' experiences contribute significantly to their learning process. By establishing tools for probing learning identity, I can later expand the scope to include a more complete view of the learning process.

Physics Learning Identity

Given that learning is integrally tied to the context and that learning is the process of transforming identity, I want to examine learning identity and its relationship to learning goals of the classroom. The broad notion of disciplinary learning identity as defined here can be applied to any specific branch of science or humanities. In defining physics learning identity, I am making the distinction that there are expectations, attitudes and norms that characterize doing physics and shape the identity that results in doing physics. In order to articulate what I mean by identity, it is necessary to be specific about what kind of identity because it is context specific. In order for the definition to be useful in practice, it is also necessary to be able to answer (a) what is it and what isn't it, (b) how to know if it is present/missing, and (c) how to determine how much there is**.** Before that, I will define each part of the term.

Using Wenger's notion of identity in a community of practice, we suggest that identity is the way we know how to be a member in a specific community. Identity is guided by interactions and perceptions as a result of participating in the CoP. Identity can be extended to a more holistic concept of a nexus of multimembership (NoM) which is a compilation of our identities in each CoP of which we are members. While this is beyond the scope of this study, I acknowledge that there are factors beyond a single CoP such as a physics class that can significantly impact identity development. For this study, members of a CoP have identities informed by four sources.

1. their self-image,
2. their expectations about members' roles and behaviors,
3. their perception of how others view them, and
4. their experience of interacting with others.

These inputs shape the identity in terms of feelings of *belonging* and being *capable*, ideas about what members of this CoP *do*, judgements about whether they are *aligned* with the goals of the CoP and if participation is *worthwhile*. In this sense, identity is always measured with respect to interactions with others.

In the classroom, the goal of the CoP is to help students learn, or to gain competence in dealing with the subject or field of the course. The most common identity is usually one of being a learner who is in the community to become more competent at using the *skills, tools, and knowledge* associated with the course. Often this is true even for those who view themselves as the teacher or more advanced students. Each member may be learning something different; students encountering the subject for the first time may be learning to use the context specific language and grammar, more experienced students may be re-negotiating their pre-existing ideas, while the teacher may be learning to see through the students' eyes. For this study, I am interested in understanding student learning through identity development.

Hence, I will focus primarily on examining the learners' identity as they interact in the classroom as a community of learning.

In this sense, the students' learning identity is defined as the kind of learner they are with respect to

1. their self-image: self-evaluation of the quality and kind of student they are,
2. their expectations of other members' learning identities in terms of the roles and behaviors,
3. their perception of how others view them as learners, and
4. feedback from social interactions with others.

The first three sources of learning identity originate chiefly from how the individual sees their interactions with others, while the last source stems from opportunities to interact in the classroom CoP. Consequently, the inspection of learning identity must include data from the individual as well as the community with which the individual participates. Using this construct of physics learning identity, I will be able to probe student learning as identity development by establishing analytical tools to quantitatively measure and qualitatively examine learning identity as engagement with and relationship to the classroom community of practice.

References

Adams, W. K., Perkins, K. K., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2005). The design and validation of the Colorado Learning Attitudes about Science Survey. In 2004 Physics Education Research Conference, Sacramento, California, 4-5 August, 2004 (p. 45).

Beichner, R. J., Saul, J. M., Allain, R. J., Deardorff, D. L., & Abbott, D. S. (2000). Introduction to SCALE-UP: Student-Centered Activities for Large Enrollment University Physics. Proceedings of the 2000 Annual Meeting of the American Society for Engineering Education.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J.J., Deardorff, D.L., Allain, R.J., Bonham, S.W., Dancy, M.H., & Risley, J.S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. College Park, MD: AAPT.

Belenky, M. F., Clinchy, B., Goldberger, N. R., & Tarule, J. M. (1986). Woman's Ways of Knowing. New York: Basic Books.

Bianchini, J.A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. JRST, 34(10), 1039-1065.

Boaler, J. (1998). Open and closed mathematics: student experiences and understandings. Journal for Research in Mathematics Education, 29(1), 41-62.

Borden, V. M. H., & Burton, K. L. (1999). The impact of class size on student performance in introductory courses, the Annual Conference of the AIR in Seattle, WA.

Brahmia, S.W. & Etkina, E. (2001). Switching students on to science: an innovative course design for physics students. Journal of College Science Teaching, 31(3), 183-187.

Burnstein, R. A., & Lederman, L. M. (2001). Using wireless keypads in lecture classes. The Physics Teacher, 39(8), 8-11.

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer Instruction: Engaging Students One-on-One, All at Once. Reviews in Physics Education Research, 1.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small, New Directions for Teaching and Learning, 2000(81), 5-16.

Cuseo, J. (1998). Lectures: their place and purpose, Cooperative Learning and College Teaching, 9(1), 2.

Doolittle, P. (1999). Constructivism and Online Education. 1999 Online Conference on Teaching Online in Higher Education, 1–13.

Elby, A., Frederiksen, J., Schwarz, C., & White, B. (1997). EBAPS: epistemological beliefs assessment for physical sciences. In Annual Conference of the American Educational Research Association, March (pp. 24–28).

Etkina, E., & Van Heuvelen, A. (2007). Investigative Science Learning Environment–A Science Process Approach to Learning Physics. PER-based reforms in calculus-based physics. College Park, MD: AAPT.

Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., et al. (2006). Scientific abilities and their assessment. Physical Review Special Topics-Physics Education Research, 2, 020103.

Gardiner, L. F. (1994). Redesigning higher education: producing dramatic gains in student learning. Graduate School of Education and Human Development, George Washington University.

Gibson, J. J. (1986). The Ecological Approach to Visual Perception. Lawrence Erlbaum Associates.

Glass, G. V., Cahen, L. S., Smith, M. L., & Filby, N. N. (1982). School Class Size: Research and Policy. Beverly Hills: Sage Publications.

Graetz, K.A. & Goliber, M.J. (2002). The important of physical space in learning. New Directions for Teaching Learning, 92, 13-22.

Greeno, J.G. (1998). The situativity of knowing, learning and research. American Psychologist, 53(1), 5-26.

Henriksen, E. K. & Angell, C. (2010). The role of 'talking physics' in an undergraduate physics class using an electronic audience response system. Phys. Ed. 45(3), 279.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. The physics teacher, 30(3), 141-158.

Hewitt, N. M., & Seymour, E. (1991). Factors contributing to high attrition rates among science and engineering undergraduate majors, Unpublished report to the Alfred P. Sloan Foundation.

Ishak, M., & others. (2008). Improving the Training of Pre-Service Physics Teachers in Malaysia using Didaktik Analysis.

Johnson, D. W., Johnson, R. T., Smith, K. A., & Learning, W. I. C. (2000). Cooperative Learning Returns to College. Learning from Change: Landmarks in Teaching and Learning in Higher Education from Change Magazine, 1969-1999.

Kennedy, P. E., & Siegfried, J. J. (1997). Class size and achievement in introductory economics: evidence from the tuce iii data, Economics of Education Review, 16(4), 385-394.

Kopeika, N. (1992). On the relationship of number of students to academic level, Education, IEEE Transactions on, 35(4), 294-295.

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

Levine, D. W., O'Neal, E. C., Garwood, S. G., & McDonald, P. J. (1980). Classroom Ecology: The Effects of Seating Position on Grades and Participation. Pers Soc Psychol Bull, 6(3), 409-412.

Li, S. L. & Demaree, D. (2010). Instructor facilitation of PI as a mediator for student participation. Talk given at AAPT Conference, Portland, OR.

Mazur, E. (1997). Peer instruction: A user’s manual. Upper Saddle River, NJ: Prentice Hall.

McKeachie, W. J. (1999). Mckeachie's teaching tips. Houghton Mifflin Co Boston.

Nicol, D. J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: a comparison of two interaction methods in the wired classroom, Studies in Higher Education, 28(4), 457-473.

Powell, K. (2003). Spare me the lecture. Nature, 425(6955), 234–236.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. American Journal of Physics,66(3), 212–224.

Riggs, I.M. & Enochs, L.G. (1990). Toward the development of an elemntary teacher’s science teaching efficacy belief instrument.. Science Education, 74(6). 625-637.

Sommer, R. (1967). Classroom Ecology. Journal of Applied Behavioral Science, 3(4), 489-503.

Steinzor, B. (1950). The spatial factor in face to face discussion groups. J Abnorm Soc Psychol, 45(3), 552-5.

Taylor, J., Allie, S., Demaree, D., & Lubben, F. (2009). Effect of audience on reporting of measurement results. Talk given at AAPT Conference, Chicago, IL.

von Glasersfeld, E. (1995). A constructivist approach to teaching. Constructivism in education, 3, 15.

Weinstein, C. S. (1981). Classroom design as an external condition for learning. Educational Technology, 21(8), 12-19.

Wenger, E. (1998). Communities of practice: learning, meaning, and identity. Cambridge University Press.

CHAPTER III

TOWARD A MEASURE OF PHYSICS LEARNING IDENTITY: SURVEY DEVELOPMENT AND VALIDATION

TOWARD A MEASURE OF PHYSICS LEARNING IDENTITY: SURVEY DEVELOPMENT AND VALIDATION

Abstract

Innovative science curricula aim not only to improve students' content knowledge, but also to help students develop practices and skills of authentic scientists. To the students, these classroom practices often seem very different from their previous learning experiences in terms of behavioral expectations, attitude, and the nature of learning. We propose that students must modify their identity as learners in addition to refining their conceptual understanding for productive participation in this learning environment. This paper describes the development, validation and pilot study for a new survey instrument to measure student learning identity in a college physics classroom with a curriculum based on Investigative Science Learning Environment (ISLE). In order to measure changes in learning identity, we developed a 49-item survey to assess students' (a) expectations of student and teacher roles, (b) self efficacy towards skills supported in ISLE and (c) attitudes towards social learning. Using principal component in exploratory factor analysis, we have established two factors with six total reliable sub-scales (Cronbach's $\alpha > 0.65$) in the survey. Twenty nine items were retained in these two factors measuring physics learning self-efficacy and social expectations about learning. In the pilot study the validated instrument is able to measure average

changes across a ten week course to show statistically significant changes in one self-efficacy subscale and all three sub-scales in social expectations about learning.

Introduction

University introductory science courses are usually core mandatory requirements with large student populations, leading to high student to teacher ratios. These classes are frequently taught with traditional instruction where the lone instructor gives a speech behind a podium while the students listen quietly. However, students entering universities in the last decade are very different from the population of learners for which the “traditional” curriculum with direct instruction was designed. This population of students is not only larger (US census 2006, 2000), but they also have ample experience with the internet and other media that allow for highly interactive learning outside of the classroom. Traditional direct instruction in large lectures is poorly aligned with the richness of everyday learning. An examination of large enrollment classes reveals that they are often plagued by low attendance that decline over time (Gardiner, 1984), high course drop out and failure rate (Cooper & Robinson, 2000; Hewitt & Seymour, 1999; Kopeika, 1992), and low interest and motivation (Lord, 1999), and lower student performance in classes over 100 compared to classes of 3-90 students (Borden & Burton, 1999).

In response to the problems of large enrollment lecture courses, educators have made use of active engagement curricula such as peer instruction (Crouch & Mazur, 2001) and investigative science learning environment (ISLE) (Etkina & Van Heuvelen, 2007) to support classroom learning. Because active engagement (AE) curricula depends heavily on the social nature of learning, merely implementing AE without understanding the social context is not adequate for changing the way students learn.

A common problem in reports from teachers using AE in their classes is that many students initially offer resistance to social learning modes (Woods, 1994). There are at least two reasons for this response. First, most students have had over ten years of experience doing school where they have developed ideas about how students are supposed to behave in a classroom. These expectations are not likely to change overnight. Second, students may resist AE learning because the layout of many large lecture classrooms continues to reinforce this expectation of direct instruction. In the typical lecture hall, the many rows of seats front facing the single podium indicate strongly that students are expected to sit and listen which conflicts with the teacher's encouragements to engage in social learning. A common theme in both reasons is the perception of what a student is supposed to do in a classroom. In an AE learning environment, this perception is shaped by the students' ideas about the nature of learning, the social support for behavior and thinking in that classroom, and the feedback from the students experience interacting with this environment.

I propose that this perception about AE learning is part of the students' identity as learners in this community. Identity is important because it is the way students understand how to be a part of a community including how to interact with each other, what is relevant in the community, and what are the attitudes of that community. To become science learners and succeed in the community, students must modify their learning identity in response to the learning environment. Specifically, student expectations and attitudes about the nature of science and learning must change in order for students to participate productively in an active engagement learning environment.

The goal of this study is to develop an instrument that can measure large numbers of students at multiple points in time so that changes in identity can be examined. This instrument must target components of learning identity, and be specific to the ISLE learning goals which are central to the physics education reform implemented at Oregon State University. A survey is an ideal instrument for large populations, but the existing surveys in the literature do not address all of these requirements. Existing instruments measure self-efficacy toward teaching science (Ishak, 2008; Riggs & Enochs, 1990) but not specifically learning physics or in an ISLE classroom. Other instruments (Adams et al., 2004; Elby et al., 1997; Redish et al., 1998) allude to but do not directly address social learning. Therefore, the first step is to develop a reliable instrument to measure student learning identity (as defined in the next section) so that it can be used to examine changes over time and influences on conceptual understanding.

I will start by explaining the theoretical and conceptual underpinnings that frame the research questions. The analysis of this data will include quantitative statistical analysis of survey items for reliability and preliminary results from the pilot study to demonstrate the utility of this survey. I will conclude with the strengths and limitations of the study, implications about the population of students studied, and future work that would complement this instrument.

Literature review

Implementing of active engagement learning environments appear to support more effect and rich learning in physics classrooms (Beichner et al., 2000; Etkina et al., 2006; Hake, 1998). There are many subtleties in facilitating this learning environment that impact the resulting student learning gains. A common difficulty in implementation is student resistance to AE classroom practices because students have expectations and beliefs about learning and their identity as learners that are not well aligned with being a member in the AE classroom. To successfully facilitate learning in an AE classroom, I assert that we need to better understand what learning identity students bring to the classroom and how learning identity changes after participating in the learning community.

Learning in communities of practice

Just as learning in each individual is different, the setting in which learning occurs also play a unique role in enhancing or impeding one's ability to construct meaningful understanding (Greeno, 1998). In this view, students learn by attuning to the constraints and affordances in the learning environment in order to participate in the negotiation of meaning through social interactions (Lave & Wenger, 1991). According to Vygotsky, social interaction is "central and necessary to learning and not merely ancillary" (Lemke, 2001, p296). This is reflected in practice as proponents of social learning find improved performance on tests and course grades as well as attitude and interest in science (Beichner et al., 2000; Christensen, 2005; Crouch & Mazur, 2001; Hake, 1998; Smith et al., 2009). Wenger proposes that by engaging in social interactions, people learn by making sense of their experiences to help them function in the world (1998). The concept of a community of practice (CoP) is used to model a group of people pursuing a common goal through social interactions with each other (Wenger, 1998). Members of a CoP interact to shape practices, or ways of doing things, by contributing their ideas and negotiating the meaning of the existing ideas of what is expected or appropriate for that community (Wenger, 1998). Wenger's notion of a CoP can be applied to the AE classroom where the community members work together to become science learners and users.

The nature of learning through social interaction means that students have a voice in shaping and are expected to contribute to the practices of the classroom community. Consequently, knowledge and practices are developed in a shared manner so that members can become authors and defenders of knowledge. This notion of shared contributions is aligned with goals in many AE teaching strategies so that it is one indicator of how competent the students are becoming.

Learning as identity development

Using Wenger's notion of identity in a community of practice, we suggest that identity is the way we know how to be a member in a specific community. Identity is guided by interactions and perceptions as a result of participating in the CoP. Identity can be extended to a more holistic concept of a nexus of multimembership which is a compilation of our identities in each CoP of which we are members. While this is beyond the scope of this study, we acknowledge that there are factors beyond a single CoP such as a physics class that can significantly impact identity development.

Members of the classroom CoP have identities which encompass their perceived role, their relationship with others, their day to day interactions with others and their experiences in other CoPs. Additionally, identity includes alignment with the CoP in which the individual wants to pursue the common goals and believes the practices and are valuable for achieving the goals. A legitimate peripheral participant (LPP) is a novice member of the community engaging in an apprentice role with the expectation of a center-bound trajectory (Lave & Wenger, 1991). Many students entering an introductory college science course can be considered LPPs because they don't yet know the expectations and practices of this specific CoP. Most students quickly recognize the expectations of the classroom while the teacher acts as a broker who connects between two CoP such as the classroom and the physics community. As a broker, the teacher supports the students' apprentice role to engage in the community practices. At the periphery, students have the opportunity to participate in low-risk tasks such as listening to a small group discussion and using the vocabulary and norms of the community in order to gradually become a more central part.

For at risk students in college physics courses, a position of LPP may be related to low confidence level and low expectation of success in physics, feelings of being an "imposter" who isn't smart enough to have the right to be learning physics, and a lack of a sense of community due to having few peers with whom to identify (Brahmia & Etkina, 2001). Understanding of trajectories of identity development will be valuable in helping LPP students come to grips with being a genuine part of the community and feel able to engage in the classroom practices.

Self-efficacy theory further supports the need examine identity development as increasing participation because people are most likely to persist and improve at a task if they believe that they are capable of succeeding (Bandura, 1997). By actively engaging in classroom practices, students are more likely to have successful mastery experiences which are the most effective way to build self-efficacy and support the persistence in further engagement. An identity of a central member of the CoP thus includes actively participating in social interactions with CoP members, perceiving and expecting to be treated as a valued member who is able and allowed to affect change in the practices, and believing that engaging in these practices will achieve the common endeavor. Thus the curricular goal regarding learning identity is to move students from LPP to more central members of the classroom CoP.

The CoP is also fluidly evolving over time where “persons and practices change, re-produce, and transform each other” (Lave, 1993, p68). This temporal nature of the CoP means the relationships between variables such as facilitation of learning, classroom practices, and assessment of conceptual understanding must also be studied over time with a developing history rather than at a single point in time. For individual members, this history is the trajectory along which members become more or less involved in shaping knowledge and practices of the community. By studying how trajectories change, we can gain insight into how to support students being more involved and in control of their learning in class.

To examine learning identity in this study, we must first define the construct of physics learning identity (PLI) in a CoP where the goal is to become physics learners and users. This construct is informed by four sources from the students:

1. their self-image,
2. their expectations about their roles and behaviors,
3. their perception of how others view them, and
4. their experience of interacting with others.

These sources shape the identity in terms of feelings of belonging, beliefs about being capable, ideas about what members of this CoP do, judgments about whether they like participating in the CoP and if participation is worthwhile. These sources are consistent with the interactions and practices in a CoP that support students moving from LPP to more central members.

The assessment of learning identity needs to be able to sample a large number of students and measure student characteristics that contribute to identity as learners. A survey is an ideal mode of assessment for large populations. Existing instruments measure self-efficacy toward teaching science (Ishak, 2008) and sources of self-efficacy (Fencl & Scheel, 2005) but not specifically for learning physics or in an ISLE classroom which support specific practices that. Other instruments (Elby et al., 1997; Redish et al., 1998; Adams et al., 2004; Hazari et al., 2010) allude to but do not directly address attitudes towards social learning. For example, the most applicable dimension on the Maryland Physics Expectations Survey (Redish et al., 1998) considers expectations about how a student should learn physics but not how a student should learning physics with others. This is a crucial missing element because the CoP perspective regards learning as social interaction. Therefore this study aims to fill the knowledge void by developing a survey as an analytical tool to assess student physics learning identity from a CoP perspective in active engagement learning environments.

The survey was constructed to probe four dimensions which describe the first two sources of physics learning identity:

1. expectations of student roles
2. expectations of teacher roles
3. attitudes about social learning environments, and
4. physics learning self-efficacy.

These dimensions primarily addresses the first two sources of PLI mentioned previously—self image and expectations about roles and behaviors. Dimensions 1 and 2 in the survey probe the classroom practices as expectations about the CoP interactions. Dimension 3 probes alignment with CoP practices and goals while dimension 4 addresses self-efficacy about ISLE abilities since they are part of the curricular learning goals. This survey focus was selected because the self-reported nature of survey responses is suited to measure the self-evaluation involved in the first two sources of PLI as well as self-efficacy. The last two sources of PLI (perception of other's views, and experiences of interacting with others) address social interactions with others where the unit of analysis is not only the individual. These two social sources of PLI will be addressed in later studies.

Method

The development of this survey for pilot study involved three parts. In the first part, I describe the creation of the survey content based on the CoP and self-efficacy conceptual frameworks. In the second part, I conduct statistical analyses on pre-test responses to select a factor structure and assess its reliability. In the third part, the survey responses for the pre-test and post-test are used to measure change in physics learning identity in the pilot study student population.

The target population for this survey was students in a large-lecture active engagement learning environment using the ISLE curriculum. We selected the calculus based introductory physics sequence (PH21X) which is required for most engineers at OSU, and regularly consisted of 60-80% engineering majors and approximately 70% male students. In this (fall quarter of 2009) PH211 course (first quarter of PH21X), 497 students were enrolled. The majority of the students were white (66% White, 5% Asian, 4% Hispanic, 25% other or declined to respond), engineering majors (67% engineering, 12% science, 1% liberal arts, 1% forestry, 1% agricultural science, 18% other or undeclared) and male (80% male, 20% female). In this pilot study, the online survey was administered to students enrolled in PH211 which is the first term of the three in the PH21X sequence.

Prior to the start of term, the course instructor sent a welcome email to the 497 students enrolled in the course and invited them to take the survey on a voluntary basis. Before the first day of class, 145 students submitted survey responses. After removing incomplete submissions and those who did not answer item SE17 ("We use this statement to discard the survey of people who are not reading the questions. Please select "only a little" for this question to preserve your answers.") correctly, 130 responses were used in the analysis. Due to the voluntary nature of the survey, the responses may be biased towards a portion of the class that is more willing to do voluntary work. However the scales established in this study for measuring aspects of student identity are valid because items are grouped within a scale based on how they correlate with each other. This assumes that students would rate items that they perceive to be about the same idea in the same way regardless of whether they would rank that idea highly. For example, if a scale measures friendliness towards pets, a person who answers favorably towards cats would likely also rank favorably on an item about dogs. The reverse is true so the items would be grouped together in the analysis because they correlated, not because the population scored higher or lower on the particular scale.

The survey contains 49 statements or items for students to rank on a five-point scale. Eighteen self efficacy questions were modified from an existing instrument for self-efficacy about learning biology (Baldwin et al., 1999). The statements from the original survey were modified by replacing "biology" with "physics" and substituting ISLE abilities in place of biology specific task using similar sentence structure to those in the original survey. Students were asked to rate their responses about their confidence level on a five-point scale where 1 = "not at all" to 5 = "totally." The remaining thirty-one statements were created by the researcher based on the CoP framework and the construct of PLI. Responses were ranked on a five-point scale ranging 1 = "strongly agree" to 5 = "strongly disagree." The items were subject to face validation to check how the wording in each item could be interpreted on face value. A panel of experts consisting of two science education researchers who reviewed the items independently and negotiated the wording until meaning agreement was achieved. The reviewed items as shown in Appendix A were used to create an online survey on the physics department website. An additional statement (item SE17) was included in the survey to check if the students were reading each item before responding. The survey did not require a log in but could only be accessed with the specific link.

A large portion (~70%) of the population are male students since this course is required by most engineering majors at OSU; however, this heavily male distribution is typical of most calculus based introductory physics courses in other four year universities so the instrument can be applicable to similar courses. Students at OSU usually take their math and chemistry requirements in their freshman year before taking the physics sequence as sophomores. The pilot study population is not from the main sequence but the trailer sequence. The trailer sequence is often taken by sophomore students repeating the course or first time students who have AP credit in physics and math that allow them to take the course in the fall of their freshman year. This results in a bimodal population of generally academically weaker students and very strong students whereas the main sequence is a more homogenous group in academic ability.

Survey analysis

The items in the survey are analyzed using principal component exploratory factor analysis (EFA) to examine the survey factor structure and reliability analysis to create subscales for use. The survey responses for all 49 items were analyzed in SPSS version 18 using principle components EFA with varimax rotation to group survey items into factors that measure a single construct. This method partitions the total variance in the survey responses into independent components of successively smaller variance. Principal components analysis was selected because it is able to accommodate the variation in the student responses in the newly developed items by the researcher to create new scales. The resulting factors contained groups of survey items with factor loadings over 0.40 indicating that students responded similarly on the items as a group. As suggested by Kaiser (1974), I retained factors with eigenvalues over 1 and items with factor loadings over 0.40. Larger eigenvalues indicate more variance explained by the survey item, and factor loadings are a measure of how well the items within the factor correlate with each other. The self efficacy dimension formed three independent factors with no items crossloading from other items in the survey. The items for attitudes about social nature of learning and expectation of student and teacher roles contributed to factors containing items from all three dimensions. Consequently the three dimensions were combined into a single dimension describing student social expectations about learning within the classroom. The collapsing of the three dimensions is consistent with the nature of identity as both individual and communal according to the theoretical framework. This combined dimension also formed three independent factors.

Results and discussion

The survey had 49 items; the analysis produced two independent dimensions with six total factors or subscales based on 28 of the 49 items. For each of the two dimensions, the same EFA was conducted to refine the items into factors or subscales which measured a single construct. Each dimension was divided into three subscales containing three or more items as a result of the factor analysis. Each set of the three subscales explained about 60% of the variance in the student responses to items in their respective dimensions. Reliability analysis was conducted on the subscales from the EFA of each factor to determine how well the items in each subscale were related to each other. Physics learning self-efficacy contains three subscales using sixteen items. The survey items retained and grouped into the self-efficacy sub-scales are shown in Table 3.1. Cronbach's alpha for each subscale was calculated as the average of all the possible split-half correlations as a way to indicate how well items in a subscale measure the same construct. Items in each subscale were retained to maximize the subscale Cronbach's alpha. All three subscales had high reliabilities with Cronbach's alphas over 0.70 indicating strongly that the items within each subscale measure a single construct. The item-total correlations (ITC) for all three subscales were over 0.45 and further support the internal consistency of these subscales to justify grouping the item responses into a subscale score. The ITC is calculated using the average correlations between pairs of items in the subscale as well as the total score based on all items in the subscale. Both of these measures of reliability are above the typical criteria (alpha over 0.65; ITC over 0.40) for reliable subscales (Vaske, 2008). High reliability was expected since the items were modified from an existing validated instrument (Baldwin et al., 1999). Furthermore, the original survey had three sub-scales with items grouped similarly to the version modified for physics learning. These three subscales are also consistent with the conceptual framework and the curricular goals of ISLE.

The subscales for the physics learning self-efficacy factor measure 1) *self-efficacy in communicating physics knowledge* which is an integral part of learning through social interactions, 2) *self-efficacy in problem solving specifically using the learning cycle* that is central to the curriculum, and 3) *self-efficacy for succeeding in math and physics*. The names for these three subscales were created based on what the items in each subscale described as interpreted independently by two researchers. The interpretations matched well between the researchers with minor wording changes in the descriptions. Higher scores in self-efficacy are expected to predict higher actual success in those tasks according to self-efficacy theory (Bandura, 1997). We are interested in measuring self-efficacy for practices promoted in the AE classroom CoP as an indicator of students' willingness and ability to interact with the community as a result of their belief that they are able to engage in these practices.

Table 3.1. Reliability analysis of subscales in physics learning self-efficacy dimension

Item code	Item	Item-total correlation	α if deleted	α
Self-efficacy in communicating physics knowledge in a real world context[1]				0.86
SE06	How confident are you that you can convince another person of your reasoning?	0.58	0.85	
SE07	How confident are you that you can critique the reasoning of another person?	0.58	0.85	
SE12	How confident are you that you could ask a meaningful question that could be answered experimentally?	0.64	0.84	
SE13	How confident are you that you could explain something that you learned in this physics course to another person?	0.63	0.84	
SE16	How confident are you that after reading an article about a physics experiment, you could explain its main ideas to another person?	0.67	0.83	
SE18	How confident are you that after watching a TV documentary dealing with some aspect of physics, you could explain its main points to another person?	0.65	0.84	
SE19	How confident are you that after listening to a public lecture regarding some physics topic, you could explain its main points to another person?	0.64	0.84	
Self-efficacy for problem solving with ISLE learning cycle[1]				0.87
SE02	How confident are you that you could describe your observations of a physics event?	0.66	0.85	
SE03	How confident are you that you could use multiple representations (e.g. sketches, graphs, equations, etc) to reason about physical phenomena?	0.65	0.85	
SE04	How confident are you that you could come up with plausible explanations for patterns you observe in physics phenomena?	0.72	0.84	
SE05	How confident are you that you could devise an experiment to test your explanation of patterns?	0.68	0.85	
SE14	How confident are you that you could use a scientific approach to solve a problem at home?	0.65	0.85	
SE15	How confident are you that you could decide what would be a reasonable value for the answer in a physics problem?	0.65	0.85	

Self-efficacy in academic success (math, physics)[1]				0.72
SE08	How confident are you that you will be successful in this physics course?	0.65	0.49	
SE09	How confident are you that you will be successful in a calculus course?	0.47	0.72	
SE10	How confident are you that you will learn enough in this course to be successful in your next physics course?	0.52	0.66	

[1] Measured on a five-point scale ranging from 1 “Totally” to 5 “Not at all.”

Items from the social expectations about learning factor contained three subscales with sixteen items (shown in Table 3.2). All three subscales had acceptable reliabilities with Cronbach’s alphas over 0.65 and ITC over 0.35 which is above the 0.30 criteria for newly created items (Vaske, 2008). The first two subscales in this factor describe 1) *teacher and student as learning team*, and 2) *valuing group work for learning physics*. These subscales are consistent with the notion that being a member of a CoP means that one values the associated practices used and mutual contributions from community members. These two subscales also reflect key characteristics of knowledge and practice development as socially constructed. The second subscale *valuing group work for learning physics* has the lowest but acceptable Cronbach’s alpha (0.65) and low item-total correlation; however it is a reasonable start for newly created items because the item text has good face validity in that they all address using group work for learning physics. Since the participation with members in the CoP is key to learning, it will be important to retain and refine this subscale through improved wording of text and additional items. The third subscale measures how students perceive the responsibility for learning; it is consistent with the curricular goal for increasing student agency in being authors and defenders of the knowledge they construct. This subscale will help differentiate between learning environments where the responsibility to “make” students learn lies with the teacher rather than the student.

Table 3.2. Reliability analysis of subscales in social expectations about learning items dimension

Item code	Item	Item-total correlation	α if deleted	α
Teacher and student as learning team[1]				0.74
SR02	As a student, I am supposed to think about what the teacher tells me.	0.51	0.71	
SR09	As a student, I expect the teacher I expect the teacher to be willing to listen to what I have to say about physics.	0.60	0.61	
TR03	I expect the teacher to provide learning opportunities.	0.60	0.60	
Valuing group work for learning physics[1]				0.65
SNL01	To understand physics I discuss it with friends and other students.	0.40	0.60	
SNL03	Working together to come up with a solution to a physics problem helps me understand physics concepts.	0.56	0.48	
SNL04[2]	Learning in groups is not helpful because I have to take exams individually.	0.37	0.63	
SNL05	Trying to convince other students that my answer is correct helps me understand physics ideas.	0.40	0.60	
Student as responsible for learning[1]				0.70
SR04	As a student, I can help other students learn.	0.40	0.64	
SR05	As a student, I am responsible for making sure what the teacher tells me makes sense to me.	0.48	0.60	
SR06	As a student, I am responsible for seeking help when I do not understand.	0.56	0.60	
SR07	As a student, I am responsible for my own learning.	0.39	0.65	
TR05	I expect the teacher to acknowledge what I say in class, whether or not I am correct.	0.42	0.64	

[1] Items responses on a five-point scale of 1 = strongly agree to 5 = strongly disagree.
[2] Reverse coded for analysis.

The items that did not load onto factors may be inspected and rephrased for clarity. Additional items may also be created based on the subscales established in this study to strengthen the reliability.

Measuring identity change

Students enrolled in the fall 2009 PH211 were also asked to take the same online survey at the end of the 10 week term. Because there was another unrelated survey given at the same time, the roster was divided alphabetically by last name. Students with last name beginning with A-L were asked to take this identity survey. The post survey was administered online using the same website as the pre survey. Using the student pre survey responses (n = 130) and the post survey responses (n = 141), 51 matched responses were found. This matched population is 25% of the enrolled students and has 63% male compared to the 80% in the whole class.

A comparison of the whole pre survey population (n = 130) and the matched population (n = 51) is shown in figure 3.1 for each subscale. There did not appear to be a difference between the average pre survey subscale scores for the whole population and the matched subset which allowed for analysis using only the matched subset.

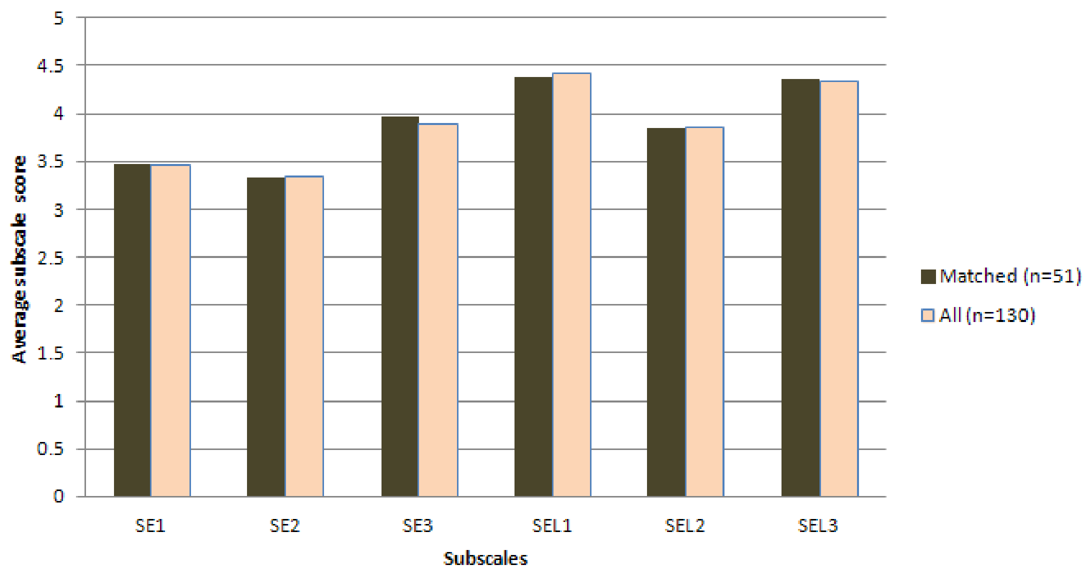

Figure 3.1 Comparison of average pre-survey subscale scores for all responses in Fall 2009 compared to the subset with matched pre-post surveys. (Subscale labels SE1 = Self-efficacy in communicating physics in a real world context, SE2 = Self-efficacy for problem solving with ISLE learning cycle, SE3 = Self-efficacy in academic success, SEL1 = Teacher and student as learning team, SEL2 = Valuing group work for learning physics, SEL3 = Student as responsible for learning)

Using the matched population, I compared the pre and post scores for each subscale. As shown in Table 3.3, the paired t-test results show that there were statistically significant differences in one of the *physics learning self-efficacy* subscales and all of the *social expectations about learning* subscales. Comparison using t-test is appropriate here because the subscale scores are averaged from the individual item responses making the scale continuous. The survey results show that this subset of the enrolled population believed they were “fairly” (3) to “very” (4) confident in their ability to learn physics in ways consistent with the ISLE goals. For *self-efficacy dealing with communication of physics in a real world context* and *solving problems using elements of the ISLE learning cycle*, students’ belief in their ability remain unchanged. This is consistent with the experiences of ISLE teachers who anecdotally report that students need about nine weeks to adjust to learning this way. After experience in this learning environment for a 10-week term, students more strongly believed in their ability to succeed academically in math and physics courses. This is a statistically significant ($p<0.01$) difference with a medium to large effect size based on Cohen's d of 0.67 (Cohen, 1988). Cohen's d is a measure of sample average differences that is standardized with respect to the standard deviation. A Cohen's d of 0.67 means the difference between the average pre and post subscale scores is 0.67 standard deviations. This is a promising development because success and persistence are correlated with higher self-efficacy (Bandura, 1997); the survey results suggest that asking students to learn physics through active engagement has a large effect on boosting their belief that they can succeed in the course. It should be noted that the other two self-efficacy subscales did not change significantly suggesting that students may not yet believe a change in their ability to do specific tasks such as communicate physics or problem solve in the ISLE context; however, the third subscale of self-efficacy in academic success may indicate a more general sense that students feel they are more capable in physics and math. This is potentially due to the many opportunities for students to engage in doing physics in lecture. The two most effective ways to increase self-efficacy are mastery experience and vicarious experience. Through peer instruction activities with clicker questions, students are usually asked to work with their neighbors or to convince other students of their reasoning. This provides regular opportunities for students to succeed in doing physics and easily observe others do the same.

Table 3.3 t-test comparisons of pre and post survey subscale scores as a measure of learning identity change

Subscale	Subscale score		Cohen's d
	Pre	Post	
Dimension 1: Physics learning self-efficacy[1]			
Self-efficacy in communicating physics in a real world context	3.45	3.46	0.02
Self-efficacy for problem solving with ISLE learning cycle	3.30	3.44	0.23
Self-efficacy in academic success (math, physics)	3.96	3.45**	0.67
Dimension 2: Social expectations about learning[2]			
Teacher and student as learning team	4.38	4.21*	0.40
Valuing group work for learning physics	3.84	3.57**	0.40
Student as responsible for learning	4.35	4.11*	0.46

[1] Measured on a five-point scale ranging from 1 "Totally" to 5 "Not at all."
[2] Items responses on a five-point scale of 1 = strongly agree to 5 = strongly disagree.
* t-test comparison to pre scores shows $p < 0.05$
** t-test comparison to pre scores shows $p < 0.01$

The students' social expectations about learning were fairly negative in that they tended to disagree with all three subscales prior to the class. The survey results after experiencing the course show that on average students still disagreed on all three subscales but less than before the course. These changes are statistically significant ($p<0.05$) with medium effect sizes based on Cohen's d (Cohen, 1988) which shows changes of almost half a standard deviation in the average means towards more favorable social expectations about learning. These student expectations about social learning are not surprising given the common prior learning experiences in traditional classrooms and the behavioral expectations conveyed by the large auditorium style lecture hall. However, the results of the survey indicate that a ten week period was long enough to begin to change the students' minds about active engagement learning environment in an ISLE based classroom.

Over these ten weeks, the teacher engaged in practices that were intended to change student expectations. During lecture, the teacher made explicit that she could not provide the students with pre-made notes because she was generating lecture notes with the class as they worked through problems and concepts. This practice was reinforced throughout the term where student input in problem solving and in-class experiments was regularly solicited and recorded on the class notes. The teacher was the main driver for this practice as a way to provide opportunities for students to contribute to the shared repertoire of knowledge. By engaging in this practice, students could experience being part of a learning team each with responsibilities for the CoP goal of learning physics. The favorable changes in social expectations about learning subscales suggest that students' physics learning identity may be aligning with the curricular goals and may be used to highlight particular students or subsets of the class to examine more closely.

Both teacher and students engaged in classroom practices that supported the subscale for valuing group work for learning physics. Students were asked to engage in group discussions about physics every lecture period. After about two weeks of lecture, students were more willing to engage in discussions as noted by the volume of student talk during group work and the number of students who engaged in conversation with neighboring students. It was observed that teacher prompting and encouragements significantly increased participation throughout the term suggesting that group work for learning physics needed to be supported even as students become more accustomed to the practice and the subscale indicated they were beginning to find social learning more valuable. Later in the term, more instances were observed where pockets of students continuing to have discussions after the teacher concluded the group activity. This suggests that students increasingly wanted to engage in group work on physics which may contribute to their expectation that group work is valuable for physics learning.

Conclusions

After removing items that did not load onto factors and dropping items from subscales to improve reliability, 28 of the 49 original items were retained and grouped into reliable subscales. While this fraction is low, it is reasonable since many of the items were not previously validated. Of the items modified from an existing instrument 16 of 18 of the original items were retained with high reliability. These results support developing a useful instrument for research on student learning identity in active engagement learning environments.

In the pilot study using the survey to examine a subset of the students enrolled in a calculus based introductory physics course, the subscales were sensitive enough to measure some statistically significant changes with medium effect sizes based on Cohen's d. The subscale changes over a ten week term suggest that students' learning identity is moving in the direction supported by the curriculum

A limitation to the use of this survey is that it does not address all aspects of physics learning identity as described in the literature review; identity is a rich and complex part of a person and a simple survey with two factors with six subscales cannot adequately describe the subtleties of identity. As stated at the end of the literature review, this survey was constructed to examine only the first two sources of physics learning identity because the self-reported nature of a survey is suited to probe the individual aspects but does not lend itself well to the more social aspects of PLI. As a first pass measurement to characterize students, this survey can be used to indicate the state of and changes in student identity in an active engagement classroom. The ability to categorize student identities provides a means to examine the details of various facets of identity including:

1. Characterization of each student to be sorted into high, medium and low ranges on each subscale/factor
2. Fine grained correlation analysis of high/medium/low scores in each subscale with assessments of student conceptual understanding
3. Characterize the class as a whole to help the teacher support student learning

I have developed a preliminary instrument that addresses some aspects of learning identity and demonstrated its reliability through statistical analyses. In future work, I will refine the items to improve reliability and use the instrument in conjunction with qualitative data to examine learning identity in a classroom CoP.

Acknowledgments

The authors wish to thank Larry Enochs, Sue Ellen DeChenne, Mark Needham, and the OSUPER research group for their contributions to this work.

References

Adams, W. K., Perkins, K. K., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2005). The design and validation of the Colorado Learning Attitudes about Science Survey. In 2004 Physics Education Research Conference, Sacramento, California, 4-5 August, 2004 (p. 45).

Baldwin, J. A., Ebert-May, D., & Burns, D. J. (1999). The development of a college biology self-efficacy instrument for nonmajors. *Science Education*, *83*(4), 397–408.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Worth Publishers.

Beichner, R. J., Saul, J. M., Allain, R. J., Deardorff, D. L., & Abbott, D. S. (2000). Introduction to SCALE-UP: Student-centered activities for large enrollment university physics. In *Proceedings of the 2000 Annual meeting of the American Society for Engineering Education* (pp. 18–21).

Borden, V. M., & Burton, K. L. (1999). The impact of class size on student performance in introductory courses. In 39th Annual Conference of the AIR in Seattle, WA.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small. *New Directions for Teaching and Learning*, *2000*(81), 5–16.

Christensen, T. (2005). Changing the Learning Environment in Large General Education Astronomy Classes. Journal of College Science Teaching, 35(3), 5.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, *69*, 970.

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer Instruction: Engaging Students One-on-One, All at Once. *Reviews in Physics Education Research*, *1*.

Elby, A., Frederiksen, J., Schwarz, C., & White, B. (1997). EBAPS: epistemological beliefs assessment for physical sciences. In *Annual Conference of the American Educational Research Association, March* (pp. 24–28).

Etkina, E., Personal communication (2009)

Etkina, E., & Van Heuvelen, A. (2007). Investigative Science Learning Environment–A Science Process Approach to Learning Physics. PER-based reforms in calculus-based physics. College Park, MD: AAPT.

Fencl, H. & Scheel, K. (2005). "Engaging Students: An Examination of the Effects of Teaching Strategies on Self-Efficacy and Course Climate in a Nonmajors Physics Course" *JCST* 35 (1), 20-24.

Gardiner, L. F. (1994). *Redesigning higher education: producing dramatic gains in student learning*. Graduate School of Education and Human Development, George Washington University.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64–74.

Hazari, Z., Sonnert, G., Sandler, P.M., & Shanahan, M.C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *JRST* 47(8), 978-1003.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 20*, 141-158.

Hewitt, N. M., & Seymour, E. (1991). Factors contributing to high attrition rates among science and engineering undergraduate majors, *Unpublished report to the Alfred P. Sloan Foundation*.

Hou, J. W. (1994). *Class Size and Determinants of Learning Effectiveness.* (ERIC Document Reproduction Service No. ED 377 239)

Ishak, M., & others. (2008). Improving the Training of Pre-Service Physics Teachers in Malaysia using Didaktik Analysis.

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika,* 39(1), 31-36.

Kennedy, P. E., & Siegfried, J. J. (1997). Class size and achievement in introductory economics: Evidence from the TUCE III data. Economics of Education Review, 16(4), 385–394.

Kopeika, N. S. (1992). On the relationship of number of students to academic level. IEEE Transactions on Education, 35(4), 294–295.

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

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. American Journal of Physics, 66(3), 212–224.

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, *323*(5910), 122.

Sommer, R. (1967). Classroom ecology. *The Journal of Applied Behavioral Science*, *3*(4), 489.

Tice, D. M., & Wallace, H. (2003). The reflected self: Creating yourself as (you think) others see you. In M. R. Leary & J. P. Tangney (Eds.), Handbook of self and identity: 91– 105. New York: Guilford Press.

Vaske, J.J. (2008). *Survey research and analysis: applications in parks, recreation and human dimensions*. Venture Publishing: State College, Pa.

Weinstein, C. S. (1981). Classroom design as an external condition for learning. *Educational Technology*, *21*(8), 12–19.

Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge University Press

CHAPTER IV

PROBING PHYSICS LEARNING IDENTITY: INTERVIEW AND CLASS OBSERVATIONS

PROBING PHYSICS LEARNING IDENTITY: INTERVIEW AND CLASS OBSERVATIONS

Abstract

Social interactions provide learning opportunities for facts and concepts. That is clearly not the only learning that occurs in social interactions. We also learn how to communicate with and understand each other, determine what behaviors are appropriate, decide if we like the interaction, and more. When we think about learning through social interactions in the classroom, we must also consider the learning goals beyond conceptual understanding and include the notion of students becoming science learners. Using a survey instrument to measure student identity physics learner, I selected a student as a case study to examine identity development in an active engagement classroom. The purpose of this chapter is to demonstrate the use of classroom observations and student interviews using personal meaning maps (Falk, 2003) as complements to statistical measures of PLI. Using this combination of research tools, I show a detailed case study of a student who appeared to be successful by traditional conceptual assessments and how his identity of a physics learner was influenced in our active engagement learning environment.

Introduction

At Oregon State University, the introductory physics sequence is undergoing curricular reforms in pedagogical classroom environment that heavily utilize active engagement in physics discussions as a learning tool. The curricular reform is modeled after the Interactive Science Learning Environment (ISLE) developed at Rutgers University with the following learning goals (Etkina & van Heuvelen, 2007):

1. Multiple representations: Students use multiple representations (graphical, mathematical, etc) to make sense of and justify their understanding.
2. Authentic skills: Students engaged in activities of authentic physicists to foster scientific skills such as conducting and evaluating experiments to test their explanation.
3. Ownership: Encourage students to be authors and defenders of knowledge.
4. Communication: Fostering scientific social interactions by taking on the practices of the general physics community in sharing understanding, supporting claims, and defending reasoning.

By providing opportunities for social interaction, we aim to support students' development as critical thinkers who can take these scientific practices to their major fields which are often not physics in the introductory course population. These goals are in part supported by engaging students in these practices as newcomers to the classroom and with the general physics community with teacher guidance. Through these learning experiences, students have opportunities to develop their identity as physics learners along with their conceptual understanding of physics. However subtle differences in classroom interaction facilitation can have vastly different learning outcomes for individual students as well as for the whole class. I assert that one way to attend to these subtleties is by being sensitive to the students learning identity. I will use the construct of physics learning identity (PLI) which is composed of four sources that shift the unit of analysis between the individual level to the community level. The four sources are the learners' (a) self-image, (b) expectations about their roles and behaviors, (c) perception of how others view them, and (d) experience of interacting with others. This paper aims to connect the individual dimensions of PLI to the more social dimensions as they pertain to learning identity development through student interviews and observations of classroom interactions.

In this study, I begin by motivating social interaction as a vital part of learning. I will then propose a conceptual framework with which to view aspects of this classroom. I will then present interview and classroom observation data to show the ways students participate and discuss findings about how students' PLI develop as they engage in the learning goals of the curriculum.

Learning through participation

Learning math and science by engaging in discussion and debate has been a major theme in many curricula such as Peer Instruction (Crouch et al., 2007), Tutorials in Introductory Physics (McDermott & Shaffer, 2002), and the ISLE curriculum (Etkina & van Heuvelen, 2007). A well known study in physics education examined gains in student performance in the force concept inventory, a standardized assessment instrument, for high school and college students studying introductory physics and found higher gains in students who learned in interactive engagement classrooms compared to those in traditional lecture classrooms (Hake, 1998). This trend persisted even across class sizes ranging from under 100 to over 200 students (ibid.). Utilizing interactive small group discussions in large lecture science courses, researchers report improved attendance retention over the term (Cooper & Robinson, 2000), students perception that group activities help their learning (Christensen, 2005), and positive affect towards the subject (Cooper & Robinson, 1999; Yazedjian & Kolkhorst, 2007).

On a more cognitive level, studies suggest that students are able to make more diverse and deeper connections and meanings with discussion in groups compared to individually (Hatano & Inagaki, 1993). They also suggest that students in discussion where they take sides and defend their reasoning makes the "comprehension more effective because it served to divide the task into several manageable parts" (Hatano & Inagaki, 1993, p340). In addition, McKeachie and Svinicki (2006) suggest that talking about ideas and concepts is a deeper thinking process than merely listening or repeating them. By engaging in deeper thinking processes, students are more likely to remember those ideas and concepts when they need to be applied (McKeachie & Svinicki, 2006).

Participating in the social interactions appears to improve and deepen classroom learning. This assertion is supported by the conceptual framework of a community of practice where learning is mediated by social interaction. This will be further explained in the next section. Therefore insight into how students make use of the learning environment to build upon their learning identity should center on the mechanisms and contexts of participation.

Conceptual framework

In the process of developing the authentic scientist abilities in ISLE, students develop both conceptual understanding and build identities of what it means to be a physics learner in this environment. Identity is the way people understand how to be a part of a community as guided by their personal perspective as well as interactions with the community. The identity of a physics learner in an academic setting is supported from two sides. From within the classroom, the context of the learning environment strongly influences the identity formation. From outside the classroom and past experiences, the students bring in their own understanding which also shapes their identity as physics learners in the classroom.

First I will consider the context of the learning environment. Human beings learn to function in the world and make sense of our experiences through social interactions (Wenger, 1998). According to social constructivism, learning requires social interactions where the participants come to understand more about the world by creating new knowledge for themselves (von Glasersfeld, 1995). The knowledge we build is thus more than the symbolic manipulation of ideas and information in the mind; rather, it also encompasses the ways of communicating and behaving which is situated in the context of the environment and its participants (Wenger, 1998). Wenger calls this context the community of practice (CoP) where the ways of interacting with participants, or members, of the community are considered practices. The specific context in which learning is situated mediates the process and outcome of learning (Greeno, 1998); therefore the context must be analyzed together with rather than separate from individual learning. Knowledge is developed with members in a CoP through “social relations in which persons and practices change, re-produce, and transform each other” (Lave, 1993, p68). In this perspective, a physics student interacts in the classroom CoP to build an understanding of conceptual knowledge (equations and laws), social knowledge (how to respectfully engage in debates), and disciplinary knowledge (what counts as evidence to support claims, conventions of recording data). The students may also contribute to the knowledge and practices of the classroom CoP by proposing alternative problem solving approaches (conceptual), suggesting the practice of asking disruptive students to leave the classroom (social), or using unconventional axis labels on a graph by justifying that the labels were arbitrary in the first place (disciplinary).

When students arrive at a college classroom, they are already experts at being students and bring with them prior knowledge and expectations about what students do. However, they are newcomers to the specific classroom CoP. Often students begin as legitimate peripheral participants (LPP) who are recognized as a member of the community who may not fully engage in the practices of the community as they begin to make sense of those practices. As newcomers interact with others in the community "through a social process of increasing centripetal participation, which depends on legitimate access to community practice" (Lave, 1993, p68), they come to negotiate and make sense of the shared practices. The process of moving between being a less active peripheral member and a more active or "central" member of the CoP is what Wenger terms the trajectory (1998). Students develop their physics learning identity as they move along their own unique trajectory over time. I will study this development through in class observations of student engagement with other members and the practices of the community.

Second, I must also consider the student background and experiences from beyond the classroom because learning about physics is not confined to the physics classroom. The sociocultural perspective incorporates the historical and social aspects of an individual to frame the identity development (John-Steinger & Mahn, 1996; Wertsch, 1988). First, students bring with them previous experiences with school and science that are historical foundations that inform the way they participate in the physics classroom community. Second, the time students spend in the classroom is very small compared to the rest of their waking hours during which they may do physics. Looking beyond the four walls of the classroom where students also engage in scientific endeavors, we can examine how these communities of practice are linked to and interact with the classroom community to support PLI development.

The implication of these two ways of influencing learning identity in a classroom is that while the individual student is the focus of analysis, the unit of analysis needs to flexibly include the historical and social learning environment. Specifically we must examine the student discourse as it mediates participation in classroom interactions, and we must also examine the students' prior experiences and existing notions about doing physics.

Examining participation as discourse

I have asserted that learning is mediated by social interactions; therefore the primary mode of participation in the science classroom CoP is verbal discourse. While non-verbal modes of discourse also play a role in social interactions, scientific discourse involves presentation of information and reasoning which is highly language based. However by nature of interacting with other people, non-verbal modes of communication must be considered in this study although not as the main focus.

Using psychology, linguistics and anthropology, Cazden (2001) examines the use and development of language in school learning with a focus on how classroom linguistics connect to knowledge building by reconceptualizing learning in the context of the classroom environment as a community of learners. In order to examine the diverse range of classroom discourse, Cazden characterizes three features of classroom language:

1. Language of curriculum: to convey cognitive information,
2. Language of control: to establish and maintain social relationships,
3. Language of personal identity: to express attitude and identity (Cazden, 2001).

Using these functions of language to guide the analysis, Cazden studies patterns in language use as they help establish what counts as knowledge and learning, and help students appropriate socially constructed knowledge into their mental knowledge systems (2001). In the ISLE classroom, students make use of all three features of language in their negotiation of knowledge and practices. Conceptual knowledge is largely supported by the language of curriculum; this is the most prominent feature of classroom language. Social knowledge is supported by the language of control that helps community members figure out how to engage in scientific discourse while maintaining desired social relationships. Disciplinary knowledge is about the norms of the community; the language of personal identity can be used to express how the member relates to the community in terms of alignment of goals and feelings of belonging.

Cazden considers the patterns in discourse in the classroom community of learners as “situated language use in one social setting” (2001, p3). In schools, these patterns are unlike out of school conversations because classroom discourse is often switching between monologue and dialogue under the control of the teacher rather than shared by multiple conversants. This results in sequences of talk that are easily recognizable as “classroom talk” as distinct from real world talk. In non-traditional classrooms characterized as discourse intensive, the patterns of talk may still begin like classroom talk but lead to more complex and extended discussions with no fixed pattern but instead an overall goal such as “help[ing] students articulate their beliefs and conceptions” (van Zee & Minstrell, 1997, p212). Discourse patterns that contain aspects of real world talk with shared conversation in the classroom context may help students use their classroom knowledge in situations outside of the classroom.

Examining the practices of the classroom community in addition to classroom language, Engle and Conant (2002) draw on cognitive science and discourse analysis to study student engagement in discussion-based learning. Specifically, the analysis of classroom discussion centers on the construct of productive disciplinary engagement (PDE) in a community of learners. Engagement in classroom discourse is defined to involve a coordinated group effort to make substantive contributions to the discussion that is characterized by body position and eye gaze towards other members of the group, emotional displays and prolonged or repeated engagement (Engle & Conant, 2002). The disciplinary aspect is similar to the idea of contextualization discussed by Cazden in that the discussion has some connection to the issues and practices of the discipline or the real world that students are able to recognize and utilize in discussion. This conception of discipline is what I have referred to as the general CoP which consists of practitioners in the field beyond the members of the classroom CoP. What makes disciplinary engagement productive is characterized by students making intellectual progress, increasing sophistication in argumentation, being able to recognize confusion, and connection ideas (Engle & Conant, 2002). The authors further describe the aspects of the learning environment that support students in PDE with four principles which are consistent with the ISLE goals in our physics classroom.

1. Problemetizing: involves students being encouraged to take on intellectual problems by sustaining the discussion over a period of time and by legitimizing the activity as valued,
2. Authority: involves student agency in being a contributor with power to affect change and being a stakeholder who takes ownership of the knowledge constructed,
3. Accountability: involves being responsive to the contributions of others such that each person is responsible for justifying knowledge authored and

negotiating ideas contributed according to the dynamic practices and meanings of the CoP,

4. Resources: involves being provided with adequate resources, such as time and reference materials, to achieve PDE (Engle & Conant, 2002).

Using these ways of supporting PDE, classroom activities can be analyzed to examine when these supports are present in learning environment. These categories can also be used to highlight when and how students are engaging in the practices supported by the learning environment.

The affordances and constraints pertaining to the practices, social interactions and expectations of a learning community mediate the students' relationship to the discipline. In a study of two very different learning environments in high school mathematics classrooms, Boaler (1999) found that learners develop not only difference ways of doing math, but also different identities as math learners depending on the learning environment. In the “open” classroom characterized by increased peer interactions and student choice, Boaler found that while conceptual test performance was similar to the more traditional “closed” classroom, students in the “open” classroom were more likely to be creative in their problem solving and to like doing math (1999). In the salient points of Boaler's work on situativity and the role of participation are that we must study student engagement in learning activities in classroom learning environment as “intact activity systems”(IAS) (Greeno & MMAP, 1998) rather than as qualities of individuals or as events independent of the learning environment. Consequently, the results of her studies suggest three major implications about learning.

1. The behaviors and practices of the participants are emergent from the IAS.
2. The types of practices in which students participate mediate the type of knowledge built.
3. The student's knowledge of how to do math and what it means to do math bring to bear upon his/her ability to use math knowledge outside of the classroom learning environment (Boaler, 1999).

Cazden's work focuses primarily on the behaviors and practices of participants as students engage in verbal discourse while Engle & Conant detail practices in desired type of participation for optimal knowledge building. Additionally, the types of practices in which students participate mediate the type of knowledge built (Boaler, 1999). In this way, Boaler extends the conceptual framework to connect the type of knowledge built as constituted by the classroom practices (1999). Additionally, Boaler's framework differ noticeably from the other two researchers in that the constructs of affordances and constraints allow factors to be considered to be either or both depending on the context of learning. This also provides for greater flexibility to describe and analyze the learning environment where the features of language use may be inadequate or definitions of PDE too narrow. As a result, Boaler's framework supported by perspectives and constructs from the work of Cazden and Engle & Conant is used to yield a more complete analysis of the classroom interactions in our ISLE based physics class.

This paper considers the learning experience of a student in this classroom in the context of their personal experience and history. This perspective is appropriate because "to be truly skillful outside school, people must develop situation-specific forms of competence" (Resnick, 1987, p15). By attending to the context of classroom participation and discourse in conjunction with what students bring from outside of class, I can better understand the mediating factors of learning identity development in the classroom CoP and how students may be supported in recontextualizing their understanding in new situations or contexts outside of the classroom. I will examine participation and the associated environmental, social and historical mediators in order to characterize the classroom community for deeper understand. I will do this with a case study of a student through in class observations and an individual interview. This will showcase how the PLI fits in with the students' lives connected to the physics classroom community and enable us examine how the students' perceived identity is brought to bear on building competence in the classroom CoP.

Method

The target population for this survey was students in a large-lecture active engagement learning environment using the ISLE curriculum. In Fall of 2009 prior to the start of term, students in this PH211 course were invited to take the online survey developed to measure physics learning identity along two dimensions: physics learning self-efficacy and social expectations about learning. Using the survey results, student responses were scored along the following six subscales (three in each dimension).

1. Self-efficacy in communicating physics in a real world context
2. Self-efficacy for problem solving with ISLE learning cycle
3. Self-efficacy in academic success (math, physics)
4. Teacher and student as learning team
5. Valuing group work for learning physics
6. Student as responsible for learning

Using these scores, a subset of the student population was selected based on having extreme high or low scores on the subscales. Of this subset of students, ten students agreed to be closely studied in the classroom observations described next. These students also agreed to participate in individual end of term interviews.

In order to examine the practices in the classroom community as interactions mediated by discourse, audiovisual recordings of a small subset of the student group work during lecture were collected and transcribed. This was recorded with video cameras and wireless microphones placed on the student desks. Because there are only three video cameras, recording of student interactions in lecture was rotated through the group of students. A researcher observing the class used a rubric to record the types of interactions and activities observed. The observation rubric was developed based on the potential interactions between teacher and student, student and student, and teacher addressing the whole class. Over time the rubric (shown in Appendix B) was refined by adding interactions in the learning cycle specific to the ISLE curriculum and by clarifying teacher interactions based on actual practices observed in class.

In order to explore the role physics plays in the students' daily life, interviews were conducted with individual students using personal meaning maps (Falk, 2003). At the end of the ten week quarter, I invited the ten students from the group selected using pre-survey scores previously described. Prior to the interview, these students were also asked to answer four questions (Shown in Appendix C) via email. Their written responses were used to guide the interview conversation. Each student was invited for an individual thirty minute semi-structured interview conducted by one researcher. In order to examine the student's perception of the communities of practice, the interviews were conducted using the personal meaning map (Falk, 2003) as a tool to minimize researcher bias as well as allow the student to think beyond the practices in lecture. To create the personal meaning map (PMM), the student was given a blank piece of paper with the word *physics* printed in the center. The student was instructed to "Write down as many words, ideas, images, phrases or thoughts as come to mind when you see or think of physics." Five minutes were allotted to filling out the map, and the remainder of the interview was a discussion of the contents of the map. To start the conversation, the interviewer asked about the student's thought process while drawing the map. The conversation was student driven and open ended questions were asked for clarification. Students were encouraged to describe, from their perspective, the out-of-class contexts where they do physics and the physics practices that are inherent in those communities of practice.

Analysis and Discussion

Students with extreme high or low scores were selected to participate in the study. Subscale scores can range from 1 to 5. Since the average subscale scores for all students who volunteered to take the survey were skewed high (self efficacy scales average 3.56, social expectations about learning scales average 4.20), extreme low was defined to be scores below 3.00 and extreme high was defined to be scores above 4.50. In this subset of students, ten agreed to be video recorded during lecture with wireless microphones on their desks for audio recording. These ten also agreed to be interviewed at the end of term. The pre survey subscale scores for each student are shown in Appendix D with their final course grades. These students encompassed a range of course performance (course grades from A to C+) and degree of classroom participation as observed by the researcher during lecture.

From this group of ten students, student E was selected to as a case study. For ease of discussion, I will rename this student Erik for the remainder of this dissertation. Erik was an interesting case because he was able to succeed by traditional standards of exams and grades in the course with minimal identity change. Using conventional conceptual assessments, Erik would have been a simple success story. However using the survey results, interview and classroom observation data, I am able to examine the ways in which the learning environment often failed to support growth his identity as a physics learner.

Erik did very well in the course in terms of exam scores and course grade. He often sat in the second row from the front of the classroom, attended class regularly, engaged in group work activities, and very rarely spoke up in the whole class setting. At a glance, he looks like a student who is able to succeed in the PH211 classroom, is engaging in practices of the CoP, and in general a student who does not warrant much worry or attention from the teacher. However, on deeper examination, Erik is performing the conceptual tasks and social practices expected in the CoP without having to change his learning identity. I argue that there was no motivation to change because his existing learning identity and cognitive abilities were adequate for success in the CoP with small cosmetic changes to his practices. I will present his case first with PMM interview to establish his attitude and orientation toward his experience in the ISLE classroom. Then I will present a description of a small group discussion activity to show how he engages in the classroom practices.

Personal meaning map interview

The personal meaning maps were varied in the way students expressed their thoughts in terms of representation (pictures or words) and organization (outline form, scattered around the word *physics*, elaborate webs connecting relating ideas). However there are also similarities in that all students wrote down many of the concepts covered in class suggesting that their identity as physics learners are significantly grounded in practices and concepts on which they were evaluated. Additionally, each student represented some of those ideas as diagrams or graphs. This is consistent with the ISLE goal to encourage students in using multiple representations in their problem solving process.

Erik's personal meaning map (shown in Figure 4.1) is very typical in that it is entirely text with a few equations. Most students make a list of topics in the course when asked to draw a PMM and ignore the word "physics" in the center. Erik took this one step further and wrote his map with the word up-side-down. His list began with a series of equations and led to ideas related to his major as a nuclear engineer. He explained the top right section were "random thoughts;" but when he reached the bottom left section, he was trying "to go back to what physics means to me." This section involved three main ideas: (a) connecting observations to math, (b) explaining phenomena, and (c) ideas about forces discuss in class with a nuclear physics focus. The first two ideas were reiterated in the discussion that followed. The third idea is consistent with his being a nuclear engineering major in that his thinking about physics is tied back to his expressed area of interest.

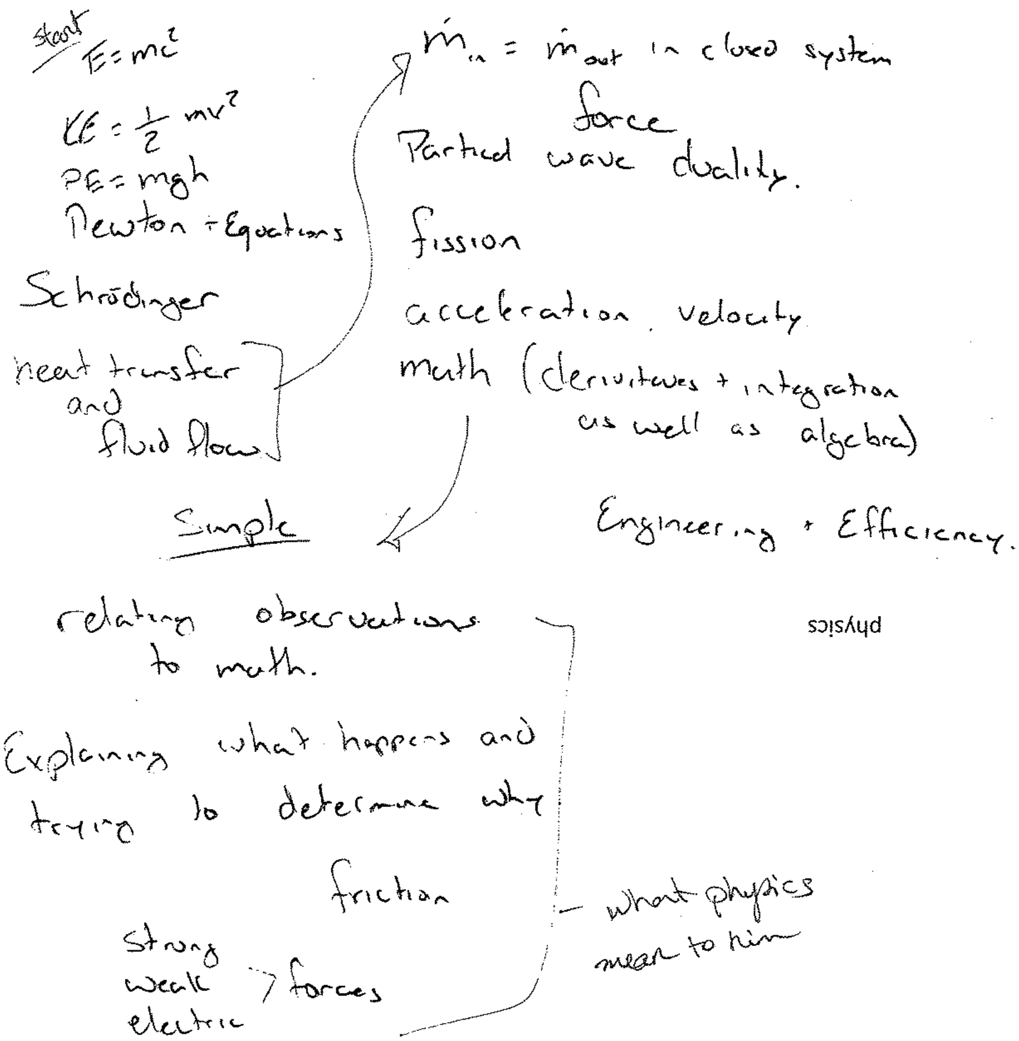

Figure 4.1 Erik's personal meaning map (Label "start" at the top left corner, arrows and comment "what physics mean to him" are added by the interviewer as clarifying notes during the interview)

Mathematical equations were a large part of problem solving for Erik and it was something at which he excelled. In his previous experiences with physics tests, he was expected to recall equations from memory and to solve problems quickly.

When Erik explained his approach to problem solving, "it's just grabbing an equation and putting in the numbers." Beyond that, "there's not any further thought that I need." This attitude was consistent with his written response to the first email question that asked him to rank a list of skills in order of importance for succeeding in physics. His top two choices were "solving equations" and "looking for patterns in physical situations/observations." Erik explained this priority:

> "I'd say that looking for patterns… gives you the equations you need. When you look at the physics problem you're trying to see what's happening, and you know last time I had a problem like this. So you relate the two patterns, you rate the likeness, you know which equations you need to solve. And then it goes right back to that. The goal is just basically getting a number."

His explanation suggests that equations and math are his primary tools when engaging in problem solving. He felt so strongly about this way of solving problems that while he was giving his explanation above, the interviewer tried twice to comment or ask a question and Erik talked over both attempts. His approach to the practice of problem solving appears to be sophisticated and flexible enough to accommodate the problem solving required in this class. As a result he saw no need to make significant changes to his thinking. This attitude is also consistent with his survey scores for the subscales dealing with physics learning self-efficacy which are all fairly high with a full 5.00 for his belief that he will succeed academically. He is the least confident that he can solve problems using ISLE steps which is reflected in his having a different way to solve problems that worked very well for him in this course.

Another part of doing physics is explaining phenomena. While Erik's PMM showed that he recognized this as a feature of doing physics, his interview responses suggest that he is not interested in "[understanding] the why but rather the how." In particular, he described his strength and weakness in helping others solve physics problems.

> "I can help somebody figure out what they need to do to get through the problem, but as far as understanding the why's behind it, it doesn't… I don't find it interesting. I don't care why it happens the way it does. I know it does and I can solve it. So I don't… when I'm helping someone else, I don't emphasize "you use this equation *because* it makes sense because of this." You just use it because you do because that's what you're supposed to."

In this passage, Erik stressed acknowledged twice that explaining why is a part of doing physics that he does not want to do. First that he doesn't find "the why's behind it" interesting, and second that he doesn't emphasize the "because" when helping someone else. The word "because" is in italics here to indicate the tonal emphasis he used. The word was drawn out and spoken slower relative to the rest of the sentence as though it was laborious. In contrast, the last sentence describing his reason for his choice of solution was spoken more quickly suggesting that this was more straightforward to him. In other words, he appeared to view problem solving as a task to "get through" rather than a situation to study at length.

To use the terminology of productive disciplinary engagement, I assert that Erik was not problemetizing the activity of working the problem. From his point of view, there is little value in extending the problem solving tasks because "the easiest way for [him] to learn is to get a problem and practice, and just example after example." In another response about problem solving in situations where he does not have prior knowledge (as he did in this physics class), his response was consistent with this view.

> "I guess my attitude toward it is you read the problem and you put methods into it [gestures back and forth with right hand perpendicular to table, inserting hand forward and down] and if they don't work you try a different method. You end up getting it done."

Erik's description further demonstrates that he considers problem solving to be more like a straightforward physical task rather than a mental deliberation. Here he explained that "you put the methods into it" by gesturing with his hand as though placing a physical object into the problem. His emphasis at the end that he "ends up getting it done" was echoed in his comment from the first passage that the "goal is just basically getting a number" and in the second passage that he can help other students "to get through the problem." This belief about problem solving was challenged but appeared to remain unaltered by this course because he was able to achieve success in the course assessments. While this belief appear to prevent him from engaging more deeply with physics, I show later in the episode of classroom interaction that he is willing to engage in sense making when someone else initiates the problemetizing of the activity.

Another emergent attitude from the PMM interview conversation was that Erik appeared to take a good deal of responsibility and initiative in his learning. When he has difficulties with a problem, he doesn't like to ask for help before having a chance to "figure it out by [himself] first" because the process "re-emphasizes what [he's] learned for [himself]." In this sense, Erik believes that he is responsible for his own learning and he clearly regards the learning gain as his own. Yet his survey score for the subscale measuring *student as responsible for learning* shows that he strongly disagrees with this notion. This inconsistency is less contradictory upon inspection of the items in this subscale (shown in Table 3.2). More than half the items involve being responsible for learning in a social context such that the responsibility is not only for doing the work yourself. This notion of learning responsibility is derived from the CoP framework where learning is common goal so each member has the agency and responsibility help achieve this goal. From Erik's responses, his idea of being responsible for learning involves working hard individually. This mismatch in definition highlights the fact that Erik's identity as a learner in this classroom is largely unchanged because his prior experiences have established a learning identity with attitudes and practices that continue to serve him well in the PH211 CoP.

Classroom observation of small group discussion

Described here is an example of a small group discussion involving Erik and two other students during lecture. This discussion occurred in week 9 in a 10 week quarter so the students have had time and exposure to develop a foundation of common meaning and practices to support their learning in this activity. The class had just observed a demonstration where they discussed the potential and kinetic energy of a swinging bowling ball. The activity was introduced with the teacher prompt, "And now it is your turn. I want you guys to do this with your neighbors and I'll come around and look." The problem description and instructions were shown on projector screens for the duration of the activity. The problem asked the students to use energy bar charts to represent a cat that falls off the roof and interpret into mathematical representations.

One curricular goal supported by the social interactions in this classroom is to help students learn to engage in scientific dialogue that uses the language of curriculum. In discussion 1 below, Erik's group has determined what the problem asked them to do and they begin to figure out how to answer this problem involving a cat falling off a roof. The group consisted mainly of Erik (E) and student 2 (S2) working with each other while student 3 (S3) thought out loud.

Line		
18	S2:	We just need to define this…
19	E:	…the states. So initial is… exactly what it says, just after leaving the roof. [S2 writes]
20	S3:	[to himself] Well initial and final would be the same… but…
21	E:	[to S2] And then you have to state the origin is… the ground.

(Discussion 1)

The language used in this discussion was predominantly for conveying cognitive information such as the location of the origin. Erik and S2 were engaged in two practices of the classroom CoP that were imposed by the teacher and the discipline. The first practice in which the students engaged was clearly defining the parameters of the problem such as the initial state (line 19) and the location of the origin (line 21). This practice is imposed by the teacher by providing on the first day of class a detailed problem solving rubric where one of the first steps is to define parameters. This practice is reinforced throughout the term as the teacher modeled the problem solving process in lecture. The way both students said that they "need to define" and "have to state" the parameters suggests that they engaged in the practice because it was required of them and they had little say in the matter. The second, more subtle practice in which students engaged in was using a common set of terms and phrases such as "initial and final [states]" and "origin" imposed by the discipline in order to talk about physics. The students' use of the terminology indicated that they understood this is how physicists talk and they accepted aspects of physicist identity by using this language.

Later on in the same discussion, the group of students tackled the more open ended question of selecting a system that would be helpful for considering the phenomenon of the falling cat. Here, S2 was focused on doing individual work while S3 engages Erik in a discussion about the system choice in the problem.

Line		
43	S3:	[turns to Erik who turns to face S3] Would the system be the… I know it's the cat and Earth at least, but would the… roof be part of the system or…
44	E:	It wouldn't need to be.
45	S3:	Yeah…
46	E:	Cause the only thing interacting is the cat with the ground, with the Earth due to gravity.
47	S3:	Yeah.
48	E:	That's our only interaction. We're going…
49	S3:	It's pretty much just the position and place. [pause] Doesn't add or take anything away from it, except just gives it a position for the cat to be on.
50	E:	It is what gives the cat the initial potential energy.
51	S3:	Yeah.
52	E:	Cause the cat got up there. That's what it amounts to. If you get up there you've expended energy, you have to gain that back to get back down.
53	S2	[Erik turns to look at S2's notebook] We didn't really write a mathematical representation, did we?
54	S3	[Erik turns back to face S3] Yeah. But technically though, if you expend the energy to go up and go back down… you technically… physically, in

> physics you gain… it's equal but when… biological sense, you don't get it back.
>
> (Discussion 2)

One practice in which the students engaged was to support their claims with justification. This practice was described as a step in the previously mentioned problem solving rubric; it was regularly modeled by the teacher, and it was elicited by the teacher when students answer questions before the whole class and in small group discussion. Due to the open-ended nature of the question the students were trying to answer, students had more choice in how to answer and defend their choice with reasoning in the process of creating the shared meaning of appropriate system choice. The justifications of Erik tended more towards reasoning similar to those given by the teacher who used interacting objects to decide what needed to be in the system; Erik cited interactions in his explanations twice in line 46 and 48. In contrast, the justifications of S3 tended more towards reasoning that had to do with the physical situation; S3 explained the purpose of the roof in the problem in line 49 and pointed out the logical prerequisite and consequence of "the cat [getting] up there." Both types of justification were accepted by the two students engaged in the discussion which suggests that the students were aware of the greater degree of flexibility afforded by the type of question and multiple explanations are reasonable.

It should be noted that the problem does not ask the students to make a system choice although the problem is contextually rich for supporting such a discussion. The rich context and open-ended nature of the physical situation provided an opportunity for the students to problemetize and delve into sense making beyond answering the question. Recall that Erik's primary problem solving goals as reflected in his PMM interview responses is to get through the problem and find the answer. In discussion 2, S3 prompts Erik to engage in a conversation beyond fulfilling Erik's problem solving goals. While Erik did not initiate the conversation and almost shut down the conversation in line 44, he became willing to engage in meaning making that drew on resources outside of the immediate problem context. At mentioned before, Erik's reasoning at the start of the discussion used concise physics language. As the discussion proceeded, Erik's justification involved more of the physical situation and sense making language (line 52) that sounded more like everyday conversation. This shift in language of the curriculum to everyday language suggests that Erik's reasoning perspective was moving from how physicists think to how he personally thinks. This shift appeared to hold his attention strongly enough that he was only momentarily distracted in line 52 by S2's comment that they have not completed the task. Erik did not answer S2 except with a brief look and immediately turned back to the conversation with S3 in line 54. In this instance, the openness of the task and interaction with S3 were able to provide a context in which Erik appeared to become interested in the "why's" of the problem.

Based on Erik's PMM interview and observations of his classroom interactions, it appears that his prior experiences and his attitudes about learning act as constraints to changes in his learning identity. However, ISLE classroom affords him opportunities to experience problem solving as meaning making in addition to answer seeking. As a result, his trajectory over the course of the term became more central in the sense that he did participate in the social interactions and engaged in some meaning making; however his alignment with the beliefs and attitudes of the nature of learning remained fairly peripheral in terms of this classroom CoP because his existing identity of a science learner was not often sufficiently challenged to motivate growth.

Conclusions

While the current curricular reforms can aid student learning in developing some practices of authentic scientists, the interview analysis revealed that participation in the class community of practice and success in course performance were not sufficient to affect changes in learning identity as promoted by the curricular goals. Rather we have to also take into account the students' prior experiences and existing learning identity in order to facilitate student development into central members of the classroom CoP in terms of both conceptual mastery and science learners. The more holistic view of student physic learning as a participant of a learning community derived from analysis using the set of tools described in this study would help teachers attend to the students' learning needs and inform teachers how to attend to details in the classroom interactions and practices that foster identity growth.

References

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1997). *Women's ways of knowing: The development of self, voice, and mind*. Basic Books.

Boaler, J. (1999). Participation, knowledge and beliefs: A community perspective on mathematics learning. *Educational Studies in Mathematics*, *40*(3), 259–281.

Boaler, J. (2000). Exploring situated insights into research and learning. *Journal for Research in Mathematics Education, 39*(1), 113-119.

Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning*. Portsmouth, NH: Heinemann.

Christensen, T. (2005). Changing the Learning Environment in Large General Education Astronomy Classes. *Journal of College Science Teaching*, *35*(3), 5.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small. *New Directions for Teaching and Learning*, *2000*(81), 5–16.

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer Instruction: Engaging Students One-on-One, All at Once. *Reviews in Physics Education Research*, 1.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, *20*(4), 399–483.

Etkina, E., & Van Heuvelen, A. (2007). Investigative Science Learning Environment–A Science Process Approach to Learning Physics. *PER-based reforms in calculus-based physics*. College Park, MD: AAPT.

Falk, J. H. (2003). Personal meaning mapping. *Museums and creativity: a study into the role of museums in design education*. Powerhouse Publishing, Sydney.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64–74.

Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. *Perspectives on socially shared cognition,* 331–348.

Lampert, M., Rittenhouse, P., & Crumbaugh, C. (1996). Agreeing to disagree: Developing sociable mathematical discourse. *The handbook of education and human development: New models of learning, teaching, and schooling*, 731–764.

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on socially shared cognition*, 63–82.

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

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316.

McDermott, L., & Shaffer, P. (2002). *Tutorials in introductory physics*. Upper Saddle River, NJ: Prentice Hall.

McKeachie, W. J., & Svinicki, M. (2006). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers*. Houghton Mifflin Boston.

Resnick, L. B. (1987). Learning in school and out. *Educational researcher*, *16*(9), 13–20.

Van Zee, E. H., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education*, *19*(2), 209–228.

von Glasersfeld, E. (1995). A constructivist approach to teaching. *Constructivism in education*, 3, 15.

Wenger, E. (1998). Communities of practice: learning, meaning, and identity. Cambridge University Press.

Yazedjian, A., & Kolkhorst, B. B. (2007). Implementing Small-Group Activities in Large Lecture Classes. *College Teaching*, *55*(4), 164–169.

CHAPTER V

CONCLUSIONS

CONCLUSIONS

Identity is a complex notion. While integral to define who one is, it is difficult for someone's identity to be fully grasped by another person. Wenger (1998) proposes in communities of practice that identity is the result of learning experiences. Boaler (1998) proposes a triadic model relating identity, knowledge, and practice where the practices of the learning environment shape the quality of knowledge and the learner's identity in relation to the discipline. In this dissertation, I used this perspective to extend the assessment of learning outcomes beyond conceptual understanding which is often the only measure of student success in a science course. Examination of learning identity development is needed for several reasons. On a practical level, we need a way to assess learning identity because moving toward authentic scientist identities is often an implicit learning goal in active engagement reform curricula, but there is not a systematic method to assess the progress towards this goal. For teachers attending to the nuanced ways to facilitate identity development toward more authentic scientists, this analytical tool can highlight the subtle details. On a research level, the understanding of learning identity development in relation to the learning environment advances the field by adding a critical dimension for considering the whole experience of learning in a way that integrates the strengths of quantitative and qualitative measurements.

In this dissertation I have narrowed the task by focusing on the notion of physics learning identity from a situated perspective. Framed in the communities of practice model, learning is mediated by social interaction which is the focus of the analysis. Consequently, physics learning identity has four main sources: (a) self-image, (b) expectations about community member roles and behaviors, (c) their perception of how others view them, and (d) their experience of interacting with others. This is a shift from the convention view of school science learning which is focused on the individual and tasks that are informational and largely ignores the relational. When considering learning this with this model, we are able to encompass the individual and the social aspects of identity. This is possible because the construct of physic learning identity incorporates both ends of the spectrum, and the set of research tools discussed in this dissertation allow for different unit of analysis to be examined.

In this study, I have described the development and validation of a survey in chapter three to measure the more individual dimensions of physics learning identity. Using principal component exploratory factor analysis, I found a two factor structure with seven total reliable subscales that measure self-efficacy about learning physics and expectations about social learning. Using these factors, I scored the student responses on each subscale. I found that the sample population of students tended to be fairly confident in their ability to learn physics in an ISLE classroom but generally hold expectations about social learning that do not agree with the goals of the curriculum. However, student expectations about social learning improve over the ten week quarter—students still disagree with statements supporting social learning but they disagree less. Student self-efficacy about learning physics improved or remained unchanged. The findings demonstrate that the survey was sensitive enough to observe some differences in pre-post surveys spanning ten weeks. The observed changes suggest that some of the dimensions of physics learning identity are changing as intended by the curriculum.

In order to probe more deeply about students' learning identity, I used the survey to select a subset of students with extreme high or low subscale scores to observe their interactions during lecture and conduct individual interviews with them at the end of the ten week quarter. In chapter four, I present one particular student in this subset as a case study to demonstrate the utility of the identity survey with qualitative methods as an analytical toolset to systematically examine physics learning identity. This student was selected because he appeared to be a competent and successful student in the traditional sense; however his identity as a science leaner changed only minimally. Using qualitative data from a personal meaning map guided interview and in class observations, I examined the student's identity and practice surrounding learning mediated by social interactions. I found that the student was resistant to change in his conception of what a physic learner does. While the student did not actively oppose the trajectory toward becoming a central member in the ISLE classroom CoP, he only made minimal surface adoption of ISLE practices without changing his expectations and attitudes about how learning physics should be. Through the analysis, it became apparent that he had an existing identity with practices that were more than adequate for succeeding in the course and he believed strongly that he is capable of learning physics; therefore had no motivation to adopt a different identity. In the instance during a small group discussion in class, he exhibited willingness and progress toward exploring the problem beyond arriving at the answer. This portion of the interaction was supported by a group member asking the group to consider more open-ended aspects of the problem. The student became interested and his language shifted from that of the curriculum and discipline to a more everyday way of speaking suggesting that he was asserting with his own voice and his ideas rather than that of the discipline.

Using the analytical toolset presented in this dissertation, I was able to use the survey to select a student who believed strongly in his ability to learn physics and succeed in the class but disagreed with the practices and attitudes regarding learning through social interactions. The qualitative analysis that followed allowed me to highlight how and when the learning environment could or could not support growth in aspects of his learning identity. Using these analysis tools, researchers and teachers who develop, create and support an active engagement learning environment can study and refine the facilitation of learning for individual students as the class as a whole.

There are two major directions for moving forward from this dissertation. First, the survey instrument requires refinement with the addition of items to more reliably measure constructs, particularly those that did not have sufficient reliability to be used in this study. The survey also needs to be used on other populations of introductory physics students to determine how robust the factors are. This will be needed in order for the survey to be used widely in other active engagement learning environments. One way to make the survey more usable in other physics classrooms is to modify the self-efficacy items to address skills and abilities that are not only specific to the ISLE classroom. Second, the qualitative data from the remaining nine students studied in chapter four need to be analyzed to show a more detailed description of the identity trajectories at multiple points in time during the learning experience. Additionally the results of these analyses would inform the refinement of the survey in pointing out what is lacking and what may be too subtle for a quantitative measure.

Beyond the refinement of the research tools, the results of this dissertation are significant for both science education researchers and teachers. For researchers and curriculum developers who want to examine the relationship between identity development and the learning environment in which it occurs. This approach to studying learning identity development can illuminate the contexts that support shifts in identity. In addition and potentially more useful, this approach allows us to examine how the contexts afford and constrain identity change. For teachers, I believe this combination of qualitative and quantitative research methods can a very effective way to inform teaching and support professional development. The survey can be administered and analyzed very quickly. The personal meaning map interviews require little to no training to conduct although they do take significantly more time to analyze. For practitioners, they already observe the student interactions in their classrooms. Armed with the survey results and insight from the interviews, teachers can be reflective about learning facilitation in a way that is systematic in addressing aspects of identity and social interaction practices.

References

Boaler, J. (1998). Open and closed mathematics: student experiences and understandings. *Journal for Research in Mathematics Education,* 29(1), 41-62.

Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge University Press.

BIBLIOGRAPHY

Bibliography

Adams, W. K., Perkins, K. K., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2005). The design and validation of the Colorado Learning Attitudes about Science Survey. In 2004 Physics Education Research Conference, Sacramento, California, 4-5 August, 2004 (p. 45).

Baldwin, J. A., Ebert-May, D., & Burns, D. J. (1999). The development of a college biology self-efficacy instrument for nonmajors. *Science Education*, *83*(4), 397–408.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. Worth Publishers.

Beichner, R. J., Saul, J. M., Allain, R. J., Deardorff, D. L., & Abbott, D. S. (2000). Introduction to SCALE-UP: Student-centered activities for large enrollment university physics. In *Proceedings of the 2000 Annual meeting of the American Society for Engineering Education,* 18–21.

Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J.J., Deardorff, D.L., Allain, R.J., Bonham, S.W., Dancy, M.H., & Risley, J.S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project*. College Park, MD: AAPT*.

Belenky, M. F., Clinchy, B., Goldberger, N. R., & Tarule, J. M. (1986). *Woman's Ways of Knowing*. New York: Basic Books.

Bianchini, J.A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *JRST*, 34(10), 1039-1065.

Boaler, J. (1998). Open and closed mathematics: student experiences and understandings. *Journal for Research in Mathematics Education,* 29(1), 41-62.

Boaler, J. (2000). Exploring situated insights into research and learning. *Journal for Research in Mathematics Education, 39*(1), 113-119.

Borden, V. M., & Burton, K. L. (1999). The impact of class size on student performance in introductory courses. In 39th Annual Conference of the AIR in Seattle, WA.

Brahmia, S., & Etkina, E. (2001). Switching Students on to Science: An Innovative Course Design for Physics Students. *Journal of College Science Teaching*, *31*(3), 183–187.

Burnstein, R. A., & Lederman, L. M. (2001). Using wireless keypads in lecture classes. *The Physics Teacher*, *39*(8), 8-11.

Christensen, T. (2005). Changing the Learning Environment in Large General Education Astronomy Classes. Journal of College Science Teaching, 35(3), 5.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small. *New Directions for Teaching and Learning*, *2000*(81), 5–16.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, *69*, 970.

Crouch, C. H., Watkins, J., Fagen, A. P., & Mazur, E. (2007). Peer Instruction: Engaging Students One-on-One, All at Once. *Reviews in Physics Education Research*, *1*.

Cuseo, J. (1998). Lectures: their place and purpose, *Cooperative Learning and College Teaching*, 9(1), 2.

Doolittle, P. (1999). Constructivism and Online Education. *1999 Online Conference on Teaching Online in Higher Education*, 1–13.

Elby, A., Frederiksen, J., Schwarz, C., & White, B. (1997). EBAPS: epistemological beliefs assessment for physical sciences. In *Annual Conference of the American Educational Research Association, March* (pp. 24–28).

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, *20*(4), 399–483.

Etkina, E., Personal communication (2009)

Etkina, E., & Van Heuvelen, A. (2007). Investigative Science Learning Environment–A Science Process Approach to Learning Physics. PER-based reforms in calculus-based physics. College Park, MD: AAPT.

Etkina, E., Van Heuvelen, A., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., et al. (2006). Scientific abilities and their assessment. *Physical Review Special Topics-Physics Education Research*, *2*, 020103.

Falk, J. H. (2003). Personal meaning mapping. *Museums and creativity: a study into the role of museums in design education*. Powerhouse Publishing, Sydney.

Fencl, H. & Scheel, K. (2005). “Engaging Students: An Examination of the Effects of Teaching Strategies on Self-Efficacy and Course Climate in a Nonmajors Physics Course” *JCST* 35 (1), 20-24.

Gardiner, L. F. (1994). *Redesigning higher education: producing dramatic gains in student learning*. Graduate School of Education and Human Development, George Washington University.

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Lawrence Erlbaum Associates.

Glass, G. V., Cahen, L. S., Smith, M. L., & Filby, N. N. (1982). *School Class Size: Research and Policy.* Beverly Hills: Sage Publications.

Greeno, J.G. (1998). The situativity of knowing, learning and research. *American Psychologist*, 53(1), 5-26.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64–74.

Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. *Perspectives on socially shared cognition*, 331–348.

Hazari, Z., Sonnert, G., Sandler, P.M., & Shanahan, M.C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *JRST* 47(8), 978-1003.

Henriksen, E. K. & Angell, C. (2010). The role of ‘talking physics’ in an undergraduate physics class using an electronic audience response system. *Phys. Ed*. **45**(3), 279.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 20*, 141-158.

Hewitt, N. M., & Seymour, E. (1991). Factors contributing to high attrition rates among science and engineering undergraduate majors, *Unpublished report to the Alfred P. Sloan Foundation*.

Hou, J. W. (1994). *Class Size and Determinants of Learning Effectiveness.* (ERIC Document Reproduction Service No. ED 377 239)

Ishak, M., & others. (2008). Improving the Training of Pre-Service Physics Teachers in Malaysia using Didaktik Analysis.

Johnson, D. W., Johnson, R. T., Smith, K. A., & Learning, W. I. C. (2000). Cooperative Learning Returns to College. Learning from Change: Landmarks in Teaching and Learning in Higher Education from *Change Magazine, 1969-1999*.

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika,* 39(1), 31-36.

Kennedy, P. E., & Siegfried, J. J. (1997). Class size and achievement in introductory economics: Evidence from the TUCE III data. Economics of Education Review, 16(4), 385–394.

Kopeika, N. S. (1992). On the relationship of number of students to academic level. IEEE Transactions on Education, 35(4), 294–295.

Krych, A. J., March, C. N., Bryan, R. E., Peake, B. J., Pawlina, W., & Carmichael, S. W. (2005). Reciprocal peer teaching: students teaching students in the gross anatomy laboratory, *Clinical Anatomy*, 18(4), 296-301.

Lampert, M., Rittenhouse, P., & Crumbaugh, C. (1996). Agreeing to disagree: Developing sociable mathematical discourse. *The handbook of education and human development: New models of learning, teaching, and schooling*, 731–764.

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on socially shared cognition*, 63–82.

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

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316.

Levine, D. W., O'Neal, E. C., Garwood, S. G., & McDonald, P. J. (1980). Classroom Ecology: The Effects of Seating Position on Grades and Participation. *Pers Soc Psychol Bull*, *6*(3), 409-412.

