Introductory Biology in Social Context: The Effects of an Issues-Based Laboratory Course on Biology Student Motivation

Krissi M. Hewitt,† Jana Bouwma-Gearhart,‡ Heather Kitada,§ Robert Mason,∥ and Lori J. Kayes*†

†Office of Research, Planning and Assessment, North Carolina School of Science and Mathematics, Durham, NC 27705; ‡College of Education and ∥Department of Integrative Biology, Oregon State University, Corvallis, OR 97331; §Mathematics Department, Reed College, Portland, OR 97202

ABSTRACT

We investigated the effects of a laboratory curriculum developed using the socio-scientific issues (SSI) framework to contextualize scientific and socially relevant issues for students. Using self-determination theory and hierarchical linear modeling, we examined the effects of the SSI curriculum relative to a control curriculum on student motivation in a large introductory biology course for life science majors. The SSI group had a significant increase in motivation for engaging in the laboratory work relative to motivation of the control group. Additionally, the SSI group showed higher levels of more autonomous forms of regulation concerning participation in laboratory tasks compared with the control group. Interestingly, the SSI-based curriculum seemed to have a buffering effect on typically observed decreases in student motivation over the course of a term. This buffering effect could potentially indicate greater self-determination in students experiencing an SSI-based curriculum, which could lead to greater student success and persistence. Qualitative data suggest that this increased motivation of the SSI group relative to the control group is due to enhanced feelings of relatedness experienced by students, likely due to the SSI.

INTRODUCTION

Recent advancements in the biological sciences have resulted in a large number of social, political, and technological issues that require action from both scientists and citizens (e.g., genetic modification of foods; American Association for the Advancement of Science [AAAS], 1989, 2011). These issues have led to an increasing demand on postsecondary educators to help develop citizens who are biologically literate (AAAS, 2011; Hall et al., 2011). Functional biological literacy is an active form of scientific literacy indicated by an individual’s ability to read about, comprehend, communicate, and form opinions about biological issues (Laugksch, 2000). While formal education experiences can be put in place to help foster these skills, research indicates that typical postsecondary biology education experiences tend to focus on rote memorization of facts and concepts devoid of social context (Seymour and Hewitt, 1997; AAAS, 2011). Transformation of curricula and instruction to incorporate activities that engage students in authentic scientific practices and the application of these practices to real-world problems (Barab and Plucker, 2002; Chamany et al., 2008) is needed in postsecondary biology classrooms.

Socio-Scientific Issues–Based Instruction

One pedagogical approach that may help meet these goals is a socio-scientific issues–based approach (Zeidler et al., 2005; Sadler et al., 2007; Lenz and Willcox, 2012). Socio-scientific issues (hereafter SSI) are complex social problems with technological or conceptual ties to science, including a wide array of timely (and sometimes
Motivation has been commonly described as a dichotomy: either 1) intrinsic or 2) extrinsic (i.e., when a person engages in an activity only because he or she desires an outcome afforded by others, such as a reward, avoidance of punishment, or a desire to “look good” to peers). Studies have shown that students’ intrinsic motivation regarding education tasks is a strong predictor of their persistence and success (Deci and Ryan, 1985; Renninger, 1992). SDT diverges from the intrinsic/extrinsic motivation dichotomy and, rather, promotes motivation as a continuum of motivational states, including amotivation. Furthermore, SDT breaks down extrinsic motivation into four different categories that represent the continuum between autonomous (driven by internal sources) and controlled regulation (driven by external rewards or punishments; Deci and Ryan, 1985; Ryