Boundary Objects that Mediate Students’ Motivation and Identity Toward Physics
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A. Goals and Objectives

Broad Research Question: How can tools serve as boundary objects that mediate between a student’s intrinsic motivation, identity, and physics?

I take a critical perspective on science education, where I assume that a significant reason for the low rates of science majors (National Science Foundation, 2010) is because high school students’ science experiences are too often wrought with fear and failure rather than being enjoyable, empowering, and personally meaningful. As such, the purpose of the proposed project is to examine how a tool, such as the iPad, can be used to create experiences that students find engaging and personally meaningful. I postulate that for an activity to be personally meaningful it must be intrinsically motivating and be a part of one’s identity. Further, for an activity to be a part of one’s identity it must be produced by experiences that meet their basic psychological needs (Ryan, 1995). I believe that the iPad is uniquely suited for this task because, in addition to performing many of the same dynamic tasks of a laptop, the iPad has an additional affordance of acting as a boundary object (Buxton, Carlone, & Carlone, 2005), allowing student culture to blend with science classroom culture. With the support of the iSTEM Chancellor’s Award for Excellence in STEM Education, I will critically examine the effects of iPad-enhanced activities on student discourse and behavior in order to understand how a tool acting as a boundary object, can be used to foster student motivation and identification with physics.

B. Project Motivation

In my iSTEM funded pilot-study, Empowering students through the use of iPad technology, I set out to examine how iPads could be integrated into the K-20 physics classroom to produce increased scientific learning among students and decrease achievement gaps. While my research did not directly show improved learning gains for the high school physics students, several other findings emerged as being salient to student learning (Van Dusen & Otero, 2012). Perhaps the most significant finding to emerge was the iPad’s role in acting as a boundary object that created a bridge between student culture and the science classroom culture. This bridging was evidenced in several forms, both quantitative and qualitative. For example, students reported signs of increased social status (Fig. 1), peer sharing of physics assignments (Fig 2.), incorporation of self-identity into work (such as setting iPad background images to favorite bands or sports teams), and likelihood of interacting with physics students outside their class (Fig. 3). During interviews, students gave many indications of the iPad mediating the blending of science classroom culture and student culture. For example, when asked what they enjoyed about using the iPad in physics class, one student said, “I do really like the photobooth, it's really cool. I can send pictures to my email and put them up [on Facebook]. Then that's another way for people to know that we have iPads in our class. They're like, 'how did you do that?' I'm like, 'oh we have iPads in our physics class,' and they're like, "what?!!" (Sally, 1/13/12).

![Figure 1](image1.png) **Figure 1.** Peer reactions to students getting to use iPads in their physics class.

![Figure 2](image2.png) **Figure 2.** Percentage of assignments shared with fellow physics students.

![Figure 3](image3.png) **Figure 3.** Change in likelihood of interacting with physics students from other classes because of the iPad.
These findings from my pilot study led me to shift the focus of my research from learning gains to student motivation and identity. I hypothesized that through the use of a boundary object, classroom experiences might be mediated such that students find the activities to be engaging and personally meaningful. By engaging students in physics activities that meet their basic psychological needs, having a sense of competence (feeling successful), autonomy (feeling in control), and relatedness (feeling connected to peers), not only will students find science more enjoyable, but they will also be more likely to find science intrinsically motivating and to incorporate aspects of physics into their identities (Ryan & Deci, 2000; Ryan, 1995).

In designing a learning environment that fulfills students’ psychological needs, I focus on the iPad as an example of how a tool can potentially mediate a change from negative to positive experiences for students in school science, and in the process create an environment in which science may become personally meaningful to them. Drawing from the literature on identity integration and my observations of learning environments, I believe that activities that meet students’ psychological needs and are intrinsically motivating are reflexively generative and necessary for creating an environment in which the internalization of a science identity and learning may occur.

C. Theoretical Framework

Self Determination Theory is founded on the idea that experiences can shape an individual’s motivation and identity toward an activity (Deci & Eghrari, 1994). Specifically, self determination theory states that activities can shift from requiring external motivation, in the form of rewards and punishment, to being intrinsically motivated through one’s own sense of identity (Deci et al., 2001; Deci & Ryan, 2000; Gagne & Deci, 2005). The process of internalizing an activity into one’s identity requires specific types of experiences. Much like food is a required nutrient for a child to grow, experiences that meet an individual’s basic psychological needs are seen as the required nutriments for one’s identity to grow. Self determination theory further expands the construct of basic psychological needs as being comprised of feeling a sense of competence, autonomy, and relatedness (Reis, Sheldon, Gable, Roscoe, & Ryan, 2000).

The plethora of research indicating that conditions which support autonomy, competence, and relatedness facilitate [intrinsically motivated behaviors] (whereas excessive controls, overwhelming challenges, and relational insecurities debilitate them) provides a starting point for understanding the processes through which a generalized growth tendency may be shunted toward specific domains and deflected away from others. (Ryan, 1995, p. 404)

In other words, if we create environments in which students feel a sense of competence, autonomy, and relatedness, then we can expect to see positive changes in their intrinsic motivation to do science. But if we make students engage in prescriptive science activities that make them feel isolate and like a failure, then we should expect to continue to have low motivation and retention rates in the sciences.

While self determination theory illustrates what types of experiences students need to have in order to integrate an activity into their identity, it does not provide guidance for how these experiences should be structured so that they in fact fulfill individuals’ psychological needs. In order to design and understand science-classroom environments and activities that create a sense of competence, autonomy, and relatedness, I draw partially on the perspective of distributed cognition (Hutchins, 1995, 1996). This perspective views the “cognitive unit” as a socio-cultural cognitive system encompassing the individual, surrounding people, available tools, configuration of the environment, and interactions among these things. Otero describes the socio-cultural cognitive system as:

- students interacting with tools (such as laboratory apparatus and computer simulators), and students interacting with others and with tools are considered a cognitive system that generates learning.
- According to this perspective, each element of the system contributes to the cognitive product by sharing part of the cognitive load associated with a task (Otero, 2001, p. 1).

Distributed cognition considers the entire system as engaged in the learning process. The individual becomes more proficient at working within the socio-cognitive system to accomplish a task. Meanwhile, the roles of other components of the system (tools and interactions) shift systematically with changes in the role/behaviors of any one component, including changes in the way a single individual identifies with a tool in the context, or...
with the broader socio-cultural cognitive system writ large (Otero, 2004). As such, in order to attend to student growth and change, it is important to monitor the changing use of tools and the environment as students perform tasks. In this study, I would view the context of the classroom as a socio-cultural cognitive system that generates growth. Within this system, the growth I am specifically interested in is changes in student motivation and the ways students identify with science.

In order to better understand the mechanism of how a tool, such as the iPad, can serve as a bridge between students’ personal lives and the science classroom, I draw on the concept of boundary objects. A boundary object is an artifact that holds meaning in two different cultural worlds (Buxton et al., 2005; Engeström, Engeström, & Karkkainen, 1995; Star & Griesemer, 1989). For the purposes of my research I am using the term culture to refer to a group’s idioculture. Idioculture is defined as “a system of knowledge, beliefs, behaviors, and customs shared by members of an interacting group to which members can refer and employ as the basis of further interaction” (Fine, 1979). While boundary objects have different meanings in the varying social worlds their meanings and uses have enough structural similarities that allow for them to be recognizable from both cultural perspectives. This allows the object to continue to support the separate cultural worlds in acting autonomously while provide a means of translating actions between the worlds. By facilitating communication between two or more social worlds, boundary objects create a cultural bridge that fosters the interaction and blending of the worlds (Fig. 4).

In the case of my research, the iPad can serve as a boundary object that holds meaning in the cultures of both the students’ peers and in the science classroom. In the world of the students’ peers, the iPad offers students access to a variety of culturally relevant activities. For example, the iPad offers students the ability to engage in social networking through digital messaging, Facebook, YouTube, picture and video capturing and sharing, and peer gaming. In addition to mediating student access to digital social networking, in their peer culture the simple act of using an iPad endows its users with increased social status.

In the classroom setting, the iPad can facilitate many activities that are central to the science classroom culture. Of particular interest are the iPad-facilitated activities that emulate those of scientists engaged in the inductive process. For example, the iPads are used to digitally collect data, such as recording the motion of an object, capturing the image of a cell in a microscope, or tracking the growth of bacteria. The iPads are also used by students to create explanations of process, such as charging by induction and gravitational orbits. These explanations can then be digitally shared with the teacher and fellow students. Finally, students are able to engage in a form of argumentation by asynchronously providing feedback to each other about their work.

By acting as a culturally meaningful artifact in both worlds, the iPad provides a unique opportunity for the students’ cultures to bridge into the science classroom and visa versa. For example, students are able to combine social networking and the production of scientific explanations through the creation and sharing of digital media, such as screencasts. In the creation of their media files, students incorporate humor and socially meaningful references. These files are then shared with their fellow students on a facebook-like site, Edmodo, where they are able to comment each other’s work. By creating culturally blended environments that connect student interests to science classroom activities, student motivation to engage the classroom activities can be increased. Additionally, by providing a space for these two cultures to interact and blend, the iPad can mediate the integration of students’ nascent science identities with their established peer identities.

D. Specific Research Questions

In order to provide an empirical basis for understanding how activities can be made intrinsically motivating to youth in an urban school environment, I will analyze data that I have collected from iPad-enhanced classes in a Denver area school. Specifically, I will examine changes in student behaviors and peer-interactions within their iPad-enhanced science classes. In this study, I will investigate the questions: (1) In what ways do
students’ behaviors and discourses reflect feelings of competence, autonomy, and relatedness? (2) In what ways, if any, can these feelings be associated with the use of the iPad in the classroom setting? (3) In what ways do students’ identification with science change over the course of the study, as revealed by their behaviors and discourses? (4) In what ways can the iPad-enhanced classroom environment be inferred to “mediate” students’ relationships with science, if at all?

E. Experimental Methodology

Study design:

The proposed project will be a significant expansion and redirection of my current research on iPad use in high school science classes. I have introduced a classroom set of iPads into a high school physics classroom and am observing their application by the students and teacher. The study has been designed such that the students have the opportunity to provide feedback on iPad use, but the teacher ultimately determines the sanctioned iPad activities. My role within the classroom is as an observer collecting ethnographic data on student behavior and discourse. Students are engaging in a wide variety of activities with the iPads, including taking digital notes, writing digital lab reports, exploring simulations, taking pictures and videos, creating screencasts, sharing files digitally, texting, and video chatting. The iPads are a communal resource that primarily remains in the classroom, with occasional opportunities to extend student use beyond the classroom.

Study Setting:

This study’s setting is an urban high school with a high percentage of students of low socioeconomic status from groups that have been traditionally underserved and are therefore underrepresented in the sciences. Approximately 50% of the students at the school are classified as English as a Second Language (ESL) learners, and over 40% of the students are eligible for free and reduced lunch. Within this school, I have been collaborating with a teacher of physics as part of the Streamline to Mastery project (Van Dusen & Otero, 2011; Van Dusen, Ross, & Otero, 2012). As an extension of our work on Streamline to Mastery, the teacher and I have cooperated on fundraising for the purchase of iPads, planning their implementation, and collecting data about their use. Through the course of my research, I have observed over 300 students in 10 different classes.

Data Sources:

The proposed project would focus on analyzing field notes, whole class video, small group video, student interviews, survey responses, and classroom artifacts collected over the previous two-year period (Table 1). The overlapping nature of these multiple data sources and the length of time in which they cover allow for the triangulation of data within a longitudinal analysis scheme.

Table 1. Data sources

<table>
<thead>
<tr>
<th>Data type</th>
<th>Description</th>
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<tr>
<td>Field Notes</td>
<td>~100 classroom observations</td>
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<tr>
<td>Student Surveys</td>
<td>~16 digital surveys</td>
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<tr>
<td>Classroom Video</td>
<td>~100 hours</td>
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<tr>
<td>Video of One-time</td>
<td>~30 student interviews</td>
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<td>Video of Longitudinal</td>
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<td>Student Interviews</td>
<td></td>
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<tr>
<td>Artifacts</td>
<td>Digital and analogue artifacts</td>
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Data analysis:

In order to create an evidentiary base to empirically support claims about student motivation and relation to physics, I will use each data source to help inform and guide the analysis of other data sources. For example, the field notes will be distilled into a comprehensive list of events around student relationships to science and psychological needs. In addition to analyzing and coding the field notes for observed behaviors that are indicative of having their psychological needs met, this list will be used to direct the further analysis of classroom video. Student surveys will be used to compile descriptive statistics (such as students’ access technology at home and how students’ peers feel about them having iPads in class), perform paired t-test analysis (on data such as student responses to the Basic Psychological Needs Scale surveys), and to code free responses for examples of psychological needs being met and relationship to physics. Classroom video will be used to create an activity log of student interactions and behaviors, which will be coded using discourse and behavior analysis. Video of one-time student interviews will be coded for comparison of student discourse about traditional and iPad-enhanced activities. Video of longitudinal student interviews will be used to create case studies of six students. These six case studies will be coded to track shifts in student relationships to physics throughout the year. The student created digital and analogue artifacts will be coded for instantiations of psychological needs being met and relationship to science. All of these data sources

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will be layered to create a picture of how the iPads met student psychological needs and shifted student relationships with physics, if at all.

F. Project Timeframe

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<th>Task</th>
<th>Apr</th>
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<th>Jun</th>
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G. Project Outcomes

*Further personal development:*

This project will greatly benefit me as a future STEM education researcher. I have taught high school physics and science, researched in the fields of experimental condensed matter and optical physics, and worked at the National Science Foundation. My experiences have made me uniquely suited for bridging communities of STEM educators in disciplinary departments with the STEM educators in the Schools of Education. The opportunity to work under an iSTEM grant in the Discipline Based Education Research community will allow me to further develop my participation with interdisciplinary groups. In my future professorship, I will capitalize on the skill of creating vertical and horizontal integration between K-12 schools and all members of the STEM academic community. This project will also contribute to my role as an educational researcher by funding my dissertation analysis.

*Support STEM education within the School of Education:*

This project will have an immediate impact on the School of Education through one of its current research projects. The Streamline to Mastery project, which includes Denver area teachers, will be provided with expertise and resources that will allow it to branch into several new areas of research. These new research emphases also represent novel avenues of research for CU’s School of Education. Additionally, this partnership between the School of Education and DBER will inform the School of Education of the methods and findings of the DBER community. The firewall that often exists between schools of education and the sciences exacerbates the divide between the practices of social science and classical science research. It is imperative that positive interdisciplinary relationships are forged for STEM education to make the institutional changes required to modernize our educational system.

*Benefit the CU community as a whole:*

While CU Boulder is the flagship university in Colorado, it is has struggled perennially with helping recruit and retain students who have been traditionally underserved and are therefore underrepresented. With this project, I am aspiring to create the classroom of the future that, from its inception and throughout its development, capitalizes on the social, cultural, cognitive and linguistic resources of students. The findings of this research will provide avenues to connect to students from a wide range of backgrounds. The results will be disseminated both within the school of education, through the DBER community, as well as through the new Center for STEM Learning (CSL). Like instruments, each of these venues for dissemination will resonate with different parts of my findings and amplify their impact within the CU community. Hopefully, with proper distribution through high profile institutions, such as CSL and the LA program, the reforms will be further integrated into the transformation of CU course offerings.
References:


