AN ABSTRACT OF THE DISSERTATION OF

Krissi M. Hewitt for the degree of Doctor of Philosophy in Science Education presented on September 10, 2014.

Title: Fostering Relevance in Introductory Biology Courses: An Empirical Study of the Effects of a Socio-Scientific Issues-Based Course on Student Motivation through the Lens of Self-Determination Theory

Abstract approved:

________________________________________________________________

Jana L. Bouwma-Gearhart Robert T. Mason

There has been a rapid increase in technological advances in the biological sciences that has contributed to an increase in societal issues that require attention from both scientists and citizens. Consequently, there is a need for the development of biologically literate citizens who have the ability to use their knowledge and skills related to biological concepts and competencies to make informed decisions in their daily lives. In order to make progress towards this goal, there have been calls for educational approaches that develop citizens who find biology interesting and important, and who can apply biology to their own lives. Socio-Scientific Issues-Based Education (SSI) is a pedagogical approach that contextualizes science content within global and local social issues that intersect with science (e.g., GMOs, human genome sequencing, and local water quality issues). In this study, I utilized the lens of the Self-Determination Theory of motivation to investigate how the contextualization of biology laboratory course activities with scientific and socially relevant issues impacted undergraduate student motivation and student perceptions regarding their ability to apply biological knowledge and skills in their daily lives. Results from the study showed that the SSI approach positively impacted both immediate and long-term student outcomes related to student motivation and the development of biological literacy in comparison to a control group. The four manuscripts I present in
this study relate to the design, implementation and research surrounding a new introductory biology laboratory course for science majors. In Chapter 2, I present details on the SSI curriculum that was the focus of all of the studies in this dissertation, and further draw upon data from a GTA questionnaire to investigate perceptions and experiences of GTAs who taught the course. From the qualitative analyses of these data, came recommendations and considerations regarding implementation of SSI curriculum and preparation for GTAs. Specifically, the recommendations included better alignment of new introductory biology curriculum with the Next Generation Science Standards, further inclusion of GTAs in action research studies in order to aid in their development as faculty and scholars, and incorporating considerations for educators when implementing the issues-oriented model. Chapter 2 provides an example of one of the curricular modules aligned with current biology education reform initiatives (AAAS, 2011), and identifies benefits and challenges of implementing SSI curriculum through a post-survey of students after participating in the module activities. The survey assessment shows the promise of the activity in attending to student engagement, interest and valuing of the learning experience that have been shown to be benefits of SSI curriculum. In Chapter 4, I present a study where I investigated the effects of implementing an SSI-based laboratory curriculum on biology student motivation in a large introductory biology course for science majors. Through a hierarchical linear model, I examined the effects of the SSI curriculum relative to the existing curriculum in place as well as its’ effects over the course of the term on biology student motivation. An analysis of the data revealed a significant increase in motivation in the SSI group relative to the control group. In Chapter 5, I advance the field of self-determination theory with a large empirically based study that attended to further developing the relatedness construct, and determine how an SSI course that focused on fostering relevancy by contextualizing introductory biology content with locally and globally relevant socio-scientific issues affected student perceptions of relatedness. Through thematic analysis and quantification of code frequencies to facilitate comparisons between the SSI and the EXT groups, I found similarities in the ways that students perceived their peer and instructor relationships and significant differences between the two groups.
in the perceptions of the course curriculum as relevant and useful both at the time of the course and one year post. In this dissertation, I present a large, empirical study employing robust theoretical frameworks in order to advance research regarding student motivation related to SSI, and GTA perceptions of the benefits and challenges of implementing SSI curriculum.
Fostering Relevance in Introductory Biology Courses: An Empirical Study of the Effects of a Socio-Scientific Issues-Based Course on Student Motivation through the Lens of Self-Determination Theory

by
Krissi M. Hewitt

A DISSERTATION

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Doctor of Philosophy

Presented September 10, 2014
Commencement June 2015
Doctor of Philosophy dissertation of Krissi M. Hewitt presented on September 10, 2014

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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.

Krissi M. Hewitt, Author
ACKNOWLEDGEMENTS

I want to acknowledge my entire dissertation committee, Drs. Bouwma-Gearhart, Mason, Dierking, Kayes, Noakes and Bruslind, for helping me to reach this goal. It takes a village to raise a doctoral student, and all of the faculty and graduate students I have interacted with from the College of Education, College of Science and the College of Agricultural Sciences have informed my dissertation work and my development as a scholar. I would also like to thank faculty from the OSU Center for Teaching and Learning and the Graduate school, Jessica White & Robin Pappas, for helping me develop as an educator and providing me with opportunities to help others along that path. I also thank the graduate teaching assistants in biology who I have worked with throughout my time at OSU including Hannah Tavalire, Sarah Eddy, Adam Chouinard, Caity Smyth, Tim Pusack, Ehren Bentz and Taylor Fjeran. Special thanks to Heather Kitada who worked closely with me on manuscript three. I also thank David Hubert and the rest of the biology preparatory staff who helped in implementing two curricula simultaneously and in the development and testing of curriculum modules.

I want to thank my family more than anyone else. Specifically, I thank my husband for supporting me throughout my entire educational journey, and my mom and mother-in-law for always being there for me and my kids in good times and in bad. My kids, Domingo and Wyatt, deserve the most thanks as they have sacrificed time with their mommy and endured many frozen meals for me to reach this goal. I did this to help provide them with a better future and inspire them to reach their own goals in life, and I truly appreciate their sacrifices. Additionally, all of my in-laws and my Dad have always shown their support and been there to encourage me.

Finally, I thank two individuals who have been major influences in my life, but passed away shortly before my degree completion. My grandmother helped raise me and encourage me throughout my life, but sadly passed away of cancer a year before I finished. I thank her for her support, friendship and love. My first mentor, Dr. Virgil L. Woods, Jr. was one of the most influential people in my life in my development as a biologist and as an educator. I met him before my first year of
college and he saw me all the way through until he passed away. He gave me so many opportunities and encouragement throughout the years and I hope to one day make a mentee feel the way I felt working with him.
CONTRIBUTION OF AUTHORS

Chapter 2. Dr. Kayes contributed in the design and implementation of the curriculum and in the conceptualization and editing of the manuscript. Dr. Bouwma-Gearhart contributed to the conceptualization, writing and editing of the manuscript.

Chapter 3. David Hubert participated in the development of the laboratory module, the collection and analysis of data and the conceptualization and editing of the manuscript. Adam Chouinard provided ideas and guidance in the development of the module and helped to write and edit the manuscript. Dr. Kayes participated in the development of the laboratory module and in the writing and editing of the manuscript.

Chapter 4. Dr. Kayes helped to consult on data analysis and edit the manuscript. Heather Kitada performed the HLM data analysis and helped in the writing and editing of the manuscript. Dr. Bouwma-Gearhart participated in the writing and editing of the manuscript.

Chapter 5. Dr. Kayes helped in the editing of the manuscript and consulted on data analysis and visualization. Dr. Bouwma-Gearhart consulted on data collection and analyses and was involved in the conceptualization, writing and editing of the manuscript.
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In memory of Joanne Magsulit and Dr. Virgil L. Woods, Jr.
Introduction

“Education is a social process; education is growth; education is not preparation for life but is life itself.”

John Dewey (1938)

This dissertation includes the presentation of four research manuscripts based on results from a two-year study where I investigated the effects of novel introductory biology curriculum aligned with current policy documents that propose best practices for science education. I present these works from both a practitioner’s and educational theorist’s perspective. Specifically, the manuscripts focus on how the contextualization of biology course material with scientific and socially relevant issues impacts undergraduate student motivation, and the perceptions of students and graduate teaching assistants regarding teaching and learning at the intersection of science and society as presented in the curriculum studied.

Motivations for the Research Study

Scientific literacy

In our 21st Century global society, technology is allowing for scientific discoveries at a rapid pace. The increase in new scientific advances leads to new societal issues that citizens are confronted with in their daily lives. The need for people to understand the scientific evidence surrounding these issues and for them to better understand the process of science has resulted in a call for increased scientific literacy in U.S. citizens (NRC, 2009 & 1999, AAAS, 1989, AAAS, 2011). While many science education researchers, scientists and practitioners agree on the goal of scientific literacy, it is a term that has had many definitions, and has eluded clear definition, in part due to the many different interest groups involved in advocating for scientific literacy (Laugksch, 2000). One interpretation of scientific literacy is the amount of science content someone knows, typically measured by responses to factual or conceptual questions. This “deficit model” has been criticized in its portrayal of science as a litany of facts to be memorized and not as a socially and culturally situated process (Deboer, 2000, Hewitt, 2014). Although science content knowledge is imperative for informed decision-making, many critics of the deficit model have proposed a more progressive view of
science education, where science is taught in a way that contextualizes learning for students and encourages the application of science content knowledge in real-world problem-solving (DeBoer, 1991). This progressive view of education has been taken by proponents of efforts such as promoting the public understanding of science (Hunt & Millar, 2000), context-based science (Bennett, Grasel, Parchmann, & Wadington, 2005), and socio-scientific issues-based science (Sadler, 2004). In addition, there is need to move beyond an assumption that the public’s deficiency in science content knowledge is solely to blame for lackluster participation and knowledge concerning science and technology, ignorant of people’s values and beliefs (Sturgis & Allum, 2004). Thus, science education researchers have called for educational approaches that develop a scientifically literate public, one that “finds science interesting and important, who can apply science to their own lives, and who can take part in the conversations regarding science that take place in society” (DeBoer, 2000, p. 232).

Due to the large number of issues confronting scientists and citizens that require the application of biological knowledge, there has been an increasing demand for institutions of higher education to produce graduates that are not only scientifically literate, but more specifically, biologically literate (AAAS, 2011). As with the general idea of scientific literacy, biological literacy could be defined in many ways. Informed by Sadler and Zeidler (2009), I define biological literacy as an individual’s ability to apply biological concepts and competencies to real-life contexts both within and outside of the normal realm of science. My dissertation study focuses specifically on biology education and, thus, biological literacy.

Socio-Scientific Issues-Based Instruction

Several calls for reform in science education are based on research that indicates that the traditional method of teaching science is not adequate for the desired student achievement outcomes in the sciences (NRC, 2009 & 1999, AAAS, 1989, AAAS, 2011), including growing citizens capable of making informed decisions in their daily lives about societal issues that intersect with science (Sadler, 2004, Kolsto, 2001). In order to achieve goals related to the development of scientific literacy, proponents argue that these issues need to be addressed not only in philosophy or ethics courses, but integrated within science
content courses themselves. One such means for this is curriculum based on a socio-scientific issues-based (SSI) approach to science education. Socio-scientific issues are complex social problems with technological or conceptual ties to science (Sadler, 2004). These include a wide array of controversial topics that frequently are covered by the media, such as the human consumption of genetically modified organisms (GMOs), the ethics of human genomic and stem cell research, humans’ role in global warming, and local environmental issues. Policy makers and the general public are often influential in determining courses of action in regards to these issues. Meaningful discussion and approaches to addressing these issues require the application of scientific concepts and the negotiation of political, economic, and ethical factors (Sadler, 2011) and highlight the skills that are demanded from scientists and citizens to address the many challenges our world faces in the 21st century (AAAS, 2011 & 1989). Most of these socio-scientific issues have a large biological component and, specifically, require a certain level of biological literacy for public understanding.

Rooted in the Science, Technology and Society (STS) movement of the 1970s and 80s, the SSI approach to science education extended the STS approach, from isolated courses focused on issues and small asides in textbooks to broader integration of socio-scientific issues into longer-term science curriculum (Sadler, 2004). Additionally, Sadler (2004) contends that the SSI approach, “aims focus more specifically on empowering students to handle science-based issues that shape their current world and those which will determine their future world” (p. 514). Because of the focus on depth of concepts rather than breadth, there have been concerns that an SSI approach may sacrifice the learning of content knowledge. However, students have been found to display equal or more science content knowledge on pre/post assessments in SSI-based interventions when compared to learning environments that teach scientific facts and concepts in the absence of a real-world context (Zohar & Nemet, 2002, Sadler & Klosterman, 2010, Dori et al., 2003, Bulte et al., 2006, Barker & Millar, 1996, Barab et al., 2007, Barber, 2001). Studies also report learning gains with regard to understanding the nature of science, and evidence of the development of higher-order thinking (Albe, 2008, Dori et al., 2003, Harris & Ratcliffe, 2005, Khishfe & Lederman, 2006, Kortland, 1996, Pedretti, 1999, Tal

I present all of the research from this study in terms of teaching and learning related to the SSI approach to science education. Two of the research articles specifically address effects of the SSI approach on student motivation in the large, introductory biology course context.

Student motivation

Motivation is an important aspect of learning and in the application of knowledge and skills in real-world contexts as motivation predicts outcomes such as choice, effort, persistence and achievement in relation to tasks (Zusho et al., 2003). Human motivation is multifaceted and somewhat complicated. Multiple theories of human motivation have influenced education research, including self-efficacy theory (Pajares, 1996, Schunk, Hanson, & Cox, 1987), goal orientation theory (Dweck, 1986, Ames & Archer, 1988), and self-regulation of learning (Zimmerman, 1989, Bandura, 1986) that all conceptualize motivation as the “activation and persistence of behavior” that is reflected in an individual’s choice and persistence in tasks (Bandura, 1986, p. 193). These and other motivational theories posit that motivation depends on cognitive processes as well as affective ones and is highly influenced by context (Pajares, 1996, Bandura, 1986).

For my study, I operated under one prominent theory of motivation, self-determination theory (SDT). SDT conceptualizes motivation as being based upon the degree of satisfaction of three basic psychological needs - perceived autonomy, competence and relatedness (Ryan & Deci, 2000). According to SDT, all humans have goals related the fulfillment of these three basic psychological needs, and the degree that an activity is perceived to be in line with students’ personal goals for their learning or future careers contributes to perceptions of need fulfillment, leading to behavior driven by autonomous motivation that in addition to the immediate positive outcomes, tends to
be long-lasting and more likely to continue even when tasks become difficult to perform (Deci, Ryan, & Koestner, 2001, Ryan & Deci, 2002).

The need for *autonomy* refers to the need for feelings of choice and volition regarding one’s actions. In a classroom setting, educators’ allowance for student choice and explanation of classroom rules has been shown to enhance student autonomy, whereas limited choice, excessive surveillance and unexplained orders decrease student feelings of autonomy (Deci & Ryan, 1994, Niemiec & Ryan, 2009). The need for *competence* refers to the need for effectance or having the, “skills to manage various elements of one’s environment” (Deci & Ryan, 1985, p. 30). Feeling of competency, or perceived self-efficacy, gives the person a sense that they are able to complete a task (Ryan & Deci, 2000). The last need that affects motivation within the SDT framework is the need for *relatedness*. This is the need to be socially connected and to feel a sense of belonging in a social group (Niemiec & Ryan, 2009). In addition to feeling connected to people, a person can also feel connected to tasks/content if they are relevant to their own personal goals or interests (Deci, 1992). Perceived relatedness leads to feelings of personal security that have a positive impact on motivation (Ryan & Deci, 2000).

In addition, SDT postulates different loci of motivation and offers an expansion on the traditional dichotomous approach to student motivation (intrinsic/extrinsic), and categorizes motivation across six types along a continuum from controlled (low quality) to autonomous (high quality) (see Figure 1).

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Figure 1. The Self-Determination Continuum showing motivation, regulation and behavior types. Adapted from Ryan, & Deci, (2000) and Darner (2012).

Autonomous motivations more often lead to positive student outcomes in classroom contexts such as persistence and achievement (Guay, Ratelle & Channel, 2008). Ryan and
Deci (2000) define the most autonomous of motivation types, intrinsic motivation, as, “the inherent tendency to seek out novelty and challenges, to extend and exercise one’s capacities, to explore, and to learn” (p. 70). In terms of classroom contexts and activities, students are intrinsically motivated to do an activity when they perceive it as interesting and enjoyable and they do it in the absence of reward or control (Deci & Ryan, 1985). SDT posits that humans are intrinsically motivated when they are self-determined, or rather when they have agency or power over their own choices (Ryan & Deci, 2000).

Within the SDT framework, social context has a great impact on the quality of student motivation (Deci, 1992, Jarvela, 2001). Social context within a classroom can include a student’s interactions with their peers, instructors, social norms, and the tools used for learning, such as tasks or texts. Classroom environments that allow for high quality student motivation are autonomy-supportive and encourage feelings of self-determination. Autonomy-supportive instructors serve more in the apprentice role than an authoritative role, and classroom tasks and evaluations are centered on personal improvement, and learning that is, “conceptually rich, interconnected, and contextually relevant” (Blumenfeld, 1992, p. 278). In this study, I present research that investigates both the degree that a novel SSI curriculum impacted student motivation, and what aspects of the SSI approach contributed to the quality of student motivation.

Significance of the dissertation

The SSI approach has been increasingly utilized in international reform efforts, has been widely implemented in secondary science classrooms (Sadler, 2009), and to a somewhat lesser extent in undergraduate courses (Darner, 2012). This integration of increasingly complex, interdisciplinary, controversial topics in the classroom presents challenges for educators, especially in the undergraduate courses where there may be heightened perceived tensions between the goals of science education for scientific literacy and that of disciplinary preparation (AAAS, 2011). The limited, but growing amount of studies of socio-scientific issues-based educational approaches in the post-secondary setting, especially in large courses, and those serving science majors, led me to examine the practical benefits and challenges of utilizing this framework for large introductory science courses. Furthermore, the lack of research on science graduate
teaching assistants implementing science education reform approaches highlighted the need to study perceptions of graduate teaching assistants related to teaching a socio-scientific issues-based curriculum (Gardner & Jones, 2010 & 2011). This research is significant in preparing graduate teaching assistant educators for teaching SSI, and for those involved in curriculum design and implementation from practitioner and education researcher perspectives.

As mentioned previously, motivation is an important construct to consider in order to understanding the impacts of a SSI approach on the ability and drive of students to apply knowledge and skills to their lives in formal and informal settings. Given the small amount studies that have investigated SSI in the undergraduate science course context (Gardner & Jones, 2011), the research regarding undergraduate student motivation in SSI contexts is also limited especially in terms of studies that utilize motivational theories as lenses for their studies (Sadler, 2009, Darner, 2012). This study is a large, empirical study that employed robust motivational theories. In addition to making progress on understanding motivation related to SSI, this work advanced knowledge regarding the construct of relatedness in the self-determination theory framework of motivation (Deci & Ryan, 1985).

Research Questions

In the four manuscripts in this study, I both investigate research questions and describe curricular revisions based on both practical and theoretical considerations. The following is a list of the research questions investigated.

1. What were the benefits and challenges of utilizing socio-scientific issues-based instruction in a large introductory biology laboratory course?
2. What were graduate student teaching assistants experiences and perceptions related to teaching the socio-scientific issues-based laboratory curriculum?
3. What types of motivation were salient for undergraduate students in an undergraduate introductory biology course?
   a) How did the levels of the different types of motivation change over the course of the term?
4. What were the effects of a socio-scientific issues-based laboratory curriculum on undergraduate biology students’ levels of autonomous and controlled motivations with respect to engaging in the work for the laboratory compared to the control group?

5. What were the effects of a socio-scientific issues-based laboratory curriculum on undergraduate biology students’ perception of relatedness compared to the control group?
   a. What were the differences between the SSI and control groups in student perceptions of their relationship with the instructor?
   b. What were the differences between the SSI and control groups in student perceptions of their relationships with their peers?
   c. What were the differences between the SSI and control groups in student perceptions of the relevance of the learning activities?

6. In what ways did students report using the knowledge and skills gained in the socio-scientific issues-based lab course one year-out compared to the control group?

In the following discussion, I present a brief overview of the four manuscripts that address the research questions.

**Overview of the four manuscripts as one study**

The four manuscripts I present in this study relate to the design, implementation and research surrounding a new introductory biology laboratory course for science majors. I was involved as a curriculum designer, implementation team leader and researcher throughout the course of the study that spanned from 2012-2014. The efforts to build a new course and investigate new biology education frameworks began in 2011 that coincided with the publication of the AAAS policy document, *Vision and Change in Undergraduate Biology Education: A Call to Action* (2011). The Biology Program, course coordinator and I worked to align new curriculum with the Vision and Change document, utilizing pedagogical strategies based on “best practices” as identified in science education literature. In addition, there was a desire to build upon previous work in the Biology Program towards the development of a discipline-based education research agenda. All four manuscripts present data related to this multi-year initiative
and center around the themes of socio-scientific issues-based instruction and biological literacy.

Data were collected in the Spring of 2013 for the first 3 manuscripts from both students and GTAs, while the fourth manuscript also included data that were collected from a one year longitudinal questionnaire in Spring of 2014. Because there is a unifying framework that ties the manuscripts together as part of one study, there is some repetition in the introductions and educational contexts described. Although some repetition was necessary to make these four stand-alone manuscripts, I assert that they have different enough foci, relying on different subsets of the data collected, rendering them worthy to stand as separate publications.

The first manuscript presented in the study – titled “Design and Implementation of a Socio-Scientific Issues-Based Laboratory Curriculum: Insights From Graduate Teaching Assistants in a Large Introductory Biology Setting” – addressed the first two research questions regarding the benefits and challenges of utilizing socio-scientific issues-based instruction in a large introductory biology laboratory course, and graduate student teaching assistants’ (GTA) experiences and perceptions related to teaching the course. Presented with the practitioner perspective in mind, the manuscript details the curriculum design framework for the course and the specific modules and socio-scientific issues that were taught over the ten week academic term. It also presents benefits and challenges regarding the curriculum situated within the larger context of research on teaching SSI courses and professional development of educators, and with implications for GTA professional development. I present qualitative data from GTAs analyzed from open-response questions from an online survey, highlighting relevant themes and making comparisons to research on teachers from K-12 education settings. This manuscript is presented first because it gives the most details regarding the curriculum design of the course that frames all of the research presented in the three manuscripts that follow it.

The second manuscript - titled “Investigating Issues in the Laboratory: The Behavior of Red Swamp Crayfish as an Invasive Species” - is one that has been accepted for publication in American Biology Teacher and is presented here as a detailed
example of the construction of one of the SSI modules and the alignment of the module with Vision and Change (2011). I also present data collected from a student questionnaire, highlighting the way that we assessed student outcomes in a design consistent with scholarship of teaching and learning approaches. This manuscript not only provides an example of one of the curricular modules, but also provides an example to practitioners in how they can design, implement and study SSI modules. In addition to the first manuscript, it is an example of how practitioners can take part in both scholarly teaching and in the scholarship of teaching and learning. Shulman (2012) offers the following in distinguishing these two terms:

“Scholarly teaching is teaching that is well grounded in the sources and resources appropriate to the field. It reflects a thoughtful selection and integration of ideas and examples, and well-designed strategies of course design, development, transmission, interaction and assessment. Scholarly teaching should also model the methods and values of a field, avoiding dogma and the mystification of evidence, argument and warrant. We develop a scholarship of teaching when our work as teachers becomes public, peer-reviewed and critiqued, and exchanged with other members of our professional communities so they, in turn, can build on our work.” (p. 2)

The design and implementation of the course aligned with current policy documents and initiatives in biology education as well as best practices in science education research provides an example of scholarly teaching in higher education, and the publication and review amongst biology faculty and GTAs opens this work up to the larger biology education community.

The third manuscript – titled “Introductory Biology in Social Context: The Effects of an Issues-Based Laboratory Course on Biology Student Motivation” – presents results from hierarchical linear modeling analyses on undergraduate student survey data from those who took the SSI laboratory course and those who took the “control” course of the existing (non-revised) curriculum. The study specifically addresses research questions three and four in identifying both the types of motivation most salient in undergraduate biology students in an introductory course and the effects of the SSI curriculum on the prevalence of types of motivation over the course of the term and compared to the control group. The design and analysis of this study took into account the nesting of
students within lab sections with GTA instructors that were nested within larger lecture sections in order to account for variance across sections. The survey implemented was the situational motivation survey (SIMS) that asked questions of students regarding their motivation to do the work for the lab class that would reveal different types of motivation consistent with a self-determination theory of motivation, specifically, a sub-theory called Organismic Integration Theory (Ryan & Deci, 2000).

The fourth manuscript – titled “Fostering Relevance in Introductory Biology Courses: The Effects of a Socio-Scientific Issues-Based Curriculum on Relatedness Need-Fulfillment” – addressed research questions five and six with an agenda that was two-fold; 1) to advance the field of self-determination theory with a large, empirically based study that attended to further developing the relatedness construct, and 2) to determine how an SSI course that focused on fostering relevancy by contextualizing introductory biology content with locally and globally relevant socio-scientific issues affected student perceptions of relatedness. This manuscript builds upon results from the third manuscript that showed a statistically significant increase in high quality (autonomous) motivation in students who participated in the SSI course when compared to the control group. This fourth part of the dissertation is a qualitative study that represents an analysis of open-response questions collected at the same time as the quantitative data presented in manuscript three, but that develops understanding of why there was an increase in motivation. In addition, I sought to identify what particular aspects of the context of an SSI classroom experience explained the increase in motivation from quantitative measures in the SSI group.

In this dissertation, I present four manuscripts that add to the science education literature in furthering the understanding of the relationship between student motivation types, relatedness need-fulfillment and biological literacy (see Figure 2). Figure 2 illustrates the conceptual framework that unifies all of the manuscripts in this study.
Figure 2. Conceptual framework regarding SSI curriculum, motivation and biological literacy. This diagram depicts connections between major constructs in the literature.

The four manuscripts in this study each attend to one or more of the boxes in Figure 2 in order to ultimately present ideas about what is gained from socio-scientific issues based instruction in a large introductory biology setting (Sadler, 2009). As was mentioned above, the SSI framework has been found to increase student motivation in previous research studies. In addition to a need for larger empirical studies to verify the work of others in smaller studies, it is unclear from the literature exactly why the SSI approach may increase student motivation. A few research studies with small groups of students in individual courses have begun to investigate this utilizing the framework of self-determination theory (Danner, 2009 & 2013), but more work needs to be done to further understand how and why the SSI approach increases student motivation and to further investigate it’s potential to increase biological literacy.
CHAPTER 2- Design and Implementation of a Socio-Scientific Issues-Based Laboratory Curriculum: Insights From Graduate Teaching Assistants in a Large Introductory Biology Setting

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To be submitted for publication in: American Biology Teacher or CBE-Life Science
Introduction

Advancements in the biological sciences in the past two decades have resulted in an increase in the number of societal issues that intersect with science and require attention from both scientists and citizens (Laugsch, 2000, AAAS, 2011 & 1989). The large number of issues that require the application of biological knowledge has led to an increasing demand on all institutions of higher education to produce graduates in all majors that are not only scientifically literate, but more specifically, biologically literate (AAAS, 2011). Biological literacy can be defined as an individual’s ability to apply biological concepts and competencies in real-life contexts both within and outside of the normal realm of science (Sadler & Zeidler, 2009). There is a need for citizens with the ability to use their knowledge and skills related to biological concepts and competencies to make informed decisions in their daily lives (Sadler & Zeidler 2009, Sadler 2011, Zeidler, Sadler, Simmons & Howes, 2005). Socio-scientific issues are complex social problems with technological or conceptual ties to science of personal or global relevance. Approaches to solving these issues require the application of scientific concepts and the negotiation of political, economic, and ethical factors (Sadler, 2011). Many socio-scientific issues include topics that involve the biological sciences, and therefore require a certain level of biological literacy for general understanding.

One educational approach that has been found to help prepare students for dealing with real-world issues is the socio-scientific issues-based approach to science education (SSI) (Sadler, 2004). SSI is a pedagogical approach that focuses on the contextualization of science content knowledge and student participation in inquiry-based, authentic activities while addressing important socio-scientific issues that are personally and globally relevant (Lenz, 2012, etc). The SSI approach has been shown to promote positive student outcomes related to increases in students’ science content knowledge (Zohar & Nemet, 2002, Sadler & Klosterman, 2010, Barab et al., 2007), interest and motivation (Albe, 2008, Lee & Erdogan, 2007, Parchman et al., 2006, Yager et al, 2006, Zeidler et al, 2009, Sadler, 2004 & 2009), understanding of the nature of science, and the development of higher-order thinking skills (Albe, 2008, Dori et al., 2003, Harris &
Lenz & Willcox (2012) offered an SSI-oriented curricular model (Figure 1) aimed at helping practitioners design and implement SSI in biology courses. The first step in the issues-oriented model is to motivate the students by providing an issue or problem to contextualize their learning (Figure 1).

Students then “gather scientific evidence through inquiry activities and readings” (p. 552), building knowledge by participating in the activities that emphasize the nature of science and process skills. Students then apply their learning to the original issue or problem (Lenz & Willcox, 2012) via risk evaluations, collective decision-making, and the interpretation of scientific data through class discussions (Sadler, 2011). The model meets current recommendations for undergraduate biology education reform by creating student-centered classroom environments based on active learning and student discourse (AAAS, 2011). In light of these considerations, this SSI-oriented model was chosen for use in designing and implementing new introductory biology laboratory activities as described in this paper. I redesigned a ten-week introductory biology laboratory curriculum for a large research university in the Pacific Northwest using the SSI-oriented model as a framework for the design of each module.

The curriculum was implemented by graduate teaching assistants (GTAs) in the laboratory portion of a large majors introductory biology course. Research from the
implementation of the SSI approach in secondary settings has shown that this pedagogical approach can be challenging for teachers because of the focus on student discussions, and on helping students apply scientific evidence to real-world issues (Lindahl et al., 2013). A limited amount of research has indicated that GTAs teaching at the postsecondary level may experience similar, or even additional, challenges (Gardner & Jones, 2011). GTAs have typically little exposure to curriculum that incorporates socio-scientific issues. Additionally, GTAs are typically novice educators with scant training concerning pedagogy. Inquiry regarding GTA experiences concerning SSI curriculum and related instruction is warranted. This scholarship of teaching and learning study of the implementation of my SSI-oriented curriculum explores GTA experiences including support structures they deem necessary to be successful educators of such curriculum. In this paper, I describe the design and implementation of the laboratory modules and situate GTA perception data in the larger research context of SSI and GTA preparation. I conclude by offering recommendations for others intending to implement SSI-oriented curriculum at the postsecondary level, namely better alignment of new introductory biology curriculum with the Next Generation Science Standards, further inclusion of GTAs in scholarship of teaching and learning studies in order to aid in their development as faculty and scholars, and incorporating considerations for educators when implementing the issues-oriented model.

Theoretical Framework

A study by Gardner & Jones (2009) provided an in depth review of the literature surrounding GTAs in science education and found that although GTAs can be responsible for teaching up to 91% of the science laboratories at universities, there have been relatively few studies regarding GTAs teaching science courses. GTAs are critically important to the quality of undergraduate student learning experiences, but they are typically novice instructors that are in the early stages of developing pedagogical skills (Addy & Blanchard, 2009). GTAs also typically have high demands on them in terms of balancing teaching, research and coursework (Boyer, 1990, Austin & McDaniel, 2006). Since this study involved graduate teaching assistants who have different roles and needs as future faculty members, I discuss the results of this study in the context of Austin &
McDaniel’s (2006) conceptual framework regarding the preparation of faculty through doctoral education, which is built upon Boyer’s (1990) four domains of scholarship. These four domains of scholarship include; *application*, which “involves the use of a scholar’s disciplinary knowledge to address important individual, institutional, and societal problems” (Austin & McDaniel’s 2006, p.52), *discovery* or what could be seen as traditional research, *integration*, which is described as making connections within and between disciplines along with the ability to communicate these ideas to the public, and *teaching*, which is defined as participation in *scholarly teaching* or in the *scholarship of teaching and learning*. Shulman (2012) offers the following in distinguishing these two terms:

“Scholarly teaching is teaching that is well grounded in the sources and resources appropriate to the field. It reflects a thoughtful selection and integration of ideas and examples, and well-designed strategies of course design, development, transmission, interaction and assessment. Scholarly teaching should also model the methods and values of a field, avoiding dogma and the mystification of evidence, argument and warrant. We develop a scholarship of teaching when our work as teachers becomes public, peer-reviewed and critiqued, and exchanged with other members of our professional communities so they, in turn, can build on our work.” (p. 2)

All four domains are described as being part of the role of faculty members to differing degrees based on institution type. Austin and colleagues (2009) further argue that graduate education is a socialization process that includes, “learning the relevant skills, knowledge, habits, attitudes, and values of the group that one is joining” (p. 84). The disciplinary group that a graduate student participates in influences their professional identity development (Becher & Trowler, 2001). As the push for change in biology education to be more issues-based and relevant is relatively recent, it follows that GTAs may experience tensions when implementing curriculum and instruction that may be different from the way in which they were taught undergraduate biology, as this is a part of the socialization process.

There is a limited amount of research on science graduate teaching assistants; as such, there is limited knowledge regarding how GTAs perceive an SSI approach or any changes in the way the discipline is being taught. There is also limited research on the potential benefits and challenges of involving GTAs in scholarship of teaching and
In this study, I present results of a study of GTA perceptions of a new SSI curriculum. Results indicate that implementing this curriculum inspired GTAs’ consideration of the ways that they were taught, their beliefs about curriculum and instruction in their discipline, and their discipline’s roles in addressing societal issues. In this regard, the experience of teaching the SSI curriculum, in conjunction with taking part in a science education scholarship of teaching and learning study, was a socialization experience for the GTAs regarding the application, integration and teaching domains. This has implications for GTA education and training, as well as for other educators in implementing an issues-oriented model in large undergraduate biology courses.

**Methods**

This study aimed to investigate the following research questions:

1. What were the benefits and challenges of implementing a socio-scientific issues-based instruction in a large introductory biology laboratory course with graduate teaching assistant instructors?
2. What were graduate student teaching assistants’ experiences and perceptions related to teaching the socio-scientific issues-based laboratory curriculum?

**Instructional Context**

The designed SSI curriculum was for a ten-week term lab component of a course entitled Principles of Biology, for science majors course in a large public university in the Pacific Northwest. The course was one of a large year-long, non-sequential series with almost 1200 students per term. Students were required to enroll in a laboratory section that compliments the tri-weekly lectures taught by faculty members. The 40-student laboratory sections were taught by GTAs (n=25). The SSI curriculum was originally piloted in half the laboratory sections (n=13), but after revisions was implemented in all laboratory sections. The GTAs were all required to teach the same curriculum to enrolled students who participated in the 2hr. 50 min. laboratory session activities related to the lecture topics.

**Laboratory Design**

The learning outcomes for the laboratory portion of the course were developed
based on several of the core concepts and competencies outlined in Vision and Change (AAAS, 2011), the university’s Baccalaureate Core policy, and those within the revised MCAT as was appropriate for the content and level of the course (genetics, evolution, natural selection and ecology). As the curriculum designer involved in this study, I developed some of the laboratory activities and modified others from current biology education research/practitioner publications. Each lab period was centered on a socio-scientific issue that related to that week’s course content (see Table 1).

<table>
<thead>
<tr>
<th>Week No.</th>
<th>Lecture/Lab Topic</th>
<th>Example Lab Activities</th>
<th>Socio-Scientific Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mitosis &amp; Meiosis</td>
<td>Karyotype analyses of patients with case studies</td>
<td>Genetic testing – What would you want to test for?</td>
</tr>
<tr>
<td>2</td>
<td>Genetics</td>
<td>Investigate heritability of traits- compare artificial selection to genetic modification</td>
<td>Should we allow GMO agriculture in our area?</td>
</tr>
<tr>
<td>3</td>
<td>DNA Replication, Transcription &amp; Translation</td>
<td>Students extract their cheek DNA and perform PCR to find their genotype for bitter taste gene (see Merritt et al., 2012)</td>
<td>Do you want your human genome sequenced? Who should have access to it?</td>
</tr>
<tr>
<td>4</td>
<td>Molecular Biology</td>
<td>Students analyze PCR results with gel electrophoresis to determine their genotype for bitter taste gene (see Merritt et al., 2012)</td>
<td>Cont’d previous</td>
</tr>
<tr>
<td>5</td>
<td>Evolution &amp; Natural Selection</td>
<td>Students analyze mtDNA sequences from humans of different origins and design a drug trial. (see Kalinowski et al., 2012) They use Hardy Weinberg to analyze course PTC allele frequency data.</td>
<td>Should doctors treat patients with certain medications based on “race”?</td>
</tr>
<tr>
<td>6</td>
<td>Climate &amp; the Biosphere (conservation &amp; animal migration)</td>
<td>Students predict amphibian migration events based on temp. and precipitation. (see Amphibians on the Move, Urban lab)</td>
<td>What should be done about wildlife mortality on roadways?</td>
</tr>
</tbody>
</table>
I designed the curriculum to address both global and local issues thought relevant to students, such as genetic testing, genetic modification of crops, and invasive species. In order to introduce the issue to students before class, I designed pre-lab assignments that consisted of a combination of videos, news articles and scientific articles addressing the issue, followed by thought-provoking questions about the topic. Each laboratory period began with a pre-lab discussion activity during the first 20-30 minutes, such as debates or “think-pair-share” discussions.

The modules were built on the idea that students should be engaged in authentic activities that reflect the current state of biological research as has been called for in the biology education literature (AAAS, 2011). Following the model by Lenz & Willcox (2012), all of the modules included activities that had students participate in inquiry. According to Hofstein & Lunetta (2004):
“Inquiry refers to diverse ways in which scientists study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work. It also refers to more authentic ways in which learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science.”

The inquiry type engaged in by students was either structured or guided. In structured inquiry students interpret their own results, but are provided with research questions and methods; in guided inquiry students determine the research questions, and interpret results, but are provided with the methods (Blanchard, Southerland, Osborne, Sampson & Granger, 2010). For example, the crayfish module described in Chapter 3 is an example of a guided inquiry activity where students were able to decide on a research question for a small study that would inform a larger course study and interpret results, but were provided with most of the methods to conduct their experiment.

I attempted to include activities that were authentic to biologists’ work, for instance activities that relied on actual methodologies to explore timely biological problems of interest to the biology research community. I also connected each module with research being conducted at the home university where possible. For example, students were able to interact with a graduate student researcher and collect data for research projects performed by those at the home university. Laboratory summative assessments were in the form of quizzes, two scientific reports and a written press release based on scientific data collected as a class. The press release assessment was designed in order to help students better understand how science is communicated to the public. Formative assessments included participation in discussions, regular question and answer periods with the GTA instructors, and completion of the laboratory activities.

**GTA instructors’ roles and experience**

The SSI curriculum was designed to be implemented in a large introductory course with 25 GTAs. The original pilot group of SSI GTAs included five males and eight females with an average of 4.42 quarter terms of teaching experience (SD = 2.35) that is equivalent to a little over one year, which is similar to the overall population of GTAs who teach the course sections each year. In the past, some GTAs that were assigned to teach the course were teaching for the first time with no prior experience.
Therefore, it was crucial to the success of the curriculum that GTAs with relatively little teaching experience or training would be able to teach the activities as prescribed. Each GTA was responsible for a short introduction and discussion of the socio-scientific issues and the lab activities. During the remainder of the lab period, GTAs answered questions and guided students through the lab activities while formatively assessing student progress. Although the GTAs played an important role in the laboratory classroom, the lab activities were mostly designed to be completed by student groups with minimal aid on the part of the GTAs, who were instructed to serve more as a facilitator/guide.

The GTAs at the university that was the subject of this work have been provided with a professional development program for the past several years that incorporates known best practices surrounding teacher professional development (Darling-Hammond, Wei, Andree, Richardson & Orphanos, 2009). Specifically, the program consists of a one hour per week professional seminar that includes topics that are timely and relevant to the GTAs teaching practice each week. For instance, during a week where students are turning in reports, the topic might be related to grading student writing. The GTAs that piloted the SSI curriculum were also involved in the larger research study, where they were asked to participate in surveys and classroom observations. Therefore, in collaboration with the leaders of the GTA professional development seminar, I presented an hour-long session on education research and scientific teaching during the first week of the term (Handelsman et al., 2004). As part of another preparatory session with the GTAs, I discussed the issues-oriented model and changes in the landscape of biology education.

**Scholarship of Teaching and Learning Study Context**

The GTAs were part of a larger scholarship of teaching and learning (SOTL) study that was conducted in the laboratory sections associated with the larger lecture portions of an introductory biology class for majors over the course of a ten week spring term at a large research university in the Pacific Northwest. The SOTL study was primarily focused on student perceptions of the curriculum, and the design and implementation of the SSI curriculum. The data collected were also to be used in an education research study regarding student interest and motivation (see Chapters 4 & 5). The methods employed in
the SOTL study included classroom observations, journaling, student surveys over the course of the term, and a survey regarding an individual laboratory module (see Chapter 3). Since the SSI curriculum was only piloted in half of the laboratory sections with the other half remaining as comparison groups, GTAs were assigned to teach a curriculum based on their previous schedules. There were GTAs who requested to teach an alternate curriculum than the one they were assigned, but they remained in the assigned sections because of larger research design considerations.

**GTA Perceptions Questionnaire**

I asked all thirteen of the group who piloted the SSI curriculum to complete an anonymous online questionnaire at the end of the term (Appendix A). Ten of the thirteen GTAs responded to the questionnaire that was comprised of seven different questions related to their experience teaching the course. The student responses on both questionnaires were analyzed using thematic analysis and a “bottom-up” process of coding where codes for the data were determined by the text in the responses and not *a priori* (Auerbach & Silverstein, 2003). Because of the relatively sparse amount of literature related to GTAs and SSI curriculum (Gardner & Jones, 2011), I utilized a grounded theory approach to data analysis that allowed for emergent, data-driven themes as my process was open and flexible as I stayed grounded in the data itself (Glaser & Strauss, 1967, Namey et al., 2007). The major themes that emerged via thematic analysis of the responses are highlighted in the following results and discussion section.

**Results**

*Perceptions regarding student engagement and biological literacy*

Most of the GTAs (8/10) indicated that they enjoyed teaching the curriculum, describing it as interactive and engaging for the students. For example, one GTA wrote:

“I enjoyed teaching this lab very much. Most of the students I have talked with said they preferred this curriculum over the traditional curriculum because it was more interesting to them, the labs were more fun, and it felt more interactive.”

Most of the GTAs (8/10) also mentioned seeing the value of the SSI approach in the development of biological literacy. One GTA wrote:

“I think the connection to current events helps to emphasize the 'why' in the importance of possessing a basic understanding of biological concepts in order to
speak intelligibly to others and make informed decisions concerning controversial policies.”

This also suggests that GTAs were aware of the reasoning behind the design of the new course curriculum, as we explicitly discussed with them prior to the start of the course.

Concerns with Content Coverage

Some of the GTAs (4/10) felt that the curriculum did not cover as much biological knowledge as the previous curriculum or as the other courses in the general biology series. One GTA reported, “the students seemed more engaged with the new curriculum, but I fear that coverage of content may have suffered.” It seemed that while recognizing the increase in student engagement, there were still concerns for some GTAs over the amount of content students were responsible for. One GTA wrote about the need for teaching students the way he/she was taught.

“I have been trained by very dry scientists and that may bias me toward a more rigorous curriculum… I think that some of the experiments were great but it gets damaging to focus too much on trying to make it relate to their lives so they will enjoy it more.”

In this case, the GTA perceived the curriculum as less “rigorous” because of the focus on student engagement.

Concerns With Curriculum’s Bias or Advocacy Bent

The same four GTAs that were concerned with the content coverage in the course mentioned having problems with some of the labs presenting issues in a biased way or the perceived advocacy approach in the labs. One GTA wrote, “I also feel like it was the most advocacy based class that I have taught and that several of the issues brought up in the pre-labs were presented in biased ways.”

The concerns regarding the advocacy nature of some labs were mostly directed towards the three labs that were focused on conservation and invasive species. One GTA wrote:

“A lot of the labs had a conservation focus, and it was really hard not to promote a certain value stance within the material. For example, when talking about invasive species, if you say invasive species cause "harm" to the "natural" environment, you are already incorporating value judgments into the curriculum.”
One GTA who taught the course that may have not supported the SSI approach to science education wrote the following:

“I am also not a big fan of infusing emotion in teaching biology...I believe that the most important part of the biology series should be teaching them biology. If they are not getting it because they are not able to relate it to their lives, I feel that that is their problem and they don't belong in a career in biology. This course is there to train future doctors and scientists. I think that focusing on the social factors of biology is only further diluting what a BS in biology has become these days... I do think the students enjoyed the curriculum. This does not change my opinion though. The point is not that they enjoy it but that they learn biology.”

There was clearly a separation between enjoyment, emotion and learning in the views of the GTA.

**Challenges in teaching SSI curriculum**

GTAs mentioned certain aspects of the curriculum that made it challenging to teach. Three GTAs mentioned challenges related to the newness of the curriculum in that there were fewer teaching resources such as multiple sample introductions or talking points for discussions. For example, one GTA wrote, “I felt that having only the one Powerpoint intro to go off of (a limitation of this being the first time through this curriculum) limited my ability to grasp some of the material from different points of view”.

The most salient theme regarding challenges in teaching the SSI curriculum was related to the discussion portion of the lab period, requiring that they verbally engage with regarding the socio-scientific issue. Four of the ten GTA respondents mentioned that although they found the discussions to be valuable in engaging students, they were of the most challenging aspects of teaching the new curriculum. They felt a need for further development of skills in this area. For example, one GTA wrote:

“I might like a mini-session on facilitating discussions or a list of probing questions for lab discussions. This is a skill, and if discussions are an important part of the lab, you want TAs to be skilled at facilitating discussion.”

The GTAs struggled with some of the more pedagogically challenging aspects of the curriculum as novice instructors, especially in facilitating discussions.

**Skills or knowledge gained from teaching SSI curriculum**
Although facilitating discussions was the biggest challenge for GTAs in teaching the SSI curriculum, three GTAs responded that they gained skills in leading discussion from teaching the course. One GTA wrote, “leading discussions was sometimes challenging, but I think I improved over the term”. In addition to perceived improvement in facilitating discussions, most of the GTAs (6/10) mentioned that their teaching skills improved overall from teaching the course. Some of the comments described improvement in light of an overall greater awareness of various teaching approaches. For example, one GTA wrote, “I think overall this term has enhanced my teaching abilities. It also gave me more ideas for teaching methods and discussion methods.” They also became more aware of what goes into designing and implementing new curriculum. One GTA responded:

“I gained exposure to a curriculum that was designed with student engagement in mind. In the future, I may need to design and teach courses for undergraduate students. It was instructive for me to see what worked and what didn't.”

Half of the GTAs (5/10) specifically discussed that they gained knowledge and skills related to teaching, communication and public understanding of socio-scientific issues. For example, one GTA responded:

“I gained a greater awareness of the scope of biological understanding possessed by the general public. Hopefully, this experience will help me to better communicate with less informed individuals in the future.”

This is an example of how experience teaching the SSI course was perceived as useful to the GTAs continuing development as educators and scientists.

**Discussion**

**Benefits and Challenges of Teaching SSI Curriculum In Light of GTA Socialization**

Most of the GTAs thought that their teaching skills improved from teaching the course, especially in leading discussions and in being exposed to different teaching approaches. Many of the GTAs also reported gaining knowledge and skills related to teaching, communication and public understanding of socio-scientific issues. In my discussion of the benefits and challenges to GTAs, I argue that the experience of teaching the SSI
curriculum and taking part in a science education research study was a valuable socialization experience for the GTAs.

Austin et al. (2009) describe that graduate education, “…does not provide enough systematic preparation for the various roles a faculty member must fulfill, including teaching. While students often gain research experience by apprenticing with faculty members, they usually learn little about other responsibilities, such as advising, serving on institutional committees, and engaging in outreach that connects scholarly expertise with societal problems. In regard to teaching specifically, many doctoral students have minimal opportunity to develop teaching abilities in thoughtful, systematic ways.” (p. 84)

Taking into account the responses regarding both challenges and benefits regarding teaching SSI curriculum, I posit that the experience of teaching the SSI curriculum and taking part in the scholarship of teaching and learning study expanded the GTAs exposure to the application, integration and teaching domains of scholarship.

**GTA exposure to the application and integration domains of scholarship**

Some of the GTAs reported feeling uncomfortable in teaching socio-scientific issues in a majors’ biology course because of the difficulty in keeping the values of the curriculum designers or the GTA instructors themselves out of the curriculum, while others felt that the integration of issues with biology concepts was engaging for students and important for the goals of biological literacy. The discomfort raised by some of these GTAs, concerning the encroaching values of educators into the curriculum, has been noted in other studies with pre-service secondary teachers who have struggled with attempts to teach SSI without infusing their own values. A study on perceptions of high school science teachers by Witz & Lee (2009) identified:

“two types of value orientations that lead secondary-school science teachers to oppose or favour dealing with socio-scientific issues in the classroom: a ‘traditional’ view of science as objective and value-free and a ‘higher vision of science’ with strong metaphysical, moral, or aesthetic connotations.” (p. 411)

Witz and Lee’s “higher vision of science” was described by Aikenhead (2002) as a humanistic point of view that includes educators addressing science in society issues in the classroom. The different views of the GTAs who taught the SSI curriculum do
indeed reflect a much larger debate within science itself regarding science and advocacy. For example, Erlich (2002) calls for scientists to engage in advancing cultural evolution through advocacy regarding conservation. Rykiel (2001) states that there should be a recognized continuum between scientific advocacy and objectivity and that scientists should try to mask their values as much as possible to remain credible to the public. A full review of the literature regarding advocacy in science is beyond the scope of this article, but it is crucial to acknowledge the larger debates regarding science as a discipline and scientists as advocates in order to better understand the perspectives of the GTAs who are continually being socialized into disciplines, taking on the values of that community (Austin & McDaniel, 2006).

Teaching the SSI curriculum allowed the GTAs the opportunity to consider their stances on advocacy as scientists and as educators. GTAs had the opportunity to reflect on their teaching and their identity as scholars through the teaching of SSI curriculum in thinking about science and advocacy (Austin & McDaniel, 2006, Weidman, Twale & Stein, 2001). Discussing societal issues related to their own fields in biology further exposed them to the domain of application as several GTAs mentioned knowing more about the socio-scientific issues themselves after teaching the course and allowing them to further connect their scholarly expertise with societal problems. GTAs also gained interpersonal skills in communicating science with the public which is important for graduate students to develop as faculty through experiences related to the integration domain (Austin, 2009).

The curriculum included several other best practices from the literature regarding science education such as inquiry-based learning, but GTAs focused in on the socio-scientific issues portion possibly because it is the aspect of the curriculum that most challenges belief systems regarding biology as a discipline itself and their perceived roles as scientists and educators. It is possible that the GTAs who had a hard time with the SSI approach also upheld a view that their role as scientists and educators included researching and teaching scientific concepts in the most objective way possible. From the perspective of Austin & McDaniel’s (2006) description of the socialization process, GTAs are in the process of internalizing values and norms of their disciplines. Since the
dominant paradigm in biology education may not have included approaches like SSI when the GTAs were undergraduates, teaching courses that incorporate SSI might go beyond what they perceive of as their roles as biologists and educators (Venville, 2010). From the responses, it seemed that the perceived advocacy stance was mainly an issue for the three weeks of conservation and human impact on the environment. The lab content was built with the lecture textbook chapters in mind, so that the content was directly related to the lecture portion, but these content topics can be controversial as they have major implications in policy and environmental science. Indeed, the inclusion of standards related to human impacts on the environment has been one of the most controversial pieces of the Next Generation Science Standards (NGSS Lead States, 2013, Larson, 2013). Regardless of the GTA’s beliefs about their own roles in advocacy related to the application of their scholarly expertise to societal issues, the implementation of the SSI curriculum provided them with an experience where they were able to engage in discussions with their peers surrounding advocacy and science.

_GTA exposure to the teaching domain of scholarship_

According to Austin & McDaniels (2006), modeling of the way in which faculty participate in the domains of scholarship is important for graduate student development. In regards to the teaching domain, the design, implementation and research agenda related to a course aligned with current policy documents and initiatives in biology education as well as best practices in science education research provided an example of _scholarly teaching_ in higher education, and participation in the _scholarship of teaching and learning_ (Shulman, 2012). An important aspect of this study was that GTA involvement lead to their reflection about teaching practices in undergraduate biology and about ways in which they could improve their own teaching practices.

One major challenge of teaching this curriculum from the GTA perspective was in facilitating the discussion portion of the curriculum that incorporated active learning activities. Specifically, GTAs felt that they needed more support and training in this area. This was similar to a study of biology pre-service secondary teachers where the teachers felt that they needed additional support materials like training in facilitating discussions to effectively teach an SSI module (Kara, 2012). There are several studies that have
shown that many teachers are not confident in facilitating discussions, especially those that engage students in argumentation (Gray & Bryce 2006, Newton, 1999). Specifically, educators express challenges with constructing and asking ‘good’ questions that require student to think and inquire deeply to arrive at answers (Lindahl et al., 2011). Active learning strategies have been found to be challenging for science faculty, so it is not surprising that GTAs struggled with this aspect of the curriculum (Sirum, Madigan & Kilionsky, 2009). Teaching the discussion portion of this curriculum provided the GTAs with practice in implementing the active learning approaches prior to becoming faculty members. Furthermore, the process of filling out the questionnaire and discussing the teaching of the curriculum with other GTAs, engaged them in reflecting about their own practice. Specifically, the GTAs were able to reflect on how they improved over the term, and in what areas they may need more professional development. Even if some of the GTAs did not subscribe to the SSI approach, as part of this scholarship of teaching and learning project, they were still engaged in reflecting about different teaching methods and their own identities as scholars and educators, what Austin and McDaniel (2006) would claim to be the process of socialization. The more GTAs understand about the roles of faculty, the more smooth the transition is to becoming a faculty member.

**Implications**

Bieber & Worley’s study (2006), presented results that showed that graduate students were excited not only about conducting research within their disciplines but were also enthusiastic about teaching about their discipline. These results are consistent with those in Chapter Five of this study that show that students perceived the GTAs as excited to teach them biology. A lack of excitement or commitment to their job did not seem to explain any of their critique of the SSI curriculum and approach. In fact, the theory of graduate student socialization offers better insight into GTA perceptions and concerns with SSI curriculum, namely how they were taught biology, to what extent they feel that scientists should be involved in advocacy, and the overall importance of the relevancy of the curriculum to students’ lives. Results of this study point to the importance of knowing well the experiences of target populations of educators in attempting to implement curricular innovations.
The results of this study suggest that, while cognizant of these concerns, it is beneficial for graduate students to be part of implementing, and seeing the study of, new curriculum. The design and implementation of the SSI curriculum was successful in terms of GTAs’ perceived gains of knowledge and skills regarding experience with different teaching methods, communicating socio-scientific issues with the public, and considering disciplinary roles in addressing societal issues, reflecting expansion of the domains of teaching, integration and application. Towards GTAs’ better development in the scholarship of teaching, those working with GTAs should perhaps not shy away from challenging these early career educators (and themselves) with the somewhat uncomfortable process of implementing novel curricular innovations.

At the same time, curricular innovators should not negate the perceptions of disciplinary stewards. While experience with this novel SSI curriculum, and study of it, may have led to expansion of GTA skills and knowledge, socialized in their disciplines’ norms and perceptions, it is also important to highlight that GTA feedback was very meaningful towards resultant modification to the curriculum and educator training practices.

Curricular Improvements

Since the original pilot of the course I have made curricular adjustments based on GTA feedback, student feedback, and classroom observations. For example, some of the pre-labs presented biased information intentionally with the idea that it would be an opportunity for the GTA to discuss the presentation of biased information with the class, such as in a video about genetically modified organisms where the reporter presented some accurate information with very slanted inaccurate information. My observations of the GTAs teaching the curriculum revealed that in these instances, although the presentation slides had notes cuing them to do this, many GTAs did not discuss the biased view with the class. GTAs were informed of the notes in the presentations prior to the beginning of the term, but it is often the case that GTAs have very little time to prepare and may have not accessed the preparatory notes beforehand. In this case, the curriculum was not taught as it was intended. There is an expansive literature base regarding the measurement of curriculum fidelity, or rather the implementation of
curriculum by instructors other than the designers themselves (O'Donnell, 2008). Shkedi (1998) operationalized the idea of *curriculum-in-use* as the curriculum that teachers implement that is not identical to the original curriculum. The author also described that teachers often do not utilize the curriculum support materials designed for them, but most often utilize the student materials. O'Donnell (2008) states that due to the lack of utilization of preparatory materials by instructors,

> “the researcher must distinguish between the written curriculum guide, which is the document specifically designed by writers for teachers, and the perceived curriculum as viewed and implemented by teachers.” (p. 44)

Indeed, in my observations of the GTAs, I found that many did not teach based on the notes provided, but relied heavily on the presentation slides themselves for delivering the curriculum. Therefore, in further modifications of the curriculum, I relied less on the notes sections and made more slides for the GTAs to utilize.

One of the other major adjustments was the removal of videos designed to teach students about bias in media as the GTAs were not prepared to have those discussions, but this is something that the professional development seminar has addressed since then. In regards to the advocacy aspects perceived by some of the GTAs, some of the items in the curriculum were re-worded or re-framed to tone down some of the topics that might be seen as too value-laden. Reflective of larger tensions within the discipline of biology itself, the GTAs and the implementers of this curriculum ranged in their beliefs about science and advocacy and these beliefs have been taken into account in modifications to the pre-labs and discussion activities.

We have also developed more materials for the GTAs to better support them in teaching the material, such as documents that describe common pitfalls and ideas that may come up in discussions regarding the socio-scientific issues. After the initial pilot of the course, we have used this information to build sessions on facilitating discussions into the professional development seminars for the biology GTAs. Wolfensberger, Piniel, Canella & Kyburz-Graber (2010) reported that teachers found high value in watching recordings of themselves running discussions in the context of SSI and reflecting on process. This could be a valuable addition to the current professional development of the biology GTAs.
In regards to previous discussion of the balance between content and context, I recognized that this was a new curriculum that would need adjustments for future implementation. Although the laboratory course outcomes were written utilizing Vision and Change (2011), Baccalaureate Core goals and the new MCAT requirements, these documents were somewhat vague on the content and competency standards for specific courses. The piloting of this curriculum coincided with the release of the Next Generation Science Standards (NGSSs) which offer far more specified content and competency standards as a K-16 document. The alignment of the curriculum with the NGSS standards in the future would ensure the desired student outcomes for a majors introductory biology course are met and also align the outcomes to secondary science curriculum, which is important for an introductory course. Another recommendation would be to identify the alignment of the lecture portion of the course with NGSSs as well in order to better determine the outcomes that are appropriate for each portion of the course.

The data presented in this study suggests that the model should have an added component that includes an emphasis on the facilitator, especially for novice instructors attempting to implement SSI curriculum, which outlines the pedagogical knowledge and skills necessary to effectively implement the curriculum. For example, it might be included that instructors need skills and resources related to facilitating discussions. In addition, instructors may need to examine their own beliefs and values regarding science and advocacy when designing and implementing SSI curriculum. In the next three chapters, I present data regarding student interest and motivation in response to the curriculum implemented by the GTAs as described in this chapter.
CHAPTER 3- Investigating Issues in the Laboratory: The Behavior of the Red Swamp Crayfish as an Invasive Species

Krissi M. Hewitt, David Hubert, Adam Chouinard and Lori J. Kayes

To be published in:  
*American Biology Teacher* (in press)
Introduction
Research has shown that a learner’s interest in an activity can influence their relative engagement in the activity, the types of goals they set, and the learning that takes place during the activity (Hidi & Renninger, 2006). Issues-oriented science is a pedagogical approach that has been shown to increase student interest in science via their participation in inquiry-based, authentic activities while addressing important socio-scientific issues that are personally and globally relevant (Lenz, 2012). Socio-scientific issues (SSI) are complex social problems with technological or conceptual ties to science of personal or global relevance. Approaches to solving these issues require the application of scientific concepts and the negotiation of political, economic, and ethical factors (Sadler, 2011).

Many socio-scientific issues have a significant biological component, and therefore require a certain level of biological literacy for public understanding. This makes the issues-oriented instructional model outlined by Lenz & Willcox (2012) an ideal approach for introductory biology laboratory activities. This model provides the context for risk evaluations, collective decision-making, and the interpretation of scientific data through class discussions. Moreover, the model follows current recommendations for undergraduate biology education reform outlined in the AAAS Vision and Change in Undergraduate Biology Education: A Call to Action (2011: hereafter referred to as Vision & Change) by creating student-centered classroom environments based on active learning and student discourse (AAAS, 2011).

The socio-scientific issue relevant to the undergraduate introductory biology laboratory module we have developed explores the ecological and socioeconomic impact of invasive species. We linked traditional introductory biology content (animal behavior and population biology) with a current, locally relevant issue (What should be done about invasive crayfish?). This module was designed to provide context and relevance to students learning animal behavior and to align with the core concepts and competencies outlined in Vision & Change towards the goal of biological literacy (see Table 1). We designed this module for use in a large university-level majors introductory biology course in a single 3-hour class period with approximately 30 laboratory sections per week with 40 students per section (~1200 students).
Specifically, we implemented and tested a laboratory module that allowed students to investigate factors predicting the winner of agonistic interactions between invasive red-swamp crayfish and the implications for invasive species’ management using an authentic research project. Using a guided inquiry-based approach, students learned concepts and principles of animal behavior while applying this information to a real-world issue. The following are the student learning outcomes for the module based on course content.

1. Define and explain important terms and concepts in invasion biology, animal behavior and behavioral ecology.
2. Develop and test a hypothesis in order to predict winners of agonistic interactions.
3. Demonstrate the ability to collect data from live crayfish and track behavioral interactions.
4. Conduct a chi square test to determine the statistical significance of experimental results.
5. Apply knowledge of animal behavior to the issue of invasive species.
6. Discuss possible solutions to prevent the introduction of invasive species and minimize their effect on native species

**Table 1. Alignment of Laboratory Module Activities With Core Competencies.**

<table>
<thead>
<tr>
<th>Core Competency</th>
<th>Module Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to apply to the Process or Science</td>
<td>Students generate and test hypotheses, gather data, observe nature, interpret data and apply their findings.</td>
</tr>
<tr>
<td>Ability to use Quantitative Reasoning</td>
<td>Students use statistical tests to analyze and interpret their data</td>
</tr>
<tr>
<td>Ability to tap into the Interdisciplinary Nature of Science</td>
<td>Students are exposed to research from fisheries and wildlife, population biology, animal behavior and environmental advocacy.</td>
</tr>
<tr>
<td>Ability to Communicate and Collaborate with others</td>
<td>Students collaborate in groups to develop their hypothesis and perform data collection and analyses. They discuss invasive species issues in small and large groups.</td>
</tr>
<tr>
<td>Ability to Understand the Relationship between Science and Society</td>
<td>Through linking animal behavior to the socio-scientific issue of invasive species, students explore scientific procedures and the impact of scientific data on environmental policy.</td>
</tr>
</tbody>
</table>
Crayfish as Invasive Species Models

In this module, we use Red Swamp Crayfish (*Procambarus clarkii*) as the experimental organism. Using crayfish was advantageous for these topics due to their value as a model for both ecological invasion and behavior. Specifically, crayfish were chosen for this module because they provide an excellent example of a locally-relevant ecological issue. Due to the cosmopolitan nature of their role as invaders, it is also a topic that is likely to have local relevance in a great many other places, and would therefore serve as an adaptable module to many geographical areas in both secondary and post-secondary biology courses.

Additionally, while several hypotheses exist regarding the mechanisms that facilitate the exclusion of native species by invasive crayfish, there is agreement that agonistic (aggressive and submissive) interactions between and within species plays a large role in the exclusion of native species (Gherardi and Daniels, 2004, Gherardi, 2007). Agonistic behaviors are well documented, reliable, and easy to observe in a laboratory setting (Tierney et al., 2000), making them ideal for students lacking experience with behavioral analyses. Finally, crayfish are readily available from distributors and easy to maintain in a laboratory setting.

**Materials**

Table 2 outlines the materials needed for instructors to successfully run the laboratory module in a large or small course.
Table 2. Materials list per group of 4-8 students.

<table>
<thead>
<tr>
<th>Item</th>
<th># Required</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ½ gallon aquarium</td>
<td>1</td>
<td>Ideally only slightly larger than aquarium, cut to a height approximately 3 inches below the top of the aquarium. (prevents crayfish from focusing on students peeking in)</td>
</tr>
<tr>
<td>Cardboard box</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Digital scale</td>
<td>1</td>
<td>Must be accurate to at least 0.1 grams</td>
</tr>
<tr>
<td>Tray for scale</td>
<td>1</td>
<td>Sides must be high enough to keep crayfish from escaping. We used 1890 mL Tupperware containers</td>
</tr>
<tr>
<td>Crayfish housing containers</td>
<td>12</td>
<td>Must have lid and be able to hold water. We used 1890 mL Tupperware containers</td>
</tr>
<tr>
<td>Fast drying nail polish of variable colors</td>
<td>10*</td>
<td>Used to mark crayfish. Make sure it is easy to distinguish between colors.</td>
</tr>
<tr>
<td>Small square cups (with holes in bottom)</td>
<td>12</td>
<td>Need to be able to fit in container when closed. Used as shelter for crayfish and to transport them between containers. We used 3” planting pots.</td>
</tr>
<tr>
<td>Timer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Small plastic ruler</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Medium aquarium fish net</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Local invasive species pamphlet</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Rabbit food pellets, small bag</td>
<td>1*</td>
<td>Each crayfish will need 1 pellet every few days</td>
</tr>
<tr>
<td>Crayfish (Procambarus clarkii)</td>
<td>12</td>
<td>Best to order all one size, as the extreme size differences do not work very well. (we ordered from Carolina Biological Supply)</td>
</tr>
</tbody>
</table>

*Quantity will be sufficient for entire class.

Note. Crayfish supplies are enough for 15 lab sections of 40-45 students each.

Methods

Part 1: Agonistic Behavior

*Crayfish Care and Rotation:* When not in use by students, crayfish were stored individually in disposable Tupperware containers with holes in the lid. If crayfish are stored together they will establish a dominance hierarchy and will not interact during class (Bergman & Moore, 2005). The housing containers were filled with 400mL of spring water or treated tap water and a small square cup was kept in the container to provide shelter and used to catch and release crayfish. For the best results, each crayfish pair should only interact one time. In order to ensure that students and instructors could
track which crayfish had interacted, the containers were labeled (A-J) and the crayfish carapace and containers were painted with corresponding colors of nail polish. Students could select any two crayfish that had not been previously paired in a contest. They recorded the pairings on a tracking sheet that was used for subsequent class sections to ensure crayfish were matched in novel pairs for each contest. Instructors should not allow pairing between recently molted crayfish or disparately sized crayfish to prevent mortality or experimental bias. After the completion of the laboratory module, crayfish should be disposed of by first immersion in clove oil or Eugenol (0.125 mL/L) and then freezing crayfish for 3 weeks (to ensure death). This is a humane euthanasia method as per AVMA guidelines (AVMA, 2013). After freezing, crayfish can be disposed of by double bagging and putting in the garbage.

Setting the stage: Students completed a pre-module exercise where they were asked to watch a CBS video (2011) and read an article about invasive species and behavior as a proximate cause of invasion success (Holway & Suarez, 1999). Students are required to answer questions including brainstorming about which physical attributes of crayfish that might be useful to measure when comparing invasive and non-invasive crayfish and ways to standardize behavioral observations. In the laboratory class introduction, students watched a video specifically about invasive crayfish in Oregon (Oregon Public Broadcasting, 2011) that were initially released from classrooms, and read a local pamphlet about the crayfish invaders. Students then discussed in groups why people are concerned about invasive species, the types of problems they cause, their major sources of introduction, and ways to deal with populations of invasive crayfish. As a class, students discuss the cost and social ramifications of invasive species control or the lack thereof. We structured this discussion as a think-pair-share of the following 2 questions: “Should we stop spending as much money on trying to control invasive species? Why/Why not?” and “What would be the societal ramification of stopping?” Students were briefly introduced to the link between behavior and invasive species, building off the article they read prior to class (Holway & Suarez, 1999), and how to measure animal behavior. For more information on methods for data collection and analysis in animal behavior research, Martin and Bateson (2007) provide a thorough yet accessible
introduction. Students watched a video of a local researcher talking about his research and how the current module would contribute to his research on the behavior of Red Swamp crayfish in Oregon. Finally, students were instructed with regard to respecting and handling live crayfish.

*Physical Characteristic Variables:* Students are given a demonstration on how to handle the crayfish (Figure 1) and how to collect the data for 3 variables (sex, weight, and length of the outer claw; Figure 2).

![Figure 1](image1.png)

**Figure 1.** Students are given a demonstration on proper handling of crayfish. Crayfish should be picked up directly behind the thorax to prevent pinching.

![Figure 2](image2.png)

**Figure 2.** Measurements of sex and claw length were taken in addition to weight. Males have four calcified swimmerets just below the lowest legs while females lack the swimmerets. Claw length was measured on the outer side of the claw.
**Group Hypothesis Development:** Although students were previously informed that aggressive behavior of the Red-Swamp crayfish is important for their invasion success, they were also informed that their behavior patterns are still unclear, and that there are still many open scientific research questions about their social interactions. For example, local researchers are studying what factors may predict the winners of agonistic interactions between conspecifics. Students were told that they should write a hypothesis about which physical characteristic they thought would be the best predictor of a winner of an agonistic interaction (contest) between two crayfish. Students were asked to discuss how their hypothesis would relate to contests between invasive and native crayfish as a link to the topic of invasive species. The variables described above were selected due to ease of measurement and because the latter two are likely to differ between the native and invasive crayfish species (i.e. the natives weigh less and have shorter claws).

**Animal Behavior Data Collection:** Prior to each of the three contests, students recorded data for each of the three variables mentioned above for the two crayfish that were selected to participate in the contest. They also recorded the nail polish color on the crayfish and the letter on the container to track the crayfish. In order to observe the agonistic interactions, crayfish were simultaneously released into a five gallon tank (inside a box to prevent crayfish responding to students). It was important to ensure that the students are quiet and remain unseen by the crayfish. Based on multiple experimental trials done during the development of the lab module, I found it took an average of four minutes for the crayfish to acclimate and begin the interaction. It was important that the students had a consistent baseline to start recording their observations; this acclimation period of four minutes served as the standardized value for this baseline and is consistent with the behavioral observation protocols used by crayfish researchers. After four minutes, students started recording interactions in a behavior table using an ethogram developed in association with a local researcher (Table 3). Each student in the group observed and recorded the interactions of both crayfish on their own. Students tallied the different behaviors for six more minutes. After the total 10 minutes, crayfish were
removed from the arena tank and returned to their original containers. Students
determined which crayfish was the winner by totaling the positive and negative tally
marks for each behavior (note some behaviors are positive and some are negative as
indicated in Table 3).

<table>
<thead>
<tr>
<th>Crayfish Agonistic Behavior Name and Weight</th>
<th>Behavior Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach (+2)</td>
<td>Crayfish walks towards the other crayfish, generally with claws extended (perhaps posturing). Speed is greater than average walking speed. Ends when movement ceases or direction changes.</td>
</tr>
<tr>
<td>Posturing (+1)</td>
<td>Crayfish raises claws and front part of body, but does not approach other crayfish. Generally, claws are very open during this behavior. Ends when crayfish lowers claws below plane of body, or when crayfish moves towards the other crayfish.</td>
</tr>
<tr>
<td>Retreat (-1)</td>
<td>Crayfish turns and walks away from other crayfish, or postures and walks backwards; if the former, walking will be faster than average walking speed. Ends when movement ceases or direction changes (generally to approach).</td>
</tr>
<tr>
<td>Tail flip (-2)</td>
<td>A very obvious behavior. Rapid flick of telson (tip of tail) that propels the crayfish backwards with its claws extended together and down in a streamlined position. Ends when all walking legs make contact with aquarium floor again.</td>
</tr>
</tbody>
</table>

*Note. Numbers in parentheses indicate if the behavior was an attack or retreat (+/-) and the weight of the behavior (1/2). Each tally mark in the behavior table is multiplied by the number in parentheses corresponding to that behavior and then totaled.*
During the tallying process, students discussed any differences they might have had their observations numbers and took the average of their tallies across the behaviors. This allows students to assess the inter-rater reliability of their observations. The crayfish with the highest total score is the winner. Each crayfish was indicated as a winner or loser in its data table associated with its weight, sex, and claw length. Students repeated the data collection and contest two more times per group for a total of 6 crayfish per group. Class data were compiled by students or instructor as the number of winners and losers based on different traits (heavier weight, longer claws, male vs. female). For example, if the winner of contest one was a male in a male vs. female interaction, with longer claws and weighed more than the female you would add one to each of those three categories. Note: In some male/female contests the males will mate with the female rather than displaying aggressive behavior, depending on the season.

Data Analysis: Quantitative reasoning is an important skill to develop at the collegiate biology level (AAAS 2011). While many students have not yet had statistics, careful scaffolding of this activity can allow students to do an analysis using a simple chi-square test. This module allows them to use quantitative reasoning to test their original hypotheses and interpret the data. To do this analysis, students use the class totals to do a chi-square analysis based on the hypothesis each group came up with at the beginning of the class. Chi-square tests are used in this module because they are easy for students to understand and are used to compare observed data with data we would expect to obtain according to a specific hypothesis. The expected values should be based on the total winners observed if the outcome was based on random chance (i.e. sum of winners + losers/2). Students are asked to relate their results to their hypothesis and think about how the advantage of the physical attribute they explored that either did or did not result in winning might affect native crayfish populations in the event of an invasion.

Part 2: Foraging and Reproductive Behaviors

Crayfish invasions are not mediated solely by agonistic interactions; numerous other factors are likely to be involved in the displacement of native species by invaders (Gherardi, 2007). For this reason, the curriculum also explores the additional factors of foraging and reproductive behaviors. To examine these behaviors in crayfish, students
visited computer stations set up with presentation slides about foraging and reproductive behavior that they had not yet considered, discussed with their groups, and answered questions related to how the differences in these behaviors between native and invasive crayfish provided an advantage to the invasive crayfish. They also considered how parental care relates to invasive species survival in novel habitats. Depending on the time of year, it may also be possible for students to observe live crayfish with eggs/young.

**Part 3: Scientific ideas and modern society**

At the end of the module, students were asked to answer questions relating their newly constructed knowledge of invasive crayfish behavior to possible solutions or ways to prevent the spread of invasive species. The questions below had them consider issues related to environmental policy and decision-making (Maben 2004).

1. **Sounding the Alarm** – How can we, as citizens, call attention to the problem of invasive crayfish?
2. **Scientific Data Gathering** – What evidence or data did you collect about crayfish behavior during this lab that would help in our understanding of whether or not and in what way invasive crayfish can be an environmental problem?
3. **Risk Assessment** – What do you think should be done about invasive crayfish and how expensive is your proposed effort likely to be? Be specific.
4. **Public Awareness** – How will you let the public know that invasive crayfish are an environmental issue? What should they do about it?
5. **On-Going Follow-Up** – What should we do to investigate whether or not your efforts have an impact?

**Assessment of Student Learning**

Students were formatively assessed throughout the module via sharing their data, answering questions, and discussing their action plan with their instructor and classmates at checkpoints written into the curriculum. The students were also assessed via a post-module quiz based on the student learning outcomes. Our GTAs are extensively trained by an education professional in pedagogical theory including how to lead discussion, Bloom’s taxonomy, how to do effective formative and summative assessment and how to be scientific teachers.

**Survey Research on Laboratory Module**

The research of the module focused on the students’ perceptions of their learning experience immediately after completing the module (Table 5). An anonymous survey
was comprised of modified survey questions from assessments of another postsecondary science laboratory module (Kalinowski, 2012), and several questions developed by the authors that reflected the potential gains of teaching an issues-oriented science module (Lenz, 2012). Closed response survey questions used a rating system as follows: 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree. Out of the 483 students who were asked to participate in the survey, 397 agreed for a response rate of 82%. Table 4 reports the percentage of students (n = 397) that agreed, disagreed or were neutral with regard to the survey statements.

Table 4. Closed-response survey statements with corresponding course data percentages (n = 397)

<table>
<thead>
<tr>
<th>Survey Statement</th>
<th>% Agreed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>% Neutral&lt;sup&gt;b&lt;/sup&gt;</th>
<th>% Disagreed&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Crayfish lab held my interest.</td>
<td>91.44%</td>
<td>5.81%</td>
<td>2.44%</td>
</tr>
<tr>
<td>The Crayfish lab challenged me intellectually.</td>
<td>46.18%</td>
<td>36.09%</td>
<td>17.74%</td>
</tr>
<tr>
<td>During the Crayfish lab, discussing with my classmates helped me learn.</td>
<td>80.74%</td>
<td>13.46%</td>
<td>5.81%</td>
</tr>
<tr>
<td>The Crayfish lab helped me better understand the importance of studying animal behavior.</td>
<td>86.55%</td>
<td>9.48%</td>
<td>3.97%</td>
</tr>
<tr>
<td>The Crayfish lab made me want to learn more about biology topics in general.</td>
<td>63%</td>
<td>28.44%</td>
<td>8.56%</td>
</tr>
<tr>
<td>The Crayfish lab was a valuable learning experience for me.</td>
<td>73.7%</td>
<td>18.96%</td>
<td>7.03%</td>
</tr>
</tbody>
</table>

<sup>a</sup> Answers include “Strongly Agree” and “Agree”
<sup>b</sup> Answer includes “Neither Agree nor Disagree”
<sup>c</sup> Answers include “Disagree” and “Strongly Disagree”

As is apparent from the survey results, this module was incredibly successful with the students in terms of holding their interest (91.44% agreed), and giving them a better understanding of the importance of animal behavior (86.55% agreed). The students also felt that opportunities for discussion with their groups helped them learn (80.74%). The majority of students (63%) also indicated that it made them want to learn more about biology in general. Many students (46.18%) agreed that the module challenged them
intellectually, but many were also neutral in regard to this statement (36.09%) and a minority of the students (17.74%) disagreed.

**Discussion and Implications**

We have developed and implemented this laboratory module successfully in a large introductory majors’ biology course instructed by 14 different graduate teaching assistants. Both the students and the teaching assistants reported being engaged in the laboratory module. The survey assessment shows the effectiveness of the activity on student engagement, interest and valuing of the learning experience. The use of an easy to implement paper survey in class has allowed us to think about future improvements to the module. For example, some of the students did not report being intellectually challenged by the activity, so we are currently adjusting the module to be more challenging by having students use population biology concepts and modeling to predict the spread of invasive crayfish in their local waterways. In addition, this module could be made more inquiry-based by having the students come up with a wider range of hypotheses to test and by giving them less context initially.

This module allowed us to teach traditional animal behavior content with population and invasion biology while informing our students about an important issue in their local and global communities. While we were unable to use native crayfish in the contests due to the difficulty of keeping them alive in laboratory conditions, we had the students relate their hypothesis and their results to the potential invasive/native crayfish interactions as a means to get them to think about this connection and the design of their experiment. It was carefully designed based on the core concepts and competencies outlined in Vision and Change (AAAS, 2011), and it is highly adaptable to be made locally relevant to both postsecondary and secondary-level biology classes, especially in large introductory laboratory courses.

**Possible Module Extensions**

If you have more than one laboratory period for this exercise, students could develop their own ethogram as a class during the first laboratory period. Another possible extension of this activity for an animal behavior course would be to do a methodological comparison between counts of behaviors and duration of time spent in various behavioral
states to compare the two measurement techniques and discuss that would be the best method of this species. Students, also, could do some independent research on native crayfish behavior and physical characteristics for comparison purposes.
CHAPTER 4- Introductory Biology in Social Context: The Effects of an Issues-Based Laboratory Course on Biology Student Motivation.

Krissi M. Hewitt, Heather Kitada, Lori Kayes & Jana Bouwma-Gearhart

To be submitted for publication in:
Curriculum and Instruction or Journal of Higher Education
**Introduction**

Recent advancements in the biological sciences have resulted in a large number of social, political and technological issues that demand action from both scientists and citizens (AAAS, 1989 & 2011). This has led to an increasing demand on institutions of higher education to produce graduates that are not only scientifically literate, but also more biologically literate (AAAS, 2011). Recent reports such as Vision and Change (AAAS, 2011), have called for graduates who have, “a well-defined level of functional biological literacy and critical thinking skills” (AAAS, 2011, p. 5). *Functional biological literacy* is an active form of scientific literacy where an individual would have a command of biological concepts and competencies necessary to adequately read, comprehend, and communicate biological issues present in the media (Laugksch, 2000). This need for biological literacy has spurred many reform efforts in biology education at the university level (Hall, Watkins, Coffey, Cooke & Redish, 2011). In order to achieve outcomes related to this goal, research indicates that there needs to be a change in biology education away from courses that focus on rote memorization of inert facts and concepts that are devoid of social context (AAAS, 2011, Seymour & Hewitt, 1997) towards courses that incorporate activities representative of authentic scientific practices and the application of these practices to real-world problems (Chamany, Allen & Tanner, 2008, Barab & Plucker, 2002). Moreover, because the number of issues that need attention from all citizens is increasing rapidly with the advent of new technologies, it is recognized that biological literacy is a desired outcome of biology education for all university students, not only those that will continue on as biologists.

*Socio-scientific issues-based instruction*

A pedagogical approach that has been linked to positive outcomes regarding biological literacy (Sadler, 2007) is the socio-scientific issues-based approach to science education (Lenz & Willcox, 2012, Zeidler, Sadler, Simmons & Howes, 2005). Socio-scientific issues are complex social problems with technological or conceptual ties to science (Sadler, 2009). These represent a wide array of controversial topics that show up frequently in national media such as global climate change, genetic modification of foods, and problems concerning invasive species (Sadler, 2011). Approaches to solving
these issues require the application of scientific concepts and the analysis of political, economic, and ethical factors. Moreover, many socio-scientific issues are rooted in scientific advances and technologies stemming from the biological sciences, and therefore require a certain level of biological literacy for public understanding.

Rooted in the Science, Technology and Society movement of the 1970s and 80s, the Socio-scientific Issues-Based (SSI) approach to science education goes beyond the Science, Technology and Society approach, which featured isolated courses focused on issues and small asides in textbooks rather than integrating socio-scientific issues more deeply and completely across the science curriculum (Sadler, 2004). According to Sadler (2004) the SSI approach, “aims focus more specifically on empowering students to handle science-based issues that shape their current world and those which will determine their future world” (p. 514). This approach integrates socio-scientific issues into teaching about scientific content and emphasizes the analysis of such issues during class time.

Incorporating activities that focus on the authentic practices of scientific disciplines that have relevant, real-world applications to issues citizens are facing in the 21st Century has been shown to have positive influences on student learning (Edelson & Joseph, 2004, Blumenfeld 1992), interest development (Hidi & Renninger, 2006) and motivation (Deci, 1992, Jarvela, 2001). Proponents of the SSI approach to science education have found that the use of socially relevant issues helps students relate scientific content to their everyday lives and can make them more motivated to learn science (Sadler, 2009). There are several studies that show that SSI interventions have provided motivating contexts for learning from a student perspective (Albe, 2008, Barber, 2001, Bennett et al., 2005, Bulte et al. 2006, Dori et al., 2003, Harris & Ratcliffe, 2005, Lee & Erdogan, 2007, Parchman et al., 2006, Yager et al., 2006, Zeidler et al., 2009, Sadler, 2004 & 2009) although few of these studies have included college students as participants in the research or provided sufficient analyses within more robust motivational theory (Darner, 2012, Barber, 2001, Sadler, 2011).

Student motivation is an important construct that involves both affective and cognitive processing (Hidi & Reninger, 2006), regarding “what is learned, how much is learned, and how much effort will be put into the learning process” (NRC, 2000).
Motivation in classroom settings has been an important focus of research in both cognitive psychology and science education because of its role in predicting outcomes such as persistence, effort, academic achievement, and resiliency, which is why I chose to focus this study on student motivation associated with SSI curriculum (Zimmerman, 2000).

The curriculum that was the subject of this research study was designed for large introductory biology laboratories for science majors and focused on contextualizing scientific content with the integration of socio-scientific issues. The SSI approach has also typically been studied in small classroom settings in non-majors university-level courses or with secondary science classes (Darner, 2012). The purpose of this research study was to determine the impact of the SSI laboratory curriculum on student motivation in a large introductory biology course. In order to examine the effect of a SSI laboratory curriculum on students’ levels of motivation, we conducted an experimental study in which laboratory sections of an introductory biology course for science majors were randomly assigned to instructors who taught a newly developed curriculum based on the SSI model (SSI-treatment), or to those who taught the existing curriculum in place (EXT-control). I hypothesized that the SSI laboratory course would increase student motivation significantly relative to a control group that received the existing curriculum because of the contextualization of content with issues that are relevant to the student’s daily lives.

Laboratory sections of students were randomly assigned to either the SSI curriculum (treatment group) or the EXT curriculum (control group) in an introductory biology course for science majors at a large research university. Using hierarchical linear modeling to analyze survey data from 25 laboratory sections of students taught by graduate teaching assistants, I found that the sections of the course that implemented the SSI curriculum had significantly higher motivation at both the middle and at the end of the course relative to the existing curriculum. In this paper, I describe the research design and results using the framework of Deci & Ryan’s (1985) self-determination theory of motivation.

Review of Theories of Motivation

Motivation can be described as trait-like, a students’ natural disposition towards
learning, or state-like, “which refers to students’ desires to participate, study and learn in a specific context” (Brooks & Young, 2011, p. 49). The present study is concerned with the latter that is termed situational motivation (Guay, Vallerand & Blanchard, 2000). The highest quality of situational motivation that predicts positive student outcomes such as increased persistence and effort is termed intrinsic motivation (Renninger, 1992, Deci & Ryan, 1985). The self-determination theory (SDT) of motivation posits that humans are intrinsically motivated when they are self-determined, or when they have agency or power over their own choices (Ryan & Deci, 2000, Brooks & Young, 2011). According to SDT, feelings of self-determination are based upon the degree of satisfaction of three basic psychological needs - perceived autonomy, competence and relatedness (Ryan & Deci, 2000). SDT posits that all humans have goals related the fulfillment of these three basic needs, and that the fulfillment of these goals leads to feelings of self-determination that stem from a perceived internal locus of control (Deci & Ryan, 1985). In terms of educational contexts, the degree that students feel self-determined impacts their motivation relative to task engagement (Ryan & Deci, 2000).

A sub-theory of SDT, Organismic Integration Theory (OIT), postulates a continuum of motivational states that vary depending on the context and the degree of perceived need-fulfillment (Ryan & Deci, 2000, Deci & Ryan, 1985). Motivation has been commonly described as a dichotomy, as either 1) intrinsic, where the person is free from pressure or external regulation, or 2) extrinsic, where the person is solely externally regulated by the desire for an outcome whether it is a reward, avoidance of punishment, or a desire to look good to peers (Ryan & Deci, 2000). OIT goes beyond this dichotomous approach to motivation, adding amotivation, not acting at all or acting without intent, and breaking down extrinsic motivation into four different categories that represent the variation between internal and external regulation (see Figure 1).

When a person perceives the regulation of their activities as internal to their developing “self”, they are more likely to have autonomous forms of motivation, those that reflect feelings of self-determination, that in educational contexts have been shown to be predictors of persistence towards degree completion (Vallerand, 1997), increased retention and depth of learning (Vansteenkiste et al., 2004, Grolnick & Ryan, 1987), and
have been positively associated with academic achievement (Fortier, Vallerand & Guay, 1997, Ratelle, Guay Vallerand, Larose & Senecal, 2007). Autonomous motivations that lead to feelings of self-determination contain both intrinsic and extrinsic forms of motivation (Integrated and Identified regulation). In contrast, controlled motivations, those that reflect low feelings of self-determination and a locus of control external to self, have been associated with negative educational outcomes such as low creativity (Amabile, 1995) and cognitive anxiety (Ryan & Connell, 1989). Controlled motivations consist of two different types of extrinsic motivation (External and Introjected regulation). In their investigation of achievement behaviors of school children, Ryan and Deci (2000) found that,

“the more students were externally regulated the less they showed interest, value and effort toward achievement and the more they tended to disown responsibility for negative outcomes, blaming others such as the teacher” (p. 73).

<table>
<thead>
<tr>
<th>Type of Motivation</th>
<th>Amotivation</th>
<th>Extrinsic</th>
<th>Intrinsic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Regulation</td>
<td>External</td>
<td>Introjected</td>
<td>Identified</td>
</tr>
<tr>
<td>Quality of Behavior</td>
<td>Controlled</td>
<td>Autonomous</td>
<td>Autonomous</td>
</tr>
</tbody>
</table>

Figure 1. The Self-Determination Continuum showing motivation, regulation and behavior types. Adapted from Ryan, & Deci, (2000) and Darner (2012).

Since autonomous motivations are associated with numerous positive educational outcomes, it is important to investigate the effect of the SSI curriculum on autonomous and controlled motivations as well as on amotivation.

**Methods**

In this study, I sought to elucidate the impact of the SSI approach on biology student motivation using a theoretical lens of self-determination theory. Specifically, I intended to identify where students in a large, compulsory introductory majors biology course would fall on the self-determination continuum, and whether or not the SSI-based
curriculum would have the potential to cause a shift in student motivation towards the more internally regulated side of the continuum with respect to a control group. I investigated the following research questions in this study:

1. a) What types of motivations are salient for undergraduate students in an undergraduate introductory biology course?
   b) How do the levels of the different types of motivation change over the course of the term?
2. a) What was the effect of a socioscientific issues-based laboratory curriculum on undergraduate biology students' levels of autonomous and controlled motivations with respect to engaging in the work for the laboratory compared to the control group?
   b) How did these change over the course of the term?

**Educational Context**

*Socioscientific Issues-Based (SSI) Curriculum*

I, as a curriculum designer and researcher, designed the socio-scientific issues-based (SSI) curriculum that was included in the educational context relevant to this study. In creating the SSI curriculum, I made every effort to follow the guidelines for SSI-based instruction based on the model by Lenz (2012) (see Figure 2).
providing an issue or problem to contextualize their learning (Lenz & Willcox, 2012). Although the focus of this research study is on student motivation, the entire model was used as a guide in developing each laboratory module.

Each laboratory topic was similar to the topics used in the existing curriculum in order to follow the lecture sequence of the course. Students in the SSI sections were taught similar content, but in a way that integrated the SSI approach to science education. The learning outcomes for the laboratory portion of the course were developed based on several of the core concepts and competencies outlined in Vision and Change (AAAS, 2011) as was appropriate for the lecture content of the course (genetics, evolution, natural selection and ecology). Laboratory activities were either modified from current biology education research/practitioner publications or developed in house. The 2hr and 50-minute lab periods were centered on a socio-scientific issue that related to that week’s course content. I designed the curriculum to address both global and local topical issues relevant to the institution’s biology students such as genetic testing, genetic modification of crops, and local invasive species. In order to introduce the issue to students before class, I designed pre-labs that consisted of various videos, news articles and scientific articles addressing the issue, followed by thought provoking questions about the topic and the content. Each laboratory period began with a pre-lab activity during the first 20-30 minutes. I also tried to connect each module with research being conducted at the university. In one instance, students were able to interact with a graduate student researcher via video and collect data for research projects. Laboratory activities were mostly structured or guided inquiry, meaning they allowed students to determine results with a set of prescribed methodologies, or they were encouraged to develop both the methodology and the results from pre-defined research questions (Hofstein & Lunetta, 2004).

*Existing Curriculum*

The existing curriculum in the biology laboratory that would normally be taught by all of the instructors consisted of many activities from a widely used laboratory manual. Most of the modules included somewhat outdated activities (i.e. DNA puzzle to learn transcription or pop beads to learn meiosis) that were not contextualized in any way to
provide real-world relevance. The last two laboratory modules were the most similar to the SSI curriculum in that they included guided inquiry-based activities where students designed research questions and participated in a field learning experience, but the SSI module connected the experience to solving a local environmental issue. In all cases, the enactment of existing curriculum included minimal efforts to contextualize biology for students using socio-scientific topics. If socio-scientific topics were addressed, they may have only been briefly mentioned by the graduate teaching assistant instructor in the laboratory introduction as a “fun-fact” as opposed to being fully integrated into the curriculum.

Course Structure
This experiment was conducted in the laboratory sections associated with the larger lecture portions of an introductory biology class for majors over the course of a ten week spring term at a large research university in the Pacific Northwest. The SSI curriculum was implemented at the laboratory level of the course only, with the lecturers not utilizing the same framework as was used to design the laboratory sections. Students (n = 1032) were required to enroll in a concurrent laboratory with lecture sections. Students were enrolled in one of three lecture sections offered on the same days at three different times. All of the lecture sections for the course in the spring term at the university were included in the study. There were three course lecture sections that the students could choose to enroll in. Two of the lecture sections were team taught by the same two instructors with each teaching five weeks of the term. The only notable difference between these two lectures sections was that one course was taught in the morning and the other in the afternoon, denoted as section A and C in Figure 3. These two lecture sections represented the majority of the course enrollment (N = 832). There was one smaller section (N = 200) that was taught by a different instructor who taught the entire ten week term that is labeled as section B. Students were allowed to enroll in any lecture section.

The laboratory enrollment was mandatory and linked to the lecture portion of the course with a total of 25 laboratory sections taught by graduate teaching assistants
Students were nested in a lab section with a GTA and the lab sections were nested in lecture sections, creating a clustering of groups (see Figure 3).

**Figure 3.** Course structure of introductory biology for science majors

This clustering of groups was taken into account in all aspects of the design and analyses of this study (Raudenbush, 1997). Since the lab sections were not evenly distributed across lecture sections, lecture time/section was first tested as a variable and found not a significant factor in the model.

**Curriculum Implementation Procedures**

The graduate teaching assistants were introduced to the curriculum for both the treatment and control groups during weekly preparatory meetings where they were given tips on how to run the labs and were allowed to run through the activities themselves with guidance from one of two Prep Leaders. The weekly preparatory meetings were split into those instructors who taught the SSI curriculum and those who taught the existing curriculum. The course coordinator, who is the supervisor of the graduate teaching assistants and a lecturer for the course, was responsible for running the meeting for those instructors who were teaching the existing curriculum (control group). I, as the main researcher for this study, who had previously taught the existing curriculum as a graduate teaching assistant and developed the SSI curriculum, ran the meetings for those instructors who taught the SSI curriculum (treatment group). We made every effort to be similar in the way they ran the meetings as the curriculum allowed.

**Sample**

*Laboratory Sections/Graduate Teaching Assistants*
The laboratory portion of the course was taught by twenty-five Graduate Teaching Assistants (GTAs). The SSI GTAs included five males and eight females with an average of 4.42 quarter terms of teaching experience (SD = 2.35). The control group (EXT) GTAs included eight males and four females with an average of 4.54 quarter terms of teaching experience (SD = 2.16). The GTAs were assigned a lead section that they were responsible for the introduction to the lab, grading, and handling of all students’ concerns. Some of the GTAs in the EXT group had taught the spring curriculum previously, but as the SSI curriculum was newly developed and had not been previously implemented, none of the GTAs assigned to this curriculum had experience in teaching the SSI modules.

*Students*

The participants in this study were undergraduate students enrolled in the introductory life science majors’ biology course. All students participated in both lecture and laboratory sections of the majors’ biology course. This is a sample of convenience that is representative of the university population of science students and there is no reason to think that this sample differed significantly from another sample chosen during other course terms. The target enrollment for this study was 1,082 participants as this was the total initial enrollment for the course. The final enrollment of the course at the time of the final exam was 968 students. The loss of 114 students over the course of the term is typical compared to previous terms, and there was no difference in the drop rate between the treatment and control groups.

*Participant Assignment*

Since the students were nested within laboratory sections that were nested within lecture sections, and the implementation of the treatment was restricted to the laboratory class only, students were randomized at the laboratory section level. This nested structure was accounted for throughout the design and analysis of the experiment in order to allow for unbiased estimates of the treatment effect. Current literature has argued for the need to account for the nested structures of designs in statistical analyses, and this method is becoming more prevalent in education research studies (Raudenbush, 1997, Matsumura, Garnier & Spybrook, 2013).
Laboratory sections of students were assigned to either the SSI-based curriculum (treatment group) or the existing curriculum (control group) based on the laboratory room associated with their schedule number. The distribution of lab sections chosen for the new SSI curriculum was not balanced with respect to lecture sections because of more sections being assigned to one laboratory room than the other. For the team taught lecture sections, almost all of the labs for the morning sections received the traditional lab curriculum and all the afternoon lab sections received the new lab curriculum. We discuss the potential implications of this below. Students had no knowledge as to which group (treatment or control) they belonged to. Students were told during the first lecture of the course that the biology program was implementing different curricula and assessing the impacts on the students for future course curricular decisions. Students were assured that they would get the same content and that both curricula implemented accepted learning strategies.

**Procedures and Measures**

Participants were asked to complete online surveys, via emails to their university email accounts, during week 1 of the course prior to their first lab class, week 5 and week 10 of the ten-week quarter spring term. Students were awarded extra-credit for the successful completion of each survey. An alternative extra-credit assignment was offered to those who did not participate in the study. The survey given at the three time points incorporated the Situational Motivation Survey (SIMS) (Guay, Vallerand & Blanchard, 2000) and general demographic questions (Appendix B).

*Situation Motivation Scale (SIMS)*

The SIMS (Guay et al., 2000) is a relatively short survey instrument that was designed to measure situational motivation. It is context specific, meaning it was designed to measure motivation in a setting, not as an individual trait. It measures intrinsic motivation (IM), amotivation (AM) and two types of extrinsic motivation including identified regulation (IR) and external regulation (ER). The types of extrinsic motivation are categorized by the degree of self-regulation that represents an individual’s perceptions of self-determined action in a given setting (Standage & Treasure, 2002). The SIMS does not measure integrated regulation or introjected regulation types of extrinsic motivation,
postulated by self-determination theory. The SIMS is comprised of four sub-constructs with four questions for each type of motivational construct assessed. The survey is comprised of 16 Likert-Scale items that have students respond on a scale of 1-7 where 1 = corresponds not at all, and 7 = corresponds exactly to a series of statements. The statements were rated in response to the stem, “Why are you doing the work for the Biology 213 LAB?”. This was a change from the original stem that read “Why are you currently engaged in this activity?”. I only changed statements in a minor way to say “this lab” instead of “this activity”. Extensive studies on the validity and reliability of the scale have been conducted previously using correlational and factor analyses along with theoretical construct validity correlations validating the relation of the scale items to self-determination theory (Guay et al., 2002, Standage & Treasure, 2000). Cronbach’s alpha was calculated from pre-term participant survey scores to ensure reliability of the measure in this study. Cronbach’s alpha reliability estimates for the sub-scales were .91, .87, .83 and .91 for intrinsic motivation (IM), identified regulation (IR), external regulation (ER) and amotivation (AM), respectively. Analyses included scoring for each one of these sub-constructs for students at each time point.

In addition, following the work of multiple researchers (Levesque, Stanek, Zuehlke & Ryan, 2004, Vallerand, 1997), I used all four sub-construct scores to calculate one metric for motivation called the self-determination index (SDI). The SDI has been used in multiple studies and has been shown to be a valid metric for self-determination (Vallerand, 1997). It is calculated by weighting the sub-constructs of the self-determination continuum. The weighting of the sub-constructs corresponds to their position on the self-determination continuum, adding heavier weights to IM and AM (see Figure 1). SDI was thus calculated in further analyses as:

$$SDI = 2 \times IM + IR - ER - 2 \times AM$$

**Data Analysis**

**Hierarchical Analyses**

Since students (n = 698) took part in all three surveys, over roughly equal intervals (weeks 1, 5 & 10), I accounted for the temporal correlation between observations from the same individual through repeated measures methods. Thus, my data were analyzed on
the student level. However, the curricular treatments were implemented at the lab level. I accounted for the hierarchical nature of this experimental design with nested random effects in a hierarchical linear model (HLM). I worked with a statistics expert as a collaborator in this study to conduct the hierarchical linear modeling analyses that helps to confirm the accuracy of the model. HLM analysis accounts for within and between-group variances that results in a more accurate estimate of the treatment effects (Liu, Lee & Linn, 2010, Raudenbus & Bryk, 2002). Modeling allows for testing the effect of the curriculum with covariates such as lecture section, lab section, etc., as well as exploration into how the effect of treatment varies with time.

I was interested in studying the effect of the SSI lab curriculum on student self-determination. Therefore, to assess this I tested the fixed effects of the treatment and the time by treatment interaction. The latter fixed effect speaks to how the effect of the treatment changes throughout the term. Furthermore, we were interested in studying if gender or race explained any of the variance in survey scores. Data were analyzed using SAS PROC MIXED with a Satterthwaite approximation to account for the lack of balance in the responses for degrees of freedom as the laboratory sections were not equally distributed across lecture sections and times (SAS Institute Inc., 2008).

The following is the complete saturated mathematical model:

\[ Y_{ijklmnop} = \mu + \alpha_i (\text{curriculum}) + \beta_j (\text{time}) + (\alpha\beta)_{ij} + \gamma_k + \delta_l(k) + \zeta_m(kl) + \eta_{n(klm)} + \theta + \iota + \epsilon_{ijklmnop} \]

- \( Y_{ijklmnop} \) = measure of motivation (sub-construct) of the \( n^{th} \) student nested in the \( m^{th} \) lab nested in the \( l^{th} \) section nested in the \( k^{th} \) lecture at the \( j^{th} \) time receiving \( i^{th} \) treatment
- \( \mu \) = the overall mean
- \( \alpha_i \) = fixed effect for the \( i^{th} \) curriculum treatment
  - \( i = 1, 2 \), where EXT is 1 and SSI is 2
$\beta_j = \text{fixed effect of the } j^{th} \text{ time measurement}$
  
  \begin{itemize}
    \item $j = 1, 2, 3$
  \end{itemize}

$\gamma_k = \text{random effect of } k^{th} \text{ lecture}$
  
  \begin{itemize}
    \item $\gamma_k \sim N(0, \sigma^2_\gamma)$
  \end{itemize}

$\delta_{l(k)} = \text{random effect of the } l^{th} \text{ section nested in the } k^{th} \text{ lecture}$
  
  \begin{itemize}
    \item $\delta_{l(k)} \sim N(0, \sigma^2_\delta)$
  \end{itemize}

$\zeta_{m(kl)} = \text{random effect of the } m^{th} \text{ lab nested in the } l^{th} \text{ section nested in the } k^{th} \text{ lecture}$
  
  \begin{itemize}
    \item $\zeta_{m(kl)} \sim N(0, \sigma^2_\zeta)$
  \end{itemize}

$\eta_{n(klm)} = \text{random effect of the } n^{th} \text{ student nested in the } m^{th} \text{ lab nested in the } l^{th} \text{ section nested in the } k^{th} \text{ lecture}$
  
  \begin{itemize}
    \item $\eta_{n(klm)} \sim N(0, \sigma^2_\eta)$
  \end{itemize}

The resulting analyses of the SIMS scores with hierarchical linear modeling allowed us to account for the fact that a particular GTA would implement the treatment with differences in instructional style, ability and adherence to the curricular model (Gardner & Jones 2011) and therefore, students within a single laboratory section may be more similar in terms of motivation to each other than to others in different lab sections. We were also able to account for variance between lecture sections and for differences in lecturers.

**Random Effects**

There is a clear hierarchical nature in this experimental design; students are nested in labs that are nested in lecture sections that are nested in lecturer(s). Random effects were used to account for the correlation between individuals within the same lab section, lecture section, or even taught by the same lecturer(s).

**Results**

**Student Demographics**

Of the 968 students enrolled in the class at the final exam, 861 participated in the post-term survey, with an overall response rate of 89%. Table 1 reports the participant
responses to the demographics questions from the two groups; treatment (SSI; n = 443) and control (EXT; n = 418). The majority of the students in both the SSI and the EXT laboratory sections reported being in the age range 18-22 years (86.57%, SSI, 83.7%, EXT). Females represented the highest gender category in the class enrollment in both the SSI (57.93%) and the EXT (58.84%) sections. The majority of the students in both groups were European or White (67.13%, SSI, 72.40%, EXT) followed by those that marked Asian or Asian American (20.00%, SSI, 17.68%, EXT). All other Race/Ethnic Origin categories represented less than 10% of the total enrollment. Participants were allowed to select more than one category, so it is expected that many students marked multiple categories.

Table 1 Characteristics of Introductory Biology Students

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SSI</th>
<th>%</th>
<th>EXT</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-22</td>
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*Students were allowed to select more than one category, if applicable

Response Rates

The HLM analysis included only those who participated in all three surveys in order to assess individual feelings of self-determination and perceived competence over time. Of the students left in the course at the final exam (N = 968), 698 students (72%) completed all three surveys with no differences between treatment and control. Individual lab section response rates varied from 56% to 86%, but low and high rates were seen in both treatment and control groups.

Grade Analyses

Since we did not implement the SSI-based curriculum in the lecture portion of the course, based on a simple t-test we analyzed the course grades and found no significant difference between the EXT and SSI treatment groups for laboratory scores ($p = 0.8659$) or final course grades (in number of points) ($p = 0.5372$). There were also no differences in the DF or Withdraw rates between the two groups, or on the lecture exams.

Curriculum effects using the self-determination Index

In order to better visualize lab section data over time to make comparisons between the EXT and the SSI curricula in terms of motivation, I used the univariate self-determination index metric that allowed me to compute a weighted score using the SIMS sub-scale scores outlined above. In my analyses of the self-determination index scores, I found that there was a significant effect of the curriculum ($F=12.16; p = 0.0016$) (Table 2). There was an effect size of 1.394 that represents the estimated difference between the scores on the SIMS scale based on the model. Self-determination index scores can range
from -18 to +18 with the more negative values representing less feelings of self-determination.

<table>
<thead>
<tr>
<th>Table 2. Curriculum treatment effect</th>
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<tr>
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<td>Curriculum</td>
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The difference between the SSI and the EXT curricula shown in Table 2 was from an average of the lab section scores from the SIMS scale as shown in Figure 4. I used the univariate metric to plot the average motivation scores from the SIMS scale for lab sections (N = 25) in the SSI (Right) and EXT (Left) curriculum as determined by the model over time (weeks 1, 5 & 10) (Figure 3). Many of the lab sections in the SSI groups had significantly higher self-determination index scores and overall showed significantly less variance with regard to individual lab sections.

Figure 4. Plot of individual lab motivation over time, split by curriculum treatment

Figure 5 shows the grand mean of SDI scores for all laboratory sections in the EXT and the SSI groups over time (week 1, 5 & 10).
Students in the SSI group had significantly higher scores than the existing groups on the SIMS scale for both weeks 5 and 10. SSI and EXT groups were not significantly different on week 1. There was a significant effect of time on SIMS score over the course of the term (F=13.42, \( p < 0.001 \)); however, there is only weak but suggestive evidence for a curriculum by time interaction, meaning that the decrease in SIMS scores over time was not significantly different between the SSI and the EXT curricula (F=2.24, \( p < 0.1073 \)).

**Curriculum effects broken out into sub-constructs**

In addition to the univariate measurement effects reported above, I also investigated the differences between the SSI and EXT curricula on the four sub-constructs of motivation represented on the SIMS survey individually to get a better sense of the types of motivations that were most salient over the course of the term. Results of analyses breaking down the scale into the four sub-constructs are discussed below.

**Intrinsic Motivation:** There was strong evidence that there was an effect of treatment on intrinsic motivation, meaning that at the end of the term intrinsic motivation is significantly higher in the SSI group (F=27.85; \( p < 0.0001 \)). In addition, there is strong...
evidence of an interaction between treatment and time on intrinsic motivation (F=2.20; \( p \)-value=0.0081). As the term goes by, intrinsic motivation decreases in both the EXT and the SSI group, but the decrease is not as extreme for the SSI group.

**Identified Regulation:** There is strong evidence that there is an effect of treatment on identified regulation (F=11.13; \( p = 0.0030 \)). There is weak, but suggestive evidence of an interaction between treatment and time on identified regulation (F=2.20; \( p = 0.1112 \)). It appears that identified regulation decreased for both treatment groups throughout the term; however, there was a significantly larger decrease in the EXT group between week 1 and week 5 in comparison to the SSI group.

**External Regulation:** There is strong evidence that there is an effect of treatment for external regulation (F=45.86; \( p \)-value =0.0248). However, there is no evidence of an interaction between treatment and time on external regulation (F=0.82; \( p \)-value =0.4421). It appears that external regulation changes very little throughout the term for the EXT group. On the other hand, as time goes by the external regulation for the SSI group decreases.

**Amotivation:** There is strong evidence that there is an effect of treatment on amotivation, meaning that the SSI group has lower scores on this sub-scale at the end of the term (F=4.28; \( p \)-value = 0.0504). There is no evidence of an interaction between treatment and time (F=0.53; \( p \)-value=0.5867). In general, as time goes by amotivation increases for both groups; however, the amotivation for the EXT group is greater.

**Discussion**

In this study, I investigated the effects of implementing an SSI-based laboratory curriculum on biology student motivation in a large introductory biology course for science majors. I described student motivation in terms of self-determination theory and utilized a survey instrument that assessed self-determination in regards to doing the work for the laboratory class. Through a hierarchical linear model, I examined the effects of the SSI curriculum relative to the existing curriculum in place as well as its’ effects over the course of the term on biology student motivation. Analyzing the data according to the individual sub-constructs of motivation from the self-determination continuum allowed me to investigate the effects of the treatments on intrinsic motivation, integrated
regulation, extrinsic motivation and amotivation over the course of the term. In addition, weighting the scores of the sub-constructs to compute a single motivation score (SDI) from the SIMS scale allowed me to reduce the number of motivational components in the analysis and better visualize the treatment effects in the various lab sections over time (Ratelle, Guay, Vallerand, Larose & Senecal, 2007). Both of these analyses were important in better understanding the effects of the SSI curriculum compared to the existing curriculum.

The analysis of each of the sub-constructs in the SIMS scale from the self-determination continuum revealed that autonomous motivations (intrinsic motivation and identified regulation) declined over the course of the term. Research into the temporal shifts of student motivation over the course of university terms indicates that some motivational variables (such as task value) tend to decrease as the time for evaluation and feedback approaches (Wicker, Turner, Reed, McCann & Do, 2004). In addition, competitive, rigid and evaluative environments lead to more controlled types of motivation (Guay, Ratelle & Chanal, 2008). As the final exam approaches and students move towards the end of the term, they may be feeling more pressures from the final exam and grade evaluations that approach. Indeed, this is a highly probable explanation for the trends we see in decreasing autonomous motivation and the increase in amotivation in both groups over time. For both forms of autonomous regulation (intrinsic motivation and identified regulation) the decrease over time was significantly smaller for the SSI group, and the results showed a significantly larger increase in amotivation in the EXT compared to the SSI group. External regulation remained constant for the EXT group over the course of the term, but it decreased over time for the SSI group. These results suggest a possible buffering effect of the SSI curriculum on the decrease in student motivation that occurs over the span of a term when students are moving into the most stressful and demanding portion of the course. I suggest that since the SSI group’s autonomous motivations decrease significantly less and they experienced less amotivation in the same institution and course structure, then the SSI curriculum may be having a buffering effect on student motivation over time. Classroom contexts that support feelings of self-determination have been found to buffer the effects of a rigid and
competitive setting (Sheldon and Krieger, 2007). Specifically, they found that when law school students perceived faculty as autonomy supportive there was a potential buffering effect that was thought to somewhat negate the less autonomy-supportive aspects of the program such as competition and rigidity (Guay, Ratelle & Chanal, 2008).

Although it is impossible to break apart the curriculum at a micro-level to examine that aspect may have contributed the most to this buffering effect, previous research has shown that an increase in students’ perceptions of personal relevancy or importance of tasks leads to more autonomous motivations (Darner, 2012, Deci, 1992). Since the SSI curriculum focused heavily on locally and globally relevant issues for introductory biology students, it is possible that this accounts for the buffering effect in a structured, required course with content that may range outside of some students’ normal interests or goal pursuits. Studies of SDT in educational contexts have found that autonomous motivations are most salient when a student’s need for relatedness, or social connectedness (in addition to competence and autonomy) is adequately fulfilled (Deci & Ryan, 1990). A growing literature base in the SDT field on relatedness led me to identify the focus on personal relevancy or importance of the curricular tasks as possible underlying reasons for the increase in autonomous motivation seen in this study, the relatedness sub-construct of self-determination theory remains as one of the most under-studied components of the theory (Fay & Sharpe, 2008, Guay, Senecal, Gauthier, & Fernet, 2003). In Chapter Four of this study, I use a complementary qualitative subset of results collected at the same time as those in this study to further investigate the reasons for the increases in autonomous motivations and decrease in controlled motivations seen in the results of this study.

Considering that the instructional practices of the graduate teaching assistants varied, it is expected that the students would have received varying degrees or styles of treatment implementation. This concern was less of an issue in these laboratory sections than it would have been for a lecture class as the curriculum for each lab was consistent across GTAs because of the structure of the laboratory having set activities that the students needed to complete. The nested design of our analyses accounted for this variation by section. As was shown in Figure 3, the lab section SDI averages were not
only higher on average for the SSI curriculum, but they also had significantly lower variance. The reasons for this lower variance may have been in part due to the adherence of GTAs to the use of a single set of introduction slides, but I further suggest that the SSI curriculum may have been structured so that student motivation was less GTA-dependent. In a large introductory laboratory class taught by 25 novice instructors, it could be considered a positive outcome that students were able to maintain their motivation regardless of the GTA they happened to be assigned to. Indeed, standardizing the experience of students in these various sections nested in the larger lecture course is an ongoing practical concern as GTAs are often novice instructors with no formal training yet play a large role in science education in institutions of higher education (Gardner & Jones, 2011).

Implications, limitations and future directions

Proponents of the SSI approach to science education have found that the use of socially relevant issues helps students relate scientific content to their everyday lives and can make them more motivated to learn science (Sadler, 2009). There are several studies that show that SSI interventions have provided motivating contexts for learning from a student perspective (Barber, 2001, Sadler, 2004 & 2009) although few of these studies have included college students as participants in the research or been rooted in motivational theory (Darner, 2012, Barber, 2001, Sadler, 2011). This study represents a large-scale, quasi-experimental study that supports the finding that this type of approach has the potential to increase student motivation in large introductory science courses.

There have been more than 200 empirical education studies where the SDT framework has been applied to investigate educational outcomes or motivational profiles of students in different classroom contexts. Very few of these studies have focused on undergraduate introductory courses and even fewer have investigated the effects of curricular innovation on student motivation as most studies focus on teacher autonomy support or academic motivation more generally (Guay, Ratelle & Chanal, 2008). This study is amongst a few that add to the growing knowledge base of undergraduate student motivation with regard to specific courses and in response to curricular approaches.
This study also has important implications for practitioners in that there is a practical utility of using SDT as a motivational framework in better understanding the effects of socio-scientific issues-based education on student motivation, and that the results of this study have revealed ways in which instructors might increase student motivation (Guay, Ratelle & Chanal, 2008). This study may help practitioners identify ways to create learning environments that support students’ autonomous motivations in large introductory courses. The results indicate that socio-scientific issues-based courses could be a practical solution for increasing autonomous motivation and positive student outcomes.

Although we saw a significant increase in student autonomous motivation and a decrease in amotivation in the SSI group relative to the EXT (control) group, there are a number of limitations to this study that need to be taken into account. The study is limited in that individual lab modules could have motivated students differently, and students were not surveyed after every lab period. It is also not possible from this quantitative data to understand which aspect of the SSI approach caused the effect. This means that the curriculum model as a whole must be taken into account when considering these results, and not just the portion that focused on socio-scientific issues (Shadish, Cook & Campbell, 2002). Treatment diffusion is widespread throughout the study because it took place in the same institution. The limited statistical power may mean that if there is a small change, it could be misrepresented as smaller than it would be with increased power. The fact that this curriculum implementation took place in one course in a single institution is limiting, but if it is situated within the larger research base on motivation in regards to SSI-based curricula, it adds to the existing literature as it is a large quasi-experimental study with the presence of a control group that gives additional weight to any of the findings.

Due to classroom concerns, the distribution of lab sections chosen for the new SSI curriculum was not balanced with respect to lecture sections. For the team-taught sections, almost all of the labs for the morning sections received the traditional lab curriculum and all the afternoon lab sections received the new lab curriculum. Therefore, it is impossible to tease apart the effect of the curriculum from the time the class was
taught. However, we should note that when testing for differences across the lecture sections it was found that there wasn't a significant difference in motivation level for any of the motivation types ($p$-values ranged from 0.47 to 0.9).

In order to further investigate student motivation in response to the SSI curriculum, more trials are needed in other institutions. In order to control for treatment diffusion effects, a cohort model design could be used in future studies where new SSI curriculum is implemented in large courses. In addition, a recent review on educational studies regarding SDT has called for more studies that utilize a “person-centered” approach where motivational profiles are made for students (Guay, Ratelle & Chanal, 2008, Guay & Vallerand, 2007). This type of analysis could be done in future work with the same data set used for this study. Further investigations into the reasons behind the increase in student autonomous motivations are also necessary as will be discussed in the following chapter that presents the qualitative results from the study.
CHAPTER 5- The Impact of an Issues-Based Curriculum on Relatedness Need-Fulfillment: Fostering Relevance in Introductory Biology Courses

Krissi M. Hewitt, Lori Kayes, Jana Bouwma-Gearhart

To be submitted for publication in:
*International Journal of Science Education*
Introduction
There has been a rapid increase in technological advances in science that has contributed to an increase in societal issues that require attention from both scientists and citizens (AAAS, 2011). The large number of issues that require the application of biological knowledge has led to an increasing demand on institutions of higher education to produce graduates that are not only scientifically literate, but more specifically, biologically literate (AAAS, 2011). As with the general idea of scientific literacy, biological literacy could be defined in many ways. For the present study, I use the term biological literacy as a way to describe an individual’s ability to apply biological concepts and competencies in real-life contexts both within and outside of the normal realm of science (Sadler & Zeidler, 2009). This is consistent with a progressive view of science education (DeBoer, 1991) taken by proponents of efforts such as the public understanding of science (Hunt & Millar, 2000), context-based science (Bennett, Grasel, Parchmann, & Waddington, 2005), and socio-scientific issues-based science (Sadler, 2004). In line with this view, there is a need for the development of biologically literate citizens who have the ability to use their knowledge and skills related to biological concepts and competencies to make informed decisions in their daily lives (Sadler & Zeidler 2009, Sadler 2011, Zeidler, Sadler, Simmons & Howes, 2005). In order to make progress towards this goal, DeBoer (2000) calls for educational approaches that develop, “a public that finds science interesting and important, who can apply science to their own lives, and who can take part in the conversations regarding science that take place in society” (p. 598). The current study presents research findings related to the implementation of socio-scientific issues-based curriculum in undergraduate biology laboratory classes and its potential in the development of students who are motivated and able to apply their biological knowledge and skills in real-world contexts.

Socio-Scientific Issues-Based Instruction
Socio-scientific issues are complex social problems with technological or conceptual ties to science (Sadler, 2004). These represent a wide array of controversial topics that show up frequently in national media, such as the production of genetically modified organisms (GMOs) for human consumption, stem cell research, global warming, the BP oil spill in
2010, human genomic research, genetic testing, and local environmental issues. Approaches to solving these issues require the application of scientific concepts and the negotiation of political, economic, and ethical factors (Sadler, 2011). Policy makers and the general public are often influential in determining courses of action in regards to these issues. Moreover, these issues put into sharp focus the skills that are demanded from scientists and citizens to address the many challenges our world faces in the 21st century (AAAS, 2011 & 1989). Most of these socio-scientific issues have a large biological component, and therefore require a certain level of biological literacy for public understanding.

Rooted in the Science, Technology and Society (STS) movement of the 1970s and 80s, the Socio-scientific Issues (SSI) approach to science education goes beyond much of the STS approach, which featured isolated courses focused on issues and small asides in textbooks rather than integrating socio-scientific issues into science curriculum (Sadler, 2004). According to Sadler (2004) the SSI approach, “aims focus more specifically on empowering students to handle science-based issues that shape their current world and those which will determine their future world” (p.514). This approach provides the context for risk evaluations, collective decision-making, and the interpretation of scientific data through class discussions.

Because of the focus on depth of concepts rather than breadth in the SSI approach, there have been concerns that these types of approaches sacrifice the learning of content knowledge. However, students have been found to display equal or more science content knowledge on pre/post assessments in SSI-based interventions when compared to learning environments that teach scientific facts and concepts in the absence of a real-world context (Zohar & Nemet, 2002, Sadler & Klosterman, 2010, Dori et al., 2003, Bulte et al., 2006, Barker & Millar, 1996, Barab et al., 2007, Barber, 2001). Studies also report learning gains with regard to understanding the nature of science, and evidence of the development of higher-order thinking (Albe, 2008, Dori et al., 2003, Harris & Ratcliffe, 2005, Khishfe & Lederman, 2006, Kortland, 1996, Pedretti, 1999, Tal & Hochberg, 2003, Tal & Kedmi, 2006, Walker & Zeidler, 2007, Yager et al., 2006, Zeidler et al., 2009).
In addition to the aforementioned benefits of an SSI approach, there are several studies that show that SSI interventions have provided interesting and motivating contexts for learning from a student perspective (Albe, 2008, Barber, 2001, Bennett et al, 2005, Bulte et al. 2006, Dori et al., 2003, Harris & Ratcliffe, 2005, Lee & Erdogan, 2007, Parchman et al., 2006, Yager et al, 2006, Zeidler et al, 2009, Sadler, 2004 & 2009). A study by Zeidler, Sadler, Applebaum and Callahan (2009) analyzed qualitative data from a year-long intervention in two high school anatomy and physiology courses and found that in the course taught based on the SSI approach students were more motivated to learn than those in the traditional textbook-based course. Motivation is an important aspect in the application of knowledge and skills in real-world contexts because the quality of student motivation predicts outcomes such as choice, effort, persistence and achievement in relation to tasks (Zusho et al., 2003). If a learner is not motivated to apply their knowledge and skills, the quality of the resulting behaviors is likely to be poor (Zimmerman, 2000). Although current research suggests that the SSI approach provides a motivating context for learning, most of this work has been done in regards to middle and high school students (Sadler, 2009). Furthermore, few of the studies of student motivation in response to the SSI approach have presented their results with use of robust theoretical frameworks of motivation. In this study, I utilized the lens of Deci & Ryan’s (1985) self-determination theory in my investigation of the effects of SSI curriculum on specific aspects of undergraduate biology student motivation related to relevancy and application of knowledge and skills in their lives.

Self-Determination Theory

The Self-Determination Theory (SDT) of motivation posits that humans are intrinsically motivated when they are self-determined, or when they have agency or power over their own choices (Ryan & Deci, 2000, Brooks & Young, 2011). In terms of educational contexts, the degree that students feel self-determined impacts their motivation relative to task engagement (Fortier, Vallerand & Guay, 1997, Ratelle, Guay Vallerand, Larose & Senecal, 2007). According to SDT, feelings of self-determination are based upon the degree of satisfaction of three basic psychological needs - perceived autonomy, competence and relatedness (Ryan & Deci, 2000). According to SDT, all humans have
goals related the fulfillment of these three basic psychological needs, and the degree that an activity is perceived to be in line with students’ personal goals for their learning or future careers contributes to perceptions of need fulfillment, leading to behavior driven by autonomous motivation that in addition to the immediate positive outcomes, tends to be long-lasting and more likely to continue even when tasks become difficult to perform (Deci, Ryan, & Koestner, 2001; Ryan & Deci, 2002).

The need for autonomy refers to the need for feelings of choice and volition regarding one’s actions. In a classroom setting, educators’ allowance for student choice and explanation of classroom rules has been shown to enhance student autonomy, whereas limited choice, excessive surveillance and unexplained orders decrease student feelings of autonomy (Deci & Ryan, 1994, Niemiec & Ryan, 2009). The need for competence refers to the need for effectance or having the, “skills to manage various elements of one’s environment” (Deci & Ryan, 1985, p. 30). Feelings of competency, or perceived self-efficacy, gives the person a sense that they are able to complete a task (Ryan & Deci, 2000). The last need that affects motivation within the SDT framework is the need for relatedness. This is the need to be socially connected and to feel a sense of belonging in a social group (Niemiec & Ryan, 2009). In addition to feeling connected to people, a person can also feel connected to tasks/content if they are relevant to their own personal goals or interests (Ryan, 1992). Perceived relatedness leads to feelings of personal security that have a positive impact on motivation (Ryan & Deci, 2000). If the need for relatedness is not adequately fulfilled, the student is unlikely to engage in activities and is likely to exhibit motivation of low quality, controlled motivation, that has been linked to negative outcomes such as decreases in effort and persistence, as opposed to high quality or autonomous motivation that leads to positive outcomes such as increased persistence, effort and interest (Zimmerman, 2000, Deci & Ryan, 1990). Similarly to relatedness, if the needs for autonomy or competence are not adequately fulfilled motivation to engage in the activity becomes controlled.

Of the increasing amount of work being done in educational contexts utilizing the SDT framework, student perceptions of relatedness have been the least explored in research studies in comparison to studies that incorporate perceptions of autonomy and
competence (Fay & Sharpe, 2008, Guay, Senecal, Gauthier, & Fernet, 2003). An especially prevalent omission in the literature concerns the relevancy of the curriculum to perceptions of relatedness and motivation. Some researchers have argued that the relevance of curriculum allows for students’ feelings of social connectedness, described as relatedness need fulfillment (Darner, 2007 & 2009). Other research studies describe increasing context and relevancy for students in terms of curriculum and instructional practices that are autonomy-supportive (Kember & McNaught, 2007, Good & Brophy, 2000). Fostering relevance for students may increase perceptions of both autonomy and relatedness, but the current study focuses on how the SSI curriculum impacts student perceptions of relatedness in a laboratory setting.

There have been three major aspects of relatedness that have been prevalent in research on self-determination theory in classroom contexts. These involve student perceptions of their 1) relationship with the instructor 2) peer relationships and 3) the relevance or importance of the activities to their lives (Darner, 2012). Vaino, Holbrook & Rannikmae (2012) found that, “strategies for enhancing relatedness should, at the teacher-student level, include teacher behavior conveying warmth, caring, and respect to students and, at the student-student level, establishing the classroom as the kind of learning community where students are provided with frequent opportunities to collaborate with one another” (p. 3). The relevance of classroom activities as it connects to the need for relatedness for has been explored less in the literature. In two research studies, Darner (2009 & 20013) implemented an SSI curriculum in a non-majors biology course utilizing the SDT framework and she conducted interviews after the students took the course and found that many of them reported feeling more connected to their communities, and were able to relate what they learned to their daily lives. The author posited that students gained greater feelings of relatedness.

**Current Study**

Because of the focus of the SSI curriculum on fostering relevance for students through the contextualization of content with locally and globally relevant socio-scientific issues, I hypothesized that there would be differences in how those who participated in the SSI curriculum perceived the relevance of the laboratory activities.
Since previous research within the SDT framework has identified peer and instructor relationships as important sub-constructs influencing perceived relatedness, I also investigated the effects of the SSI curriculum on student-student and instructor-student interactions. This study also builds upon a results from a subset of quantitative data that were collected the same participants that found that there was an increase in autonomous motivation and a decrease in controlled motivation for students in the SSI curriculum (see Chapter 4). In this study, I further hypothesized that these differences could be at least partially explained by a change in student perceptions of relatedness in the SSI context, specifically their perceptions of the relevance of the lab activities to their daily lives. Figure 1 describes the model relevant to the conceptual framework I have presented above.

![Figure 1](image_url)

Figure 1. Conceptual framework regarding SSI curriculum, motivation and biological literacy. This diagram depicts connections between major constructs in the literature.

As reviewed above, the SSI framework has been found to increase student motivation in previous research studies. In addition to a need for larger empirical studies to verify the work of others in smaller studies, it is unclear from the literature exactly *why* the SSI approach may increase student motivation. A few research studies with small groups of students in individual courses have begun to flush this out utilizing the framework of self-determination theory (Danner, 2009 & 2013), but more work needs to be done to further understand *how* and *why* the SSI approach increases student motivation. A small amount of literature has shown a link between student perceptions of relatedness and
contextualization of curriculum, informing my hypothesis that the change in student motivation from more autonomous and less controlled could be partially explained by the effects of SSI implementation on biology student perceptions of relatedness.

In this study, I have theorized about the importance of the need for relatedness in this relationship and presented data on the effects of SSI on each sub-construct of relatedness. Implications of the research study for the relationship between student motivation, relatedness need-fulfillment and biological literacy are discussed. A small amount of literature has shown a link between student perceptions of relatedness and contextualization of curriculum, informing my hypothesis that the change in student motivation from more autonomous and less controlled could be partially explained by the effects of SSI implementation on biology student perceptions of relatedness.

Methods

Research Questions

The questions in this study were developed within the framework of self-determination theory to investigate students’ perceptions of relatedness at the end of the term and one year post-term. The research questions were:

1. What was the effect of a socioscientific issues-based laboratory curriculum on undergraduate biology students’ perception of relatedness?
   a. What were the differences between the SSI and control groups in student perceptions of their relationship with the instructor?
   b. What were the differences between the SSI and control groups in student perceptions of their relationships with their peers?
   c. What were the differences between the SSI and control groups in student perceptions of the relevance of the learning activities?

Educational Context

This study was conducted in an introductory biology course at a large public research university in the Pacific Northwest region of the United States. The biology course serves about 1000 students each ten-week spring term from a variety of science majors, including chemistry, biology, physics and the applied sciences. The purpose of this study was to investigate the impact a re-designed laboratory course that incorporated a socio-
scientific issues-based approach on biology student perceptions of relatedness. The curriculum was piloted in only half of the laboratory sections, allowing for a comparison group of students who did not experience the socio-scientific issues-based curriculum. I was deeply embedded in the depart curriculum studied, having previously taught the traditional comparison/control curriculum and having designed the new laboratory course curriculum.

**Socioscientific Issues-Based (SSI) Curriculum**

I developed the curriculum for the introductory majors biology laboratory course sections. In creating the SSI curriculum, I made every effort to follow the guidelines for SSI-based instruction based on the model by Lenz (2012) (see Figure 2).

I used the entire model as a guide in developing each laboratory module. Each laboratory topic was similar to the topics used in the existing curriculum in order to follow the lecture sequence of the course. Students in the SSI sections were taught similar content, but in a way that integrated the SSI approach to science education. I developed the learning outcomes for the laboratory portion of the course based on several of the core concepts and competencies outlined in vision and change (AAAS, 2011) as was appropriate for the lecture content of the course (genetics, evolution, natural selection and ecology). I created laboratory activities or modified those from current biology education research/practitioner publications. The 2hr and 50-minute lab periods were centered on a socio-scientific issue that related to that week’s course content. I

![Figure 2](image_url)
designed the curriculum to address both global and local issues assumed relevant to the institution’s biology students such as genetic testing, genetic modification of crops, and local invasive species. In order to introduce the issue to students before class, I designed pre-labs that consisted of various videos, news articles and scientific articles addressing the issue, followed by thought provoking questions about the topic. Each laboratory period began with a pre-lab discussion activity during first 20-30 minutes.

Existing/“Control” Curriculum

The existing curriculum in the biology laboratory typically taught by all graduate teaching assistants consisted of many activities from a widely used laboratory manual. Most of the modules included activities that were not contextualized in any way to provide real-world relevance (i.e. DNA puzzle to learn transcription or pop beads to learn meiosis). If socio-scientific topics were addressed, it was usually only in a cursory manner as a “fun-fact” reference in the laboratory introduction by the instructor. For example, in the introduction the GTA might introduce content and then make a small reference on a slide about topic like genetic modification of organisms. (Refer to Chapters 2 & 3 of this dissertation for a more detailed descriptions and comparisons of the curriculums).

Sample and Procedures

The target sample included the entire course of students (n= 1032). All participants in the study were enrolled in both the lecture and laboratory sections of the course. The course component of interest in this study were the laboratory classes (n=25) of roughly 40 students each that were taught by graduate teaching assistants. Only the laboratory portion of the course implemented the SSI approach and the format of the accompanying lecture sections (n=3) was solely up to the faculty instructors.

Students were invited to complete a questionnaire through email at the end of the ten-week term. The completion of the questionnaire was incentivized by offering extra credit points for the course. Table 1 below describes the participants (n=850) who completed the week 10 post-term questionnaire.
Table 1  
*Characteristics of Introductory Biology Students in Week 10 Survey (n=850)*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SSI (n=435)</th>
<th>%</th>
<th>EXT (n=415)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age Range</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-22</td>
<td>374</td>
<td>86.5</td>
<td>344</td>
<td>83.7</td>
</tr>
<tr>
<td>23-26</td>
<td>36</td>
<td>8.3</td>
<td>41</td>
<td>10.0</td>
</tr>
<tr>
<td>27-35</td>
<td>15</td>
<td>3.4</td>
<td>20</td>
<td>4.9</td>
</tr>
<tr>
<td>Over 35</td>
<td>7</td>
<td>1.6</td>
<td>6</td>
<td>1.5</td>
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<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>252</td>
<td>57.9</td>
<td>243</td>
<td>58.8</td>
</tr>
<tr>
<td>Male</td>
<td>181</td>
<td>41.6</td>
<td>168</td>
<td>40.7</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Race/Ethnic Origin(^a)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European or White</td>
<td>292</td>
<td>67.1</td>
<td>299</td>
<td>72.4</td>
</tr>
<tr>
<td>Asian or Asian American</td>
<td>87</td>
<td>20.0</td>
<td>73</td>
<td>17.7</td>
</tr>
<tr>
<td>Hispanic or Latino(a)</td>
<td>38</td>
<td>8.7</td>
<td>29</td>
<td>7.0</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>33</td>
<td>7.5</td>
<td>26</td>
<td>6.3</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>14</td>
<td>3.2</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>Native American</td>
<td>9</td>
<td>2.0</td>
<td>12</td>
<td>2.9</td>
</tr>
<tr>
<td>African American or Black</td>
<td>8</td>
<td>1.8</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>Middle Eastern</td>
<td>7</td>
<td>1.6</td>
<td>9</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Class Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>79</td>
<td>18.2</td>
<td>44</td>
<td>10.7</td>
</tr>
<tr>
<td>Sophmore</td>
<td>210</td>
<td>48.3</td>
<td>168</td>
<td>40.8</td>
</tr>
<tr>
<td>Junior</td>
<td>97</td>
<td>22.3</td>
<td>130</td>
<td>31.6</td>
</tr>
<tr>
<td>Senior</td>
<td>41</td>
<td>9.4</td>
<td>55</td>
<td>13.4</td>
</tr>
<tr>
<td>Other (post-bacc)</td>
<td>8</td>
<td>1.8</td>
<td>15</td>
<td>3.6</td>
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<tr>
<td><strong>Previous Biology Courses</strong></td>
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<td></td>
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<td>0</td>
<td>24</td>
<td>5.5</td>
<td>23</td>
<td>5.6</td>
</tr>
<tr>
<td>1-2</td>
<td>300</td>
<td>69.1</td>
<td>271</td>
<td>65.8</td>
</tr>
<tr>
<td>3-5</td>
<td>98</td>
<td>22.6</td>
<td>97</td>
<td>23.5</td>
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<tr>
<td>More than 5</td>
<td>12</td>
<td>2.8</td>
<td>21</td>
<td>5.1</td>
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<td><strong>University GPA</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0-2.0</td>
<td>5</td>
<td>1.2</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>2.1-2.5</td>
<td>35</td>
<td>8.1</td>
<td>43</td>
<td>10.3</td>
</tr>
<tr>
<td>2.6-2.9</td>
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<td>23.5</td>
<td>82</td>
<td>19.7</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>162</td>
<td>37.2</td>
<td>165</td>
<td>39.7</td>
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<tr>
<td>3.6-4.0</td>
<td>131</td>
<td>30.1</td>
<td>121</td>
<td>29.1</td>
</tr>
</tbody>
</table>

\(^a\)Students were allowed to select more than one category, if applicable

The week 10 open-response questionnaire was designed to explore undergraduate biology students’ perceptions of *relatedness* in the socio-scientific issues-based (SSI) laboratory curriculum compared to the comparison group in the existing curriculum (EXT). The
questions related to three major aspects of relatedness that have been prevalent in research on self-determination theory (Appendix B). These involve student perceptions of their 1) relationship with the instructor 2) peer relationships and 3) the relevance of the curriculum to their lives. The open-response questions pertinent to the research questions in this study included the following:

1. Please describe your relationship with the lead Graduate Teaching Assistant for your biology lab class. For example, did they address your questions/concerns? Did they seem excited to teach you biology?
2. Please describe your relationship with your peers in your biology lab class. For example, did you get along? Was the work distributed fairly?
3. Explain how the activities in your biology lab relate to your personal life or future career goals, if at all?

In questions 1 and 2, examples were given based on my knowledge of the literature and the specific challenges in the course that relate to GTA and peer interactions. These were given to help avoid extremely short student responses to the questions, but most likely limited student responses to the associated questions.

In addition to the week 10 questionnaire, the students who were enrolled in the course were recruited to complete an online questionnaire one year after they took the course that was designed based upon the results from the previous study. As an incentive, students who completed the questionnaire were entered into a lottery for three $50 gift cards to the university bookstore. Table 2 displays the demographic data of students (n=293) who participated in the one-year-out post study.
Table 2

Characteristics of Introductory Biology Students in One Year Post-study (n=293)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SSI (n=154)</th>
<th>EXT (n=139)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>%</td>
</tr>
<tr>
<td>Age Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-22</td>
<td>130</td>
<td>86.7</td>
</tr>
<tr>
<td>23-26</td>
<td>9</td>
<td>6.0</td>
</tr>
<tr>
<td>27-35</td>
<td>9</td>
<td>6.0</td>
</tr>
<tr>
<td>Over 35</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>93</td>
<td>61.6</td>
</tr>
<tr>
<td>Male</td>
<td>56</td>
<td>37.1</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>Race/Ethnic Origina</td>
<td></td>
<td></td>
</tr>
<tr>
<td>European or White</td>
<td>108</td>
<td>71.5</td>
</tr>
<tr>
<td>Asian or Asian American</td>
<td>26</td>
<td>17.2</td>
</tr>
<tr>
<td>Hispanic or Latino(a)</td>
<td>17</td>
<td>11.3</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>11</td>
<td>7.3</td>
</tr>
<tr>
<td>African American</td>
<td>4</td>
<td>2.6</td>
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<tr>
<td>Pacific Islander</td>
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<td>1.3</td>
</tr>
<tr>
<td>Native American</td>
<td>1</td>
<td>0.7</td>
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<td>Middle Eastern</td>
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<td>0.7</td>
</tr>
<tr>
<td>Class Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
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<td>0.0</td>
</tr>
<tr>
<td>Sophmore</td>
<td>22</td>
<td>14.6</td>
</tr>
<tr>
<td>Junior</td>
<td>90</td>
<td>59.6</td>
</tr>
<tr>
<td>Senior</td>
<td>36</td>
<td>23.8</td>
</tr>
<tr>
<td>Other (post-bacc)</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>University GPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0-2.0</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>2.1-2.5</td>
<td>9</td>
<td>6.0</td>
</tr>
<tr>
<td>2.6-2.9</td>
<td>32</td>
<td>21.3</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>61</td>
<td>40.7</td>
</tr>
<tr>
<td>3.6-4.0</td>
<td>46</td>
<td>30.7</td>
</tr>
</tbody>
</table>

aStudents were allowed to select more than one category, if applicable

As will be further described in the results section, the results from the week 10 questionnaire indicated a difference in student responses relative to the perceived relevance of the lab activities to their daily lives. In light of these results, I designed the longitudinal one-year-out post questionnaire in order to determine if students’ perceptions of relevance/usefulness of the curriculum remained consistent over time in the treatment groups (Appendix C). I asked the students the following questions to analyze student
reflections on how they used what they had learned in the biology lab curriculum over the past year. The two questions asked of the students that pertain to the scope of this paper were:

1. Since taking the biology xxx lab last year, how have you used any biological knowledge or skills gained from lab in your daily life outside of schoolwork?
2. Since taking the biology xxx lab last year, how have you used any biological knowledge or skills gained from lab in other schoolwork?

Data Analysis

The student responses on both questionnaires were analyzed with QSR International’s NVivo software (QSR International Pty Ltd. Version 10, 2012) using thematic analysis and a “bottom-up” process of coding where codes for the data were determined by the text in the responses and not a priori (Auerbach & Silverstein, 2003). The approach of analysis in this study was primarily theory-driven, meaning the analysis of the data was guided by previously determined ideas and hypotheses (Krippendorf, 1980, Weber, 1990, Namey, Guest, Thairu & Johnson, 2007). I conducted thematic analysis of the data with specific theoretical frameworks in mind (self-determination theory). Although the thematic analyses were primarily theory-driven, I used a “bottom-up” process of coding where codes for the data were determined by the text in the responses and not a priori (Auerbach & Silverstein, 2003). This allowed for emergent, data-driven themes as my process was open and flexible as I stayed grounded in the data (Glaser & Strauss, 1967, Namey et al., 2007). The following discussion provides specifics on my coding process reflecting the aforementioned methodological approaches.

My process for coding was to go through and code each individual response for a single question adding and refine categories along the way. Coded categories were determined from the wording of student’s responses. For example, one of the student responses said “the GTA really cared about our learning”, so the code was labeled “cared about learning”. Other student responses that were similar were coded in the same category. Upon completion of the coding process for a single question, I went through each code to make sure that all of the responses still fit in that category, or would move
them to a more appropriate category. At this point I would also change the name of the code if necessary. Since I was so immersed in the community that was the subject of this research and had developed the curriculum, I took extra steps to ensure the reliability of the coding of data. I had a blinded coding process where another external researcher de-identified the curriculum as SSI or EXT and created one large data set to prevent coding bias. Codes were not segregated into their corresponding curriculum until coding was complete. In addition, once coding was complete another external researcher coded 5% of the data with 73% agreement establishing good inter-rater scoring. As an additional measure, I discussed my codes and the coding process with multiple external researchers (Baezley, 2012).

Although the data collected were qualitative data from open-response questionnaires, the type of analysis I chose for the study was quantitative in nature due to the large number of small units of texts (1-3 sentences long). This is an acceptable practices that has been used frequently, especially in studies where data from many participants are collected (Bernard, 1996). Upon completion of the coding, I ran queries on the data in NVivo10 to generate code frequency reports. These reports uncovered coding themes in the data for each question on the questionnaires separated by curriculum (SSI and EXT). Specifically, frequencies were determined, “on the basis of the number of individual participants who mention[ed] a particular theme” (Namey, Guest, Thairu & Johnson, 2007, p. 143). I then compared the frequencies of each code for each of the questions for each curriculum to quantify the differences in themes generated from the student responses. I compared the frequencies by conducting a non-parametric two sample proportion tests for the coded categorical data and noted individual $p$-values in order to determine significant differences. Differences were deemed significant at a $p < 0.05$ level. In order to generate bar graphs for each question I used the number of student responses in each category relative to the total number students in that curriculum who participated in the questionnaire. To highlight the most prevalent themes, I did not graphically represent any code that represented less than 5% of the total responses to a particular question for both curricula combined.
Results

In this section I report the results for both the week 10 and the one-year-out post questionnaire parsed out by the aforementioned research questions. Table 3 below provides the codes, code frequencies and code descriptions for the five analyzed questions on the week 10 and one year post surveys.

Table 3. Student responses to questionnaires by code categories, descriptions and frequencies

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Coded Category</th>
<th>Number of References</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SSI (n=435)</td>
<td></td>
</tr>
<tr>
<td>Week 10 Survey</td>
<td>GTA Relationships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GTA</td>
<td>Excited to teach</td>
<td>178</td>
<td>GTA was perceived to be excited about teaching and/or passionate about the subject</td>
</tr>
<tr>
<td></td>
<td>Somewhat excited to teach</td>
<td>8</td>
<td>GTA was perceived to be somewhat excited about teaching or excited to teach a particular topic but not others</td>
</tr>
<tr>
<td></td>
<td>Didn’t seem excited to teach</td>
<td>9</td>
<td>GTA was not perceived to be excited about teaching and/or passionate about the subject</td>
</tr>
<tr>
<td>GTA</td>
<td>Positive about GTA quality and/or relationship</td>
<td>249</td>
<td>GTA was perceived to be “awesome”, “wonderful”, “excellent”, etc.</td>
</tr>
<tr>
<td></td>
<td>Average quality/relationship</td>
<td>13</td>
<td>GTA was perceived to be “average”, “ok”, “fine”, etc.</td>
</tr>
<tr>
<td></td>
<td>Negative/no relationship</td>
<td>14</td>
<td>GTA was perceived to be “rude”, “mean”, “cold”, etc. Some stated a general dislike for the GTA</td>
</tr>
<tr>
<td>Cares about student learning</td>
<td>264</td>
<td>240</td>
<td>GTA spent time with students giving them extra help and/or were reported to display a caring attitude about student learning</td>
</tr>
<tr>
<td>Knowledgeable</td>
<td>57</td>
<td>39</td>
<td>GTA was perceived to be knowledgeable about biology</td>
</tr>
<tr>
<td>Made things fun</td>
<td>27</td>
<td>24</td>
<td>GTA made things “fun”,</td>
</tr>
<tr>
<td>Category</td>
<td>Peer Relationships</td>
<td>Curriculum Relevance</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Confused or ill-prepared</td>
<td>28 19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good communication</td>
<td>11 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unfair grader</td>
<td>6 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low interaction</td>
<td>9 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive/friendly interactions</td>
<td>394 355</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative/problematic interactions</td>
<td>32 46</td>
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<td></td>
</tr>
<tr>
<td>Neutral interactions</td>
<td>35 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal contribution</td>
<td>244 218</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unequal contribution</td>
<td>37 50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somewhat equal contribution</td>
<td>9 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills development for career or coursework</td>
<td>194 203</td>
<td>Some activities were relevant to what they would do in their future careers or in other coursework</td>
<td></td>
</tr>
<tr>
<td>No relation</td>
<td>131 165</td>
<td>Students saw no relevance of the lab activities to their daily lives or future career goals</td>
<td></td>
</tr>
<tr>
<td>Real world relevance/informed decision-making</td>
<td>79 13</td>
<td>Lab activities helped inform students about issues important for their lives and/or gave them a sense of social responsibility</td>
<td></td>
</tr>
<tr>
<td>Interesting or enjoyable</td>
<td>54 28</td>
<td>Lab activities were “interesting”, “fun”, “enjoyable”, etc.</td>
<td></td>
</tr>
<tr>
<td>Major requirement</td>
<td>29 27</td>
<td>Relevant to completion of a major requirement</td>
<td></td>
</tr>
<tr>
<td>1 yr Post Survey</td>
<td>Usefulness to Daily life</td>
<td>SSI (n=154)</td>
<td>EXT (n=139)</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Teamwork/soci al skills</td>
<td>14</td>
<td>15</td>
<td>Developed social skills working in a collaborative setting</td>
</tr>
<tr>
<td>Changed or verified goals, interests, or career paths</td>
<td>12</td>
<td>2</td>
<td>Affirmed interests in certain careers in science or helped them explore new options</td>
</tr>
<tr>
<td>Biology relates to everything</td>
<td>7</td>
<td>9</td>
<td>It’s relevant because life is all around us</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Usefulness to Other Coursework</th>
<th>SSI (n=154)</th>
<th>EXT (n=139)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usefulness to Daily life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haven’t used knowledge or skills</td>
<td>56</td>
<td>65</td>
<td>Did not use the knowledge or skills or do not know how they might have used it</td>
</tr>
<tr>
<td>Informed decision-making or awareness of issues</td>
<td>24</td>
<td>4</td>
<td>Thought about the issues covered during every day experiences and changing their behavior regarding those issues in some cases</td>
</tr>
<tr>
<td>Career or research</td>
<td>18</td>
<td>19</td>
<td>Used skills/knowledge in work related to science career or research</td>
</tr>
<tr>
<td>Hobbies or interests</td>
<td>18</td>
<td>7</td>
<td>Used skills/knowledge in activities related to personal hobbies or interests</td>
</tr>
<tr>
<td>Observations or curiosity about life</td>
<td>12</td>
<td>12</td>
<td>General observations or curiosity about life around them</td>
</tr>
<tr>
<td>Conversations regarding science</td>
<td>10</td>
<td>8</td>
<td>Used knowledge in conversations or discussions</td>
</tr>
<tr>
<td>Understand media or current events</td>
<td>8</td>
<td>4</td>
<td>Understand media or current events</td>
</tr>
<tr>
<td>Teaching others</td>
<td>8</td>
<td>3</td>
<td>Used skills/knowledge to teach others about concepts learned</td>
</tr>
<tr>
<td>Plant or animal identification</td>
<td>4</td>
<td>5</td>
<td>Plant or animal identification</td>
</tr>
<tr>
<td>Fact-based knowledge</td>
<td>4</td>
<td>4</td>
<td>Used knowledge as trivia</td>
</tr>
<tr>
<td>Used in advanced science courses</td>
<td>74</td>
<td>69</td>
<td>Used in advanced science courses</td>
</tr>
</tbody>
</table>
Week 10 Survey

Student-Instructor Relationships

Figure 3 demonstrates the effects of the SSI curriculum on student perceptions of relatedness and includes the percent of student responses in each coded category generated from the frequencies shown in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>SSI</th>
<th>EXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haven’t used knowledge or skills</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Research/lab skills</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Foundation for other courses</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Issues/multiple perspectives</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Study skills</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 3. Participant descriptions of student-instructor relationships. Coded student responses to the question asking students to describe their relationships with their graduate teaching assistant instructor for the SSI (n=435) and the EXT (n=415) groups. Categories with significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks (* p<.05, ** p<.01).
The following includes a description of the major themes represented in Figure 3 from the coded open-response question.

**Excitement to teach biology.** One of the probes of the questions in the questionnaire specifically asked students if the graduate teaching assistant seemed excited to teach them biology. There was a significantly higher percentage of SSI students than EXT students who described their GTA as excited to teach ($p<.05$). However, in both curricula the GTA was mentioned to be excited to teach in the majority of the responses. Forty-one percent (41%) of the students in the SSI curriculum versus 33% percent of those in the EXT curriculum described the teaching assistant as excited/enthusiastic about teaching biology. One EXT respondent stated, “My Graduate TA was enthusiastic and seemed to enjoy teaching us about the labs and concepts.” A SSI respondent said that her GTA, “came to lab every day with a smile on her face and was genuinely excited to be there, even though it was 5pm on a Friday night.” Responses in this category were highly similar to the quotes represented here. A much smaller minority of students, across the group (SSI = 1.8%; EXT = 1.4%) who addressed the perceived enthusiasm of their GTA indicated that they were “moderately excited to teach biology” or only seemed enthusiastic about teaching certain lab modules. For example, one EXT respondent stated, “My T.A. seemed excited to teach the class the microbiology and genetics part of the curriculum but not so much the ecology part. This probably had to deal with the fact that my T.A. was a microbiologist.” There was no significant difference in this category across the SSI and EXT groups. A similarly small minority of students across the two groups mentioned that they did not think the GTA was excited to teach them biology (SSI = 2.1%; EXT = 4.1%). One EXT student noted that he “felt that there was a major lack of enthusiasm.” There was no significant differences between the SSI and EXT groups in the number of responses that indicated the GTA was somewhat or not excited to teach.

**Perceptions of instructor and student-instructor relationship quality.** Responses in this category included statements about students’ likes or dislikes of the GTA and positive or negative ideas about how “good” a GTA was. Responses that were coded into the positive about TA quality and/or relationship stated things like, “My TA was awesome” or that their GTA was a “fantastic lab instructor”. There was a
significantly higher percentage of responses coded in this category from the SSI curriculum than the EXT curriculum (SSI= 57.2%; EXT= 37.3%; \( p < .01 \)). A much lower percentage of responses in both curricula described the GTA as “very average for a research university” or as “ok” or “fine” with no significant differences between the two groups (SSI =3%; EXT =4.6%). Out of the total responses for each curriculum, 3.2% of the SSI group and 7.5% of the EXT group described their relationship negatively or as non-existent. One SSI respondent stated, “I got kind of a ‘cold’ vibe from her. I felt like she didn't like me very much, and it discouraged me from freely asking her questions.” An EXT student wrote that the GTA was “very controlling and irritable”. There was a significantly higher percent of responses in the EXT group than the SSI group that were negative although the percentage of responses in each group was still very low overall. Four of the negative responses in the EXT category were related to one GTA’s English speaking abilities. For example, one EXT participant wrote, “I did not like my TA because he was hard to understand, he had some trouble speaking English, and used horrible grammar on the lab quiz questions, and all of these things made it harder to learn the material in the labs.”

**Student perceptions of the warmth and caring of GTAs.** Responses in this category were related to the helpfulness, approachability and perceived caring of the GTAs about undergraduate student learning. One EXT respondent wrote that their GTA, “really did seem to honestly care about the well-being of her students.” Another SSI student wrote, “the TA was very helpful she met with me even though it was not her office hours. I am very thankful.” Many students gave examples of how GTAs went out of their way to explain difficult concepts repeatedly if they didn’t understand it initially. This category represented a high number of the responses in both the SSI and EXT groups with no significant difference between them (SSI =60.7%; EXT =57.8%).

Other themes that emerged from the data were those regarding how knowledgeable or prepared the GTA was along with minor complaints about grading, disorganization, or class size (see Figure 1 and Table 3). Although there were various themes reported here, the overall majority of the comments regarding student-instructor relationships were positive (see Table 3).
Peer Relationships

It was critical for the analysis of the effects of the SSI curriculum on relatedness need-fulfillment to uncover themes related to student-student relationships in the context of the laboratory class as described on the week 10 questionnaire. Figure 4 is a graph of the percent of student responses in each coded category generated from the frequencies shown in Table 1.

![Participant Descriptions of Peer Relationships](image)

Figure 4. Participant descriptions of peer relationships. Coded student responses to the questionnaire question asking students to describe their relationships with their peers (n=435) and the EXT (n=415) groups. Categories with significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks (* p<.05, ** p<.01).

Since the questionnaire asked, “Please describe your relationship with your peers in your biology lab class. For example, did you get along? Was the work distributed fairly?” most students simply answered the two example questions for describing their peer interactions as is reflected in Figure 4.

Quality of peer interactions. Most students in both curricula (SSI =87.8%; EXT =84.8%) responded to the “did you get along” portion of the question by giving responses such as, “we got along great” or “My group was awesome!! They were helpful and insightful.” There were also a lot of responses that indicated that they not only “got along” well with their group, but were able to more deeply connect or become friends
with their peers. For example, one SSI respondent wrote, “We all get along and we all became friends. I enjoy meeting people in a more laid back intimate environment compared to a large lecture. Labs are where I have met many of my close friends from [the university].” A much smaller percent of respondents indicated they had negative or problematic interactions with their peers (SSI =7.4%; EXT =11.1%) with responses such as the following from an EXT participant, “The relationship with my group is not well. One other member is fine, but the other two don't even want to be there, and do everything they can to leave early.” In many of the negative responses it was indicated by the respondent that (s)he wanted to learn or get work done and felt the other group members were holding them back from doing such. One SSI participant wrote, “No, I did not get along with my lab mates very well. I found myself doing a lot of the work so I would ensure I would receive a high grade. I did not trust them. I strongly advise cutting out group work. I don't like working with people that have a mentality of ‘C's get degrees’.”

A similarly small percentage of students (SSI =8.0%; EXT =6.0%) responded to the question describing neutral or ambivalent attitudes regarding their peers. One EXT participant stated, “The lab peers were fine, and we got along well enough to finish my work”. Of these three major themes in the data, there were no significant differences between the two groups and almost all described having positive relationships with their peers.

**Group-work distribution.** In response to the second example question given in the questionnaire “was the work distributed fairly”, many students in both curricula (SSI =56.1%; EXT =52.5%) mentioned that the work was distributed “fairly” or “evenly” with a much smaller percentage (SSI =8.5%; EXT =12.0%) who had complaints that were sometime attributed to curricular activities such as one EXT respondent who wrote that, “there wasn't anything for some of us to do since the labs were basically build this, or put these beads together.” Other responses indicated that one or more members would do the work while the others remained passive. One SSI respondent said, “Often times my team mates would watch the 1 or 2 people ACTUALLY doing the work.” There was also a smaller percentage of students who thought that the work was somewhat distributed fairly depending on the lab activity or the day (SSI =2.1%; EXT =3.0%). In one response, an
EXT student wrote, “Most of the time the work was distributed fairly but sometimes there was a couple of people who did not want to participate.” There were no significant differences in the frequency of responses related to this theme ($p$-values > 0.05).

Relevance of the curriculum

The final question on the week 10 questionnaire investigated differences in student perceptions of the relevance of the curriculum to their daily lives and/or career goals. Figure 5 is a graph of the percent of student responses in each coded category generated from the frequencies shown in Table 1. Below are explanations of the major themes that emerged from the data illustrated by student quotes.

Figure 5. Student descriptions of the relevance of the curriculum. Coded student responses to the questionnaire question asking students to explain the relevance of the lab activities to their daily lives and/or future career goals (n=435) and the EXT (n=415) groups. Categories with significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks. (* $p$<.05, ** $p$<.01).

**Knowledge or skills development for career or coursework.** A high percentage of responses in both groups indicated that the students felt that the lab activities were relevant in regards to knowledge or skills for their career or future coursework (SSI=44.6%; EXT=48.9%). Some of the students related biology knowledge or skills development to their career goals such as one SSI respondent who said, “I plan to be a medical student soon, having prior knowledge of biology will surely help.” Another EXT
respondent wrote, “Learning lab techniques allowed me to understand more about working under a lab setting.” Other students mentioned more specific activities that would be relevant for their future careers. One SSI student wrote, “The PTC gene lab and the apple tasting lab directly related to my future career goals because I plan to be a food scientist with an emphasis in sensory science.” There was no significant difference in the number of responses from the SSI and EXT curricula in this category.

**Lab activities were not relevant.** There was a statistically significant difference in the frequency of responses that indicated no relevance of the lab activities to the students’ daily life or career goals; the number of responses in this category was almost ten percent higher for those in the EXT curriculum (SSI=30.1%; EXT=39.8%; \( p < 0.01 \)). In response to the question, many students simply wrote, “it does not at all”, or statements such as the following from an EXT student; “I am actually not sure how this would be related to reality. The major reason I did this was because it was required.” Others wrote that they did not see a relation to their career. For example, one SSI student wrote, “It doesn't relate to really anything for me. I don't wish to work in a field or run experiments.” There were several striking comments that seemed to indicate that students did not understand the relationship between biology activities and their careers in health fields. Some students that were in pre-health fields like nursing or dentistry did not feel the lab activities related to their careers. One EXT respondent stated, “None of the activities related to my personal life or future career, as I'm majoring in the health field.”

**Personal real-world relevance.** There was a statistically significant difference between the SSI and EXT groups in the percent of responses that referenced relevance between the lab activities and students’ daily lives involving health, hobbies, and conversations or informed decision-making (SSI=18.2%; EXT=3.2%; \( p < .001 \)). In terms of health, one SSI student wrote, “What was done in Biology lab this term does not relate to my future career goals, but does relate to my personal life as we discussed genetics. We talked about karyotypes and genetic disorders, which when I plan to have a family will apply.” These students felt that topics relating to health would be helpful for them in the future regardless of their eventual career choice. Other students felt it was relevant to some of their hobbies, such as going outdoors. For example, one SSI respondent
mentioned, “How this class relates to my personal life is that I like to be outdoors and knowing animal behavior, reproduction, and plants helps me become more knowledgeable how the outdoors run.” The informed decision-making portion of this theme indicated personal relevance but some students went a step beyond just mentioning an application to their life and suggested they would be making changes in their behavior based on what they experienced. One SSI student wrote, “I talk about all the exciting things I learn about to my parents, friends and the customers I talk to at work. All the things I’ve learned has helped change the way I live, to keep the environment clean, help animals and to remember to enjoy nature more often. Biology is so badass!” Another SSI student wrote that, “Learning how invasive species are spread will help me while I travel to be careful not to bring any.”

**Interest or enjoyment.** There was a statistically significant difference between the SSI and EXT groups in the frequency of responses that related the activities to general interests or simple enjoyment (SSI=12.4%; EXT=6.7%; \( p < 0.01 \)). For example, one EXT response that mentioned a general interest in biology topics stated, “I am still curious about all things biological, thus having this lab that touches on so many different aspects of biology peaked many of my interests.” Others simply stated that they found the labs “interesting” or “very enjoyable.” Others mentioned specific activities such as in one SSI response where the student wrote, “I really enjoyed learning about invasive species.” Some students mentioned becoming more interested in certain topic areas. One SSI student wrote, “The PTC experiment gives me a rough image about the genetic techniques, which evoke my interest about genetic study.”

**Changed or strengthened interests in biology career paths.** This theme was coded for a small number of responses, but there was a statistically significant difference in the two curricula (SSI=2.8%; EXT=0.5%; \( p < 0.001 \)). The responses mostly indicated that the activities helped affirm student choices in biology careers or helped them better understand career pathways. For example, one SSI student wrote, “The lab techniques I have learned have helped me develop an understanding for research and possible career choices in my future.” Another SSI student commented,

“It introduced me to many of the possible career paths that biology could lead me in. For example, prior to this course I might have laughed at the prospect of being
a conservationist. After studying about it I find it fascinating and would love to work in conservation. I can now see the importance of it as well as different routes within that field of study that it could lead me.”

In order to better investigate the differences between the two curricula, I also determined the relative agreement of the two student groups with the more simplified categories of “relevant” and “not relevant”. Student responses could be in multiple categories as they may have identified more than one way the lab activities were relevant to them, so the percent was calculated by dividing the total number of references in a category by the total number of references overall from each curriculum and not by number of student respondents (Figure 6).

**

Figure 6. Relevance of the lab activities to daily life or career goals. Coded student responses to the week 10 questionnaire question asking students to explain the relevance of the lab activities to their daily lives and/or future career goals (n=435) and the EXT (n=415) groups were combined into two categories. The percent was calculated from the total number of responses in a coded category/total number of references. Significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks. (* p<.05, ** p<.01).

As is shown in Figure 6, there was a statistically significant difference between the SSI and EXT curricula in the perceived relevance of the curriculum to their daily lives or future career goals. This is indicated by the number of codes describing relevance in comparison to the number of those indicating that the activities were not relevant (p<0.001).

**One-year Post Longitudinal Questionnaire**

Based on the aforementioned results from the week 10 questionnaire that found
most of the student-indicated differences between the SSI and EXT curricula to be related to the relevancy of the curriculum for students, a questionnaire was conducted one year after the students enrolled in the biology lab class. The response rate for this survey was 35.4% for the SSI curriculum (n=154) and 33.5% for the EXT curriculum (n=139). Students were asked to describe the ways that they might have used the knowledge or skills from the biology lab over the past year in 1) daily life and 2) other coursework.

**Usefulness in Daily Life**

In order to investigate student perceptions of the usefulness of the previous year’s lab activities, the participants were asked how they had used the biological knowledge or skills they had gained in their daily life outside of schoolwork. Figure 7 is a graph of the percent of student responses in each coded category generated from the frequencies shown in Table 1. Below are explanations of the major themes that emerged from the data.

**Figure 7. Student descriptions of the ways they used knowledge or skills in the past year. Coded student responses to the longitudinal questionnaire question asking students to explain how they have used the knowledge or skills gained from the lab in the past year for the SSI (n=154) and the EXT (n=139) groups. Categories with significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks (* p<.05, ** p<.01).**

**Did not use knowledge or skills.** Students from both the SSI and EXT groups could not remember using the knowledge or skills in the past year; these students wrote responses like, “Not sure...I don't recall using anything in particular.” Others simply
responded they had not used these knowledge or skills with statements such as “I have not used anything from lab.” There was a significantly higher percentage of students who experienced the EXT curriculum that indicated they did not use any knowledge or skills from the lab in their daily lives over the course of a year than the SSI curriculum (SSI =36.4%; EXT =46.8%; \( p < 0.05 \)). This ten percent difference reflects a similar result in the week 10 post survey where there was a ten percent increase in the number of student responses that indicated they saw no relationship between the lab activities and their daily lives.

**Informed decision-making or awareness of issues.** Of the students who mentioned issues in their responses, they either wrote that they have thought about the issues they learned about, or that they actually used the information to make choices in their daily lives about the issues in the course. This was claimed at a significantly higher percentage in the SSI group than the EXT group (SSI =15.6%; EXT =2.9%; \( p <0.001 \)) For example, one SSI respondent wrote, “I have noticed noxious weeds some in daily life and thought about the fines that governmental agencies impose for these weeds” indicating that they had thought about the issue, but did not mention any action they may have taken using the knowledge or skills they learned. Others wrote about using what they learned in decision-making in their daily lives. One SSI respondent wrote, “I've used what we learned about GMO crops to make choices both in voting and in making choices in the grocery store.” In most instances, the responses in these categories involved an issue covered in one of the laboratory modules in the SSI curriculum. Another SSI student wrote, “I make many life decisions regarding the environment and biological systems based on the information I learned from the bio lab.” Both of the previous quotes reflect how students used knowledge or skills to make informed decisions.

**Hobbies or Interests.** Students mentioned using knowledge or skills in their daily lives while pursuing hobbies or other interests outside of schoolwork. The SSI group that gave responses within this theme significantly more than the EXT group (SSI =11.7%; EXT =5.0%; \( p <0.05 \)). Students mentioned using what they had learned while engaged in activities such as gardening or hiking in the woods. One of the SSI students reported, “I hike often and look for invasive species in the areas I go.” Other students discussed
relevance of the course to out of school learning or researching future career paths. For example, one SSI student wrote, “I am very engaged in out of school learning, and am always looking to make connections with what I learn and the real world.” Another SSI student wrote that they “used the skills gained to do my own research online into fields I may try to go into after graduation.”

Since there were several themes regarding student descriptions of the way they had used the biological knowledge or skills in their daily lives, in order to better investigate the differences between the two curricula, I also determined the relative agreement of the two student groups with the more simplified categories of “used knowledge or skills” and “haven’t used knowledge or skills”. Student responses could be in multiple categories as they may have identified more than one way they used the knowledge or skills in the past year, so the percent was calculated by dividing the total number of references in a category by the total number of references overall from each curriculum and not by number of student respondents (Figure 8).

![Figure 8. Perceived usefulness of knowledge or skills to daily life. Coded student responses to the longitudinal questionnaire question asking students to explain how they have used the knowledge or skills gained from the lab in the past year in their daily lives for the SSI (n=154) and the EXT (n=139) groups were combined into two categories. Percentages were calculated from the total number of responses in a coded category/total number of references. Significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks (** p<0.01).](image)

As is shown in figure 8, there was a statistically significant difference between the SSI and EXT curricula in the perceived usefulness of the curriculum in their daily lives as
indicated by the number of references in the categories describing use of knowledge or skills in comparison to the number of those indicating that they had not used them in the past year ($p<0.001$).

*Usefulness To Other Coursework*

In order to investigate student perceptions of the usefulness of the previous year’s lab activities, the participants were asked how they had used the biological knowledge or skills they had gained in other coursework. Figure 9 is a graph of the percent of student responses in each coded category generated from the frequencies shown in Table 1. Below are explanations of the major themes that emerged from the data.

**Use of knowledge or skills in advanced science courses.** There were no statistically significant differences in the frequency of the emergent themes between the SSI and EXT groups relating to how they used their knowledge and skills in other coursework. Many of the students, from both groups, wrote that they used what they had learned in advanced science courses. For example, one EXT student wrote, “It has helped
to give me a background in ecology which is a course I am taking.” Many others students also gave exact course numbers of classes where they felt the knowledge and skills were useful.

Haven't used knowledge or skills. Many indicated that course knowledge or skills were useful as a foundation for other science courses, but that they had, none-the-less, not actively used this knowledge or skills in other courses.

Discussion

In the previous chapter, I reported on a quantitative study of the effects of a socio-scientific issues-based (SSI) curriculum on biology student motivation utilizing Deci & Ryan’s (1985) self-determination theory as a theoretical framework that revealed a significant increase in student autonomous motivation and a decrease in controlled student motivation in response to the SSI curriculum when compared to a control group. In order to gain a greater understanding of the shift in motivation related to the fulfillment of psychological needs described by Deci & Ryan (1985), in this study I investigated student perceptions of relatedness. A small amount of literature has shown a link between student perceptions of relatedness and contextualization of curriculum, informing my hypothesis that the change in student motivation from more autonomous and less controlled could be partially explained by the effects of SSI implementation on biology student perceptions of relatedness.

My hypothesis that the SSI curriculum would increase student perceptions of relatedness, specifically the relevance of the lab activities to their lives relative to the EXT control group was investigated through the quantitative analysis of qualitative, open-response questions from a post-course questionnaire that elicited participant descriptions of student-instructor and student-student interactions and curricular relevance that are important factors in relatedness need fulfillment (Niemic & Ryan, 2009). In addition to the questionnaire immediately following the completion of the curriculum, a one-year-out longitudinal questionnaire was utilized to research student perceptions of the relevancy or usefulness of the knowledge and skills they gained to their daily lives or other coursework taken since the experience. Through thematic analysis and quantification of code frequencies to facilitate comparisons between the SSI
and the EXT groups, I found similarities in the ways that students perceived their peer and instructor relationships and significant differences between the two groups in the perceptions of the course curriculum as relevant and useful both at the time of the course and one year post.

**Student-Instructor Relationships**

The need for relatedness has been described as needing to feel a sense of social belonging, and in the classroom context the student’s perception of an instructor is particularly important (Ryan & Deci, 2000). The analysis of the qualitative open-response data asking students to describe their relationship with their GTA revealed that the overwhelming majority of students experiencing both curricula had positive perceptions of their instructors. They viewed them as knowledgeable, fun, caring and excited to teach. Only a small minority of the responses indicated negative interactions with GTAs or perceiving them as unprepared or unapproachable. This is similar to recent research by Kendall & Schussler (2012) that found undergraduates perceived GTAs as more “relaxed, laid-back, engaging, interactive, relatable, understanding, and able to personalize teaching than professors” (p. 196). Graduate students teaching the introductory biology course at the university in the current study also participated in professional development in the form of weekly teaching seminars regardless of the curriculum they taught; such training may have contributed to the positive perceptions of the GTAs.

In spite of the similarities in responses in the two groups, students in the SSI curriculum more frequently described their GTA as excited to teach and described their relationship or the quality of the GTA positively. The EXT group more often cited a negative relationship with their GTA, although the difference was small. It is not known whether or not the curriculum contributed to the higher proportion of positive perceptions of the GTAs in the SSI curriculum, but it is possible that incorporating the discussion of socio-scientific issues with students was a factor that may have contributed to the perceptions of enthusiasm and positive quality of the GTAs. It is also possible that despite the randomization of GTAs teaching the different curricula, that there were one or two more engaging GTAs in the SSI group than the EXT. Admittedly, the EXT group
had a single GTA that students found difficulty connecting with because of a language barrier.

It has been identified by previous researchers that in order to foster a classroom climate where students feel a sense of social belonging, the teacher needs to convey “warmth, caring, and respect to students” (Niemiec & Ryan, 2009). The majority of students in both curriculum groups perceived their GTA as caring about student learning and needs that indicates that some other factor(s) aside from the curriculum such as the laboratory setting or the GTAs themselves contributed to these positive perceptions of the GTAs. It is possible that the laboratory setting and the qualities or training of the GTAs were more important for conveying a sense of caring than the curriculum itself. Indeed, the collaborative nature of the laboratory setting has been shown to provide opportunities for more positive interactions with instructors (Hofstein & Lunetta, 2004).

**Peer Relationships**

The overwhelming majority of students in both curricula reported positive, friendly interactions with their peers in lab. Most indicated that the peers in their lab groups contributed equally to completing the lab exercises. There were no differences in student perceptions of peer relationships between the SSI and the EXT curriculum. As with the instructor-student relationship, it is likely that the unique setting of the laboratory or the classroom climate is responsible for the cooperation and positive interactions with peers and not the curriculum. Hofstein & Lunetta (2004) described the classroom laboratory social setting as, “usually less formal than in a conventional classroom; thus the laboratory offers opportunities for productive, cooperative interactions among students and with the teacher that have the potential to promote an especially positive learning environment” (p. 35). Student responses indicated that they appreciated being able to collaboratively interact with their peers and that the laboratory had given them a place to meet friends and study partners. The appreciation of the ability to interact with GTAs and peers may have been more pronounced in this large research university setting because the course lectures are typically large (500+ students) and offer little opportunities for students to connect with the instructor and peers outside of the
laboratory class. Further investigation into the experiences of students in large combined lecture/laboratory courses would be necessary in order to validate this assumption.

**Relevance and Usefulness of the curriculum**

The socio-scientific issues-based approach contextualizes learning for students and helps them develop skills in argumentation (Zeidler, 2004) and informed decision-making (Sadler, 2004), as well as develop understanding of content knowledge (Zohar & Nemet, 2002, Sadler & Klosterman, 2010, Dori et al., 2003). Providing a context for learning in this way has been shown to promote student perceptions of the curriculum as relevant to their lives or future goals (Barber, 2001). When students can connect with content, positive outcomes like persistence, achievement and motivation are increased (Zimmerman, 2000). Building on this previous research, I hypothesized that there would be differences between the SSI and EXT groups of students in the way they perceived the curriculum to be relevant to their daily lives or future careers. There were indeed significant differences in the frequencies of the themes. More students in the EXT group did not find the curriculum to be relevant to their lives in any way. More students in the SSI group found the curriculum to be more relevant overall when compared with the EXT group. Most notably, students in the SSI group found the curriculum more interesting and relevant to their lives. These results are similar to another study conducted by Barber (2001) where undergraduate chemistry students were found to be more interested and motivated in the context of SSI when compared to one not taught in the SSI context. The current study not only utilized a robust theoretical lens to frame the work on student motivation, but was also a much larger study with many different instructors.

The one-year-out questionnaire was designed to investigate potential long-term differences in the ways that students in the SSI and EXT curriculum perceived the knowledge and skills gained to be relevant and useful to their lives. There were indeed significant differences in the frequency of themes that emerged from the analysis of the longitudinal questions. Students that had experienced the SSI curriculum reported using the knowledge and skills they gained to make informed decisions in their pursuit of different hobbies or interests. There are many studies that have found SSI to impact
decision-making and the ability of students to reason as well as think through multiple perspectives on an issue (Sadler, Barab & Scott, 2007). These results are also consistent with other studies that have found increased interest in activities or issues in response to SSI curriculum (Albe, 2008, Barber, 2001, Bennett et al, 2005, Bulte et al. 2006, Dori et al., 2003, Harris & Ratcliffe, 2005, Lee & Erdogan, 2007, Parchman et al., 2006, Yager et al, 2006, Zeidler et al, 2009, Sadler, 2004 & 2009). Students in the EXT curriculum mentioned not using knowledge or skills at all in the past year more often than those in the SSI group, signifying greater perceptions of usefulness in the SSI group overall. These results are similar to those found by Feierabend & Eilks (2010) who observed an increase in student perception of relevance in response to participating in socio-scientific issues-based course modules. Most of the previous studies have not showed longitudinal data and most have been in secondary school settings, making this research highly relevant in determining long-term outcomes of this pedagogical approach regarding increasing relevance for students in a large research university setting.

Although I did not measure gains in knowledge or skills in this study directly, the longitudinal questionnaire asked students about the perceived usefulness of what they learned via the SSI or EXT course to their other coursework over the past year. There were no significant differences between the SSI and the EXT groups in student perceptions of the usefulness of the material in latter coursework. This is not direct evidence of knowledge or skills gains, but is consistent with the results of various studies where students have been found to display equal or more science content knowledge on pre/post assessments in SSI-based interventions when compared to learning environments that teach scientific facts and concepts in the absence of a real-world context (Zohar & Nemet, 2002, Sadler & Klosterman, 2010, Dori et al., 2003, Bulte et al., 2006, Barker & Millar, 1996, Barab et al., 2007, Barber, 2001). Studies also report learning gains with regard to understanding the nature of science, and evidence of the development of higher-order thinking (Albe, 2008, Dori et al., 2003, Harris & Ratcliffe, 2005, Khishfe & Lederman, 2006, Kortland, 1996, Pedretti, 1999, Tal & Hochberg, 2003, Tal & Kedmi, 2006, Walker & Zeidler, 2007, Yager et al., 2006, Zeidler et al., 2009). Results from my study and these similar studies may be important towards alleviating concerns that some
postsecondary educators may feel in implementing SSI-based curriculum over more traditional offerings, namely concerning the “depth versus breadth” debate. Educators may worry that more time focused on SSI-related issues may not allow for adequate breadth of content coverage, assumed detrimental to students continuing in the discipline. This is particularly a concern to be voiced regarding introductory courses for majors where students are meant to learn the foundational knowledge needed for higher level coursework. This study illustrates the potential for the implementation of the SSI approach in undergraduate majors science courses to increase relevancy for students without sacrificing perceived usefulness to their content and processes understanding or other disciplinary coursework. Admittedly, however, one limitation of this study is that it does not document actual content knowledge or disciplinary success of either curriculum’s graduates.

SSI and Biological Literacy

In this study I found that the SSI approach fosters relevancy for students, allowing them to perceive the activities as relevant to their daily lives and interests. Moreover, the longitudinal questionnaire results indicated that students were able to use what they had learned in the course to make informed decisions regarding issues and to use or search out information related to their own hobbies and interests. These results show that the SSI approach has the potential to positively impact both immediate and long-term student outcomes towards the development of biological literacy in undergraduate students.

Relatedness Need-fulfillment and Fostering Relevance in Introductory Biology Courses

Previous research on motivation regarding SSI within the framework of self-determination theory has described results from studies that connect an increased relevance for students associated with the SSI approach with the concept of relatedness need-fulfillment (Darner 2009 & 2013). In this study, I investigated the impact of an SSI curriculum on student perceptions of relatedness both immediately completing the course and in a one year longitudinal study. I found that of the three aspects of relatedness that have been described in the literature regarding relatedness in educational contexts, the relevance of the curriculum was most different between the two groups although there were some differences in the perceptions of the GTAs. This study represents a large,
empirical study investigating perceptions of relatedness need-fulfillment in a laboratory setting. It is clear from the results that there was indeed an increase in the perceived relevance of the curriculum that may partly explain the increase in student autonomous motivation found in the quantitative study (see Chapter 4). The relevance of the curriculum was included as an aspect of relatedness in this study, but it is highly likely that students felt a greater sense of autonomy as they perceived value in the learning. More studies are needed that focus on relatedness to parse out the overlap between the relatedness and autonomy constructs. It has been suggested that a students’ ability to perceive value in the learning activities depends on the social connections made in relatedness need-fulfillment (Deci, 1992). It is possible that if the relationships with the instructors and peers in the course were not seen as positive that the contextualization of the course would not have had as significant of an impact.

Limitations
In this study I found that the socio-scientific issues-based laboratory course increased the relevancy of the learning activities for undergraduate biology students and their ability to apply biological knowledge and skills in their daily lives over a one year period when compared with the existing curriculum that did not contextualize learning. Therefore, the SSI approach has the potential to increase the development of biological literacy in undergraduate students. In situating these results in the larger context of the literature and in other classroom contexts, a number of limitations of this work must be considered. The data in this study were all self-report data that are limited in estimating the overall effects of the SSI curriculum. Furthermore, this research was conducted in a single institution limiting the generalizability of the findings. The short nature of the responses prevented in depth, rich textual analysis. Although there are limitations to be mindful of, this was a large empirical study driven by motivational theory that represents one of a limited number of studies of SSI in undergraduate courses and those focused on investigating the relatedness construct in classroom contexts.
Conclusion

In this dissertation, I have presented four research manuscripts that aimed to investigate results from a two-year study on the design and implementation of a socio-scientific issues-based curriculum in a large introductory biology laboratory course for science majors. The study manuscripts aimed to advance knowledge in; 1) curriculum design and implementation aligned with science education reform movements, especially in large university courses, 2) research on what is gained from implementing socio-scientific issues-based education, 3) research regarding student motivation utilizing the lens of self-determination theory, and 4) research that advances motivational theory.

Each of the four manuscripts I have presented in this dissertation has contributed to addressing one or more of the research questions outlined below. Separately, they have each advanced research in science education and motivation from the practitioner or theorists point of view. Collectively, they have helped to inform the larger conceptual framework that I presented in the introduction of this dissertation.

Conclusions Regarding Dissertation Research Questions

The first two manuscripts presented in this dissertation investigated the two research questions below.

1. What were the benefits and challenges of utilizing socio-scientific issues-based instruction in a large introductory biology laboratory course?
2. What were graduate student teaching assistants experiences and perceptions related to teaching the socio-scientific issues-based laboratory curriculum?

In Chapter 2, I presented details on the SSI curriculum that was the focus of all of the studies in this dissertation, and further drew upon data from a GTA questionnaire to investigate perceptions and experiences of GTAs who taught the course. Qualitative analyses of these data, lead to recommendations and considerations regarding implementation of SSI curriculum and preparation for GTAs. Specifically, the recommendations included better alignment of new introductory biology curriculum with
the Next Generation Science Standards, further inclusion of GTAs in action research studies in order to aid in their development as faculty and scholars, and incorporating considerations for educators when implementing the issues-oriented model. Chapter 2 provided an example of one of the curricular modules, it’s alignment with current reform initiatives (AAAS, 2011), and addressed the first research question in identifying benefits and challenges of implementing SSI curriculum through a post-survey of students after participating in the module activities. The survey assessment of the activity revealed enhanced student engagement, interest and valuing of the learning experience, that have been shown to be benefits of SSI curriculum (Sadler, 2009). Although previous studies have noted these benefits, this study represents an SSI curriculum implemented in a large introductory course with thirteen GTA instructors that advances the literature the contexts that SSI can be successfully implemented. In addition, it reinforces the value of utilizing the issues-oriented model specifically to incorporate SSI and other best practices in the science education literature.

In Chapter 4, I investigated the effects of implementing an SSI-based laboratory curriculum on biology student motivation in a large introductory biology course for science majors. Specifically, this manuscript addressed the following research questions:

3. What types of motivation were salient for undergraduate students in an undergraduate introductory biology course?
   a) How did the levels of the different types of motivation change over the course of the term?

4. What were the effects of a socio-scientific issues-based laboratory curriculum on undergraduate biology students’ levels of autonomous and controlled motivations with respect to engaging in the work for the laboratory compared to the control group?

   I described student motivation in terms of self-determination theory and utilized a survey instrument that assessed self-determination in regard to doing the work for the laboratory class. Through a hierarchical linear model, I examined the effects of the SSI curriculum relative to the existing curriculum in place as well as its effects over the course of the term on biology student motivation. An analysis of the data weighting for
the different sub-constructs of motivation revealed a significant increase in overall motivation as determined by the self-determination index scores in the SSI group relative to the control group. The higher self-determination index score shows that the levels of autonomous motivations were higher for the SSI group.

Analyzing the data according to the individual sub-constructs of motivation from the self-determination continuum allowed me to investigate the effects of the treatments on intrinsic motivation, integrated regulation, extrinsic motivation and amotivation over the course of the term in order to further address research question three. The analysis of each of the sub-constructs in the SIMS scale from the self-determination continuum revealed that autonomous motivations (intrinsic motivation and identified regulation) declined over the course of the term for both groups, but were higher for the SSI group at each time point. Research into the temporal shifts of student motivation over the course of university terms indicates that some motivational variables (such as task value) tend to decrease as the time for evaluation and feedback approaches (Wicker, Turner, Reed, McCann & Do, 2004). As the final exam approached and students move towards the end of the term, they may have felt more pressures from the final exam and grade evaluations that approached. Indeed, this is a highly probable explanation for the trends we see in decreasing autonomous motivation and the increase in amotivation in both groups over time. External regulation remained constant for the EXT group over the course of the term, but it decreased over time for the SSI group. These results suggested a possible buffering effect of the SSI curriculum on the decrease in student motivation that occurs over the span of a term when students are moving into the most stressful and demanding portion of the course.

Very few studies utilizing the SDT framework have focused on undergraduate introductory courses and even fewer have investigated the effects of curricular innovation on student motivation as most studies focus on teacher autonomy support or academic motivation more generally (Guay, Ratelle & Chanal, 2008). This study is one of a few that add to the growing knowledge base of undergraduate student motivation with regard to specific courses and in response to curricular approaches. This study will help practitioners identify ways to create learning environments that support students’
autonomous motivations in large introductory courses. The results indicate that socio-scientific issues-based courses could be a practical solution for increasing autonomous motivation and positive student outcomes.

In Chapter 5, I investigated the research questions below:

5. What were the effects of a socioscientific issues-based laboratory curriculum on undergraduate biology students’ perception of relatedness compared to the control group?
   a. What were the differences between the SSI and control groups in student perceptions of their relationship with the instructor?
   b. What were the differences between the SSI and control groups in student perceptions of their relationships with their peers?
   c. What were the differences between the SSI and control groups in student perceptions of the relevance of the learning activities?

6. In what ways did students report using the knowledge and skills gained in the socio-scientific issues-based lab course one year-out compared to the control group?

I investigated these questions through the quantitative analysis of qualitative, open-response questions from a post-course questionnaire that elicited participant descriptions of student-instructor and student-student interactions and curricular relevance that are important factors in relatedness need fulfillment (Niemic & Ryan, 2009). In addition to the questionnaire immediately following the completion of the curriculum, a one-year-out longitudinal questionnaire was utilized to probe student perceptions of the relevancy or usefulness of the knowledge and skills they gained to their daily lives or other coursework taken since the experience. Through thematic analysis and quantification of code frequencies to facilitate comparisons between the SSI and the EXT groups, I found similarities in the ways that students perceived their peer and instructor relationships and significant differences between the two groups in the perceptions of the course curriculum as relevant and useful both at the time of the course and one year later.

I found that the SSI approach fosters relevancy for students, allowing them to perceive the activities as relevant to their daily lives and interests. Moreover, the longitudinal questionnaire results indicated that students were able to use what they had
learned in the course to make informed decisions regarding issues and to use or search out information related to their own hobbies and interests. These results show that the SSI approach has the potential to positively impact both immediate and long-term student outcomes towards the development of biological literacy in undergraduate students. In addition, I was able to further work on self-determination theory regarding the relatedness construct.

**Closing Comments**

In this dissertation, I was able to add to the limited, but growing number of studies of socio-scientific issues-based educational approaches in the post-secondary setting, especially in large courses, and those serving science majors. I examined the practical benefits and challenges of utilizing this framework for large introductory science courses and offered recommendations for practitioners who plan to implement this approach. This study also added to the sparse literature on science graduate teaching assistants implementing science education reform approaches, especially related to teaching a socio-scientific issues-based curriculum (Gardner, 2009, Gardner & Jones, 2011). This research is significant in preparing graduate teaching assistant educators for teaching SSI, and for those involved in curriculum design and implementation from practitioner and education researcher perspectives.

Motivation is an important construct to consider in order to understand the impacts of a SSI approach on the ability and drive of students to apply knowledge and skills to their lives in formal and informal settings. This study is a large, empirical study that employed robust motivational theories. In addition to making progress on understanding motivation related to SSI, this work advanced knowledge regarding the construct of relatedness in the self-determination theory framework of motivation (Deci & Ryan, 1985).
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APPENDICES
Appendix A
GTA Questionnaire

1. Please compare the Socio-scientific Issues-Based curriculum with any biology labs you may have taught in the past as a GTA.
2. Please describe your experience while teaching lab this term. For example, did you enjoy teaching the course?
3. Did you feel confident in your ability to teach this curriculum as the lead GTA? Why/Why not?
4. Please comment on any skills or knowledge you may have gained from teaching this curriculum.
5. Please share any additional comments on your experience teaching the SSI lab curriculum this term.
Appendix B

Student Questionnaire

The SIMS is an established valid and reliable instrument used by researchers in multiple fields (Guay, Vallerand & Blanchard, 2000). Open-ended questions were designed for this research study.

The Situational Motivation Scale (SIMS)-
Using the scale below, please circle the number that best describes the reason why you are doing the work for this course. Answer each item according to the following scale: 1: corresponds not at all; 2: corresponds a very little; 3: corresponds a little; 4: corresponds moderately; 5: corresponds enough; 6: corresponds a lot; 7: corresponds exactly.

Why are you doing the work for the BI213 biology lab (not lecture)?

1. Because I think that the work for the lab is interesting
2. Because I am doing it for my own good
3. Because I am supposed to do it
4. There may be good reasons to do the work for the lab, but personally I don’t see any
5. Because I think that doing the work for lab is pleasant
6. Because I think that doing the work for lab is good for me
7. Because it is something that I have to do
8. I do the work for this lab but I am not sure if it is worth it
9. Because doing the work for lab is fun
10. By personal decision
11. Because I don’t have any choice
12. I don’t know; I don’t see what doing the work for lab brings me
13. Because I feel good when doing the work for lab
14. Because I believe that doing the work for lab is important for me.
15. Because I feel that I have to do it
16. I do the work for the lab, but I am not sure it is a good thing to spend time on

**Open Response section** (week 10 only).

1. Please describe your experience in lab this term. For example, what were things you liked/disliked?

2. Please describe your relationship with your peers in your biology lab class. For example, did you get along? Was the work distributed fairly?

3. Please describe your relationship with the lead Graduate Teaching Assistant for your lab class. For example, did they address your questions/concerns? Did they seem excited to teach?

4. Please comment on how your lab class helped you make progress in learning science concepts this term, if at all.

5. Explain how the activities in lab this term relate to your personal life or future career goals, if at all.

6. Please describe how you feel in regards to your ability to be successful in completing the lab activities?

7. Could you see links between the lab activities and the lecture portion of the course?
   - Yes/no
   - Why/Why not?

8. What was your motivation for completing the work for this lab class?
Appendix C

Longitudinal Student Questionnaire

1. Please reflect back on your spring biology xxx lab experience. For example, what comes to your mind when you think about the class?

2. Which biology xxx lab activities do you remember and what about them makes them memorable?

3. Since taking the biology xxx (Spring term) lab last year, how have you used any biological knowledge or skills gained from lab in your daily life outside of schoolwork?

4. Since taking the biology xxx (Spring term) lab last year, how have you used any biological knowledge or skills gained from lab in other schoolwork?

5. Please describe your introductory biology experience in relation to your upper-division science experiences.