Li, S. L. & Demaree, D. (2010). *Instructor facilitation of PI as a mediator for student participation.* Talk given at AAPT Conference, Portland, OR.

Mazur, E. (1997). *Peer instruction: A user's manual.* Upper Saddle River, NJ: Prentice Hall.

Marbach-Ad, G. & Sokolove, P.G. (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching,* 37(8), 854-870.

McDermott, L., & Shaffer, P. (2002). *Tutorials in introductory physics*. Upper Saddle River, NJ: Prentice Hall.

McKeachie, W. J., & Svinicki, M. (2006). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers*. Houghton Mifflin Boston.

Nicol, D. J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: a comparison of two interaction methods in the wired classroom, *Studies in Higher Education*, 28(4), 457-473.

Powell, K. (2003). Spare me the lecture. *Nature*, *425*(6955), 234–236.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. American Journal of Physics, 66(3), 212–224.

Resnick, L. B. (1987). Learning in school and out. *Educational researcher*, *16*(9), 13–20.

Riggs, I.M. & Enochs, L.G. (1990). Toward the development of an elemntary teacher's science teaching efficacy belief instrument.. *Science Education*, 74(6). 625-637.

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, *323*(5910), 122.

Sommer, R. (1967). Classroom ecology. *The Journal of Applied Behavioral Science*, *3*(4), 489.

Steinzor, B. (1950). The spatial factor in face to face discussion groups. *J Abnorm Soc Psychol*, *45*(3), 552-5.

Taylor, J., Allie, S., Demaree, D., & Lubben, F. (2009). Effect of audience on reporting of measurement results. Talk given at AAPT Conference, Chicago, IL.

Tice, D. M., & Wallace, H. (2003). The reflected self: Creating yourself as (you think) others see you. In M. R. Leary & J. P. Tangney (Eds.), Handbook of self and identity: 91– 105. New York: Guilford Press.

Van Zee, E. H., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education*, *19*(2), 209–228.

Vaske, J.J. (2008). *Survey research and analysis: applications in parks, recreation and human dimensions*. Venture Publishing: State College, Pa.

von Glasersfeld, E. (1995). A constructivist approach to teaching. *Constructivism in education*, *3*, 15.

Weinstein, C. S. (1981). Classroom design as an external condition for learning. *Educational Technology*, *21*(8), 12–19.

Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge University Press.

Woods, D.R. 1994. Problem-based learning: How to gain the most from PBL. Waterdown, Ontario: Donald R. Woods.

Yazedjian, A., & Kolkhorst, B. B. (2007). Implementing Small-Group Activities in Large Lecture Classes. *College Teaching*, *55*(4), 164–169.

APPENDICES

Appendix A

Text and all items used in online survey

This survey is for all students in PH21X, and should be taken at the start and end of 211, 212, and/or 213. This is a required survey so that we can assess our courses as we undergo curricular reform. You will be given points for taking this survey that will count toward your final grade - the survey itself is not graded, you simply need to take it in full to receive the points. This should take you about 15 minutes to complete.

FIRST fill out the demographic information at the start of the survey, then answer the survey questions. The demographic information is needed in order for us to give you credit for taking the survey. Your responses will not be connected to your demographic information.

Last name:
Student ID:
Which course are you in:
First name:

Item	Text
Physics learning self-efficacy[1]	
SE01	How confident are you that you could critique a laboratory report written by another student?
SE02	How confident are you that you could describe your observations of a physics event?
SE03	How confident are you that you could use multiple representations (e.g. sketches, graphs, equations, etc) to reason about physical phenomena?
SE04	How confident are you that you could come up with plausible explanations for patterns you observe in physics phenomena?
SE05	How confident are you that you could devise an experiment to test your explanation of patterns?
SE06	How confident are you that you can convince another person of your reasoning?
SE07	How confident are you that you can critique the reasoning of another person?
SE08	How confident are you that you will be successful in this physics course?
SE09	How confident are you that you will be successful in a calculus course?

SE10	How confident are you that you will learning enough in this course to be successful in your next physics course?
SE11	How confident are you that you could analyze a set of data (i.e. look at the relationships between the variables)?
SE12	How confident are you that you could ask a meaningful question that could be answered experimentally?
SE13	How confident are you that you could explain something that you learned in this physics course to another person?
SE14	How confident are you that you could use a scientific approach to solve a problem at home?
SE15	How confident are you that you could decide what would be a reasonable value for the answer in a physics problem?
SE16	How confident are you that after reading an article about a physics experiment, you could explain its main ideas to another person?
SE17	We use this statement to discard the survey of people who are not reading the questions. Please select "only a little" for this question to preserve your answers.
SE18	How confident are you that after watching a TV documentary dealing with some aspect of physics, you could explain its main points to another person?
SE19	How confident are you that after listening to a public lecture regarding some physics topic, you could explain its main points to another person?
Social nature of learning[2]	
SNL01	To understand physics I discuss it with friends and other students.
SNL02	I prefer to work in groups with a smart student who knows the right answer.
SNL03	Working together to come up with a solution to a physics problem helps me understand physics concepts.
SNL04	Learning in groups is not helpful because I have to take exams individually.
SNL05	Trying to convince other students that my answer is correct helps me understand physics ideas.
SNL06	In class, I understand better listening to lecture rather than working in groups.
SNL07	I do not need to see other approaches to solving the problem when my answer is correct.
SNL08	Working with others on a challenging problem where no one knows the right answer is a waste of time.
Expectation of roles[2]	
SR01	As a student, I am supposed to accept what the teacher tells me.
SR02	As a student, I am supposed to think about what the teacher tells me.
SR03	As a student, I am supposed to take notes in class and figure out what it means on my own time.

SR04	As a student, I can help other students learn.
SR05	As a student, I am responsible for making sure what the teacher tells me makes sense to me.
SR06	As a student, I am responsible for seeking help when I do not understand.
SR07	As a student, I am responsible for my own learning.
SR08	As a student, I have useful things to contribute to class discussions.
SR09	As a student, I expect the teacher I expect the teacher to be willing to listen to what I have to say about physics.
SR10	As a student, I am an important part of the class community.
SR11	As a student, I should not ask questions about what I do not understand because it would slow down other people who already get it.
TR01	I expect the teacher to make me learn.
TR02	It is the teacher's job to keep me motivated to learn.
TR03	I expect the teacher to provide learning opportunities.
TR04	I expect the teacher to tell me what I need to learn to succeed in the class.
TR05	I expect the teacher to acknowledge what I say in class, whether or not I am correct.
TR06	I expect the teacher to keep order in class.
TR07	I expect the teacher to be my friend.
TR08	I cannot learn without the teacher.
TR09	I expect the teacher to tell me how to solve problems.
TR10	I expect the teacher to help me figure out how to solve physics problems in general.
TR11	I expect the teacher to tell me if I am right or wrong always.
TR12	I expect the teacher to be able to answer all my physics questions.

[1] Items responses on a five-point scale of 1 = not at all, 2 = only a little, 3 = fairly, 4 = very, 5 = totally.

[2] Items responses on a five-point scale of 1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree.

Appendix B

Observation rubric

	Interaction	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Telling/T	Example/demo/simulation																																																		
	Review																																																		
	Model skill																																																		
	Presenting information																																																		
TS dialog	Individual Q																																																		
	Small group Q																																																		
	Whole class Q																																																		
	Sampling Q																																																		
	Guiding Q																																																		
	Representation Q																																																		
	Does it make sense?																																																		
	What do you think?																																																		
	Using student input																																																		
	Direct answer																																																		
	T humor																																																		
	Express emotions																																																		
ST dialog	Answering																																																		
	Voting hands																																																		
	Lack of response																																																		
	Asking a question																																																		
	Reasoning/justification																																																		
	Challenge others																																																		
	Making sense of problem																																																		
	Metacognition																																																		
	S humor																																																		
	Express emotions																																																		
Auth.	Authority claimed by S																																																		
	Authority claimed by T																																																		
	Cede authority to text																																																		
	Cede authority to exp results																																																		
ISLE	Obs phenomenon																																																		
	Dev explanation																																																		
	Predictions, testing exp																																																		
	Assess testing exp																																																		
	SS talk																																																		
Oth	Non-instruction discourse																																																		
	Discipline (by S, by T)																																																		

Definitions

Telling/T	Example/demo/simulation	Use letters E, D, S. E are T solved problems, D are physical set ups, and S are computer set ups (or websites).	
	Review	Reminder of what was done previously, recalling old concepts, picking up from last class	
	Model skill	Use letters for specific types such as [D]iagram, [M]ath, [G]raph, etc. Mostly problem solving skills, write key for letters on the back.	
	Presenting information	Typical "lecture" mode	
TS dialog	Individual Q	Asking a Q directed at one student.	
	Small group Q	C: clicker question, S: work on it solo, P: work on it with partner(s)	
	Whole class Q	Asking a Q directed at the whole class, intended to start a WC conversation	
	Sampling Q	e.g. How many of you like blue? Raise your hand if you prefer to tilt the axes.	
	Guiding Q	Q intended to help S solve problem, might be hints. E.g. Where is the origin? Does it have to be on the tree top?	
	Representation Q	Asking S to create a representation such as a graph, a FBD, energy bar chart, sketch situation.	
	Does it make sense?	General questions to check	
	What do you think?	Open questions to invite ideas/opinions	
	Using student input	Taking student answers in example problem, incorporating in T's explanation	
	Direct answer	Yes, No, You can't do that, It should be pi over 4, Today is Tuesday, etc. Explicitly answering the question asked.	
	T humor	Sharing joke, laughing at S's joke	
	Express emotions	Positive or negative (might want to denote P/N) including encouragement, excitement, frustration, anger, happiness, etc.	
ST dialog	Answering	S responding to T question	
	Voting hands	Raising hand in response, usually to sampling Q. Might also be gesture to answer Q such as "which way does the current flow?"	
	Lack of response	May be due to confusion, not paying attention, reluctance to speak up	
	Asking a question	Any verbal response to a Q	
	Reasoning/justification	In support of answering or clarify for asking Q	
	Challenge others	Contesting others' input partially or entirely	
	Making sense of problem	Usually goes with asking Q, figuring out what is being asked, what parts of the question mean (is the curve a speed bump or turn in the road?)	
	Metacognition	Thinking about one's thinking. e.g. I thought it was A but then realized it didn't make sense b/c I forgot friction.	
	S humor	Sharing joke, laughing at T's or other S's joke	
	Express emotions	Positive or negative (might want to denote P/N) including encouragement, excitement, frustration, anger, happiness, etc.	
Auth.	Authority claimed by S	Actively being authoritative, given authority, or accepts authority ceded	Authority here is learning and knowledge creating authority, not classroom discipline. Authority includes contributing to shared knowledge, creating/expressing one's own understanding, and being labeled as true.
	Authority claimed by T	Actively being authoritative, given authority, or accepts authority ceded	
	Cede authority to text	Following text conventions, referencing text as correct	
	Cede authority to exp results	Accepting experimental results as true	
ISLE	Obs phenomenon	Includes showing phenomenon and discussion/description of the observations	
	Dev explanation	Discussion/description of potential explanations for observations	
	Predictions, testing exp	Discussion of how to test explanation, what might happen and what each result means, and actually doing testing exp	
	Assess testing exp	Post-testing exp discussion to evaluate results and refine explanations	
	SS talk	S talking to each other with minimal T contributions	
Oth	Non-instruction discourse	Talk that is not intended to build physics knowledge. e.g. when the midterm will be, announcements, clarification of HW policy, etc.	
	Discipline (by S, by T)	Denote person doing the discipline S/T	

Appendix C

Pre-interview questions sent via email

1. Which of the following skills are important for you to succeed in physics? Please **rank** in order of importance where 1 is the most important. Please add to the list for any skill we have overlooked.

- Drawing graphs/diagrams of the problem
- Discussing physics with others
- Considering limits of models and their assumptions
- Solving equations
- Looking for patterns in physical situations/observations
- Patience
- Time management
- Conducting an experiment to test your explanation
- Explaining your reasoning to others

2. From your ranking above, tell us why you think your top two choices are important and why your bottom two choices are less/not important.

3. Describe something (e.g. concept, problems, diagram, experiment etc) you had difficulty with in PH211 this term. Was the difficulty resolved? If so how did you resolve this difficulty? If not, what prevented you from resolving this difficulty?

4. Students who did well in PH211 are sometimes invited to be tutors to work with students in subsequent PH211 classes. How confident are you in your ability to be a tutor for students in PH211? What do you think your strengths and weaknesses would be as a tutor for PH211?

Appendix D

Pre-survey subscale scores and grades for ten students interviewed for PH211 in fall 2009

	Self-efficacy for			Social expectations about learning			
Student	Communicating physics	Problem solving	Academic success	Learning team	Student learning responsibility	Valuing group work	Course grade
A	4.00	3.67	3.67	**5.00**	**5.00**	**5.00**	B
B	**2.71**	**2.50**	3.00	3.67	3.80	3.25	A-
C	**4.71**	3.67	4.00	4.33	4.20	4.25	B+
D	4.29	3.67	**5.00**	**5.00**	**5.00**	3.75	B+
E	4.43	4.17	**5.00**	4.33	4.40	3.25	A
F	3.00	**2.67**	4.00	4.00	4.40	3.75	A
G	**2.71**	3.33	4.33	**5.00**	**5.00**	**4.50**	C+
H	4.14	4.17	**4.67**	4.33	4.40	**2.50**	B-
I	4.00	4.17	3.00	4.00	4.00	3.25	C+
J	4.00	3.50	**5.00**	**5.00**	**4.80**	3.00	A-

Note. Bolded scores are considered extreme high or low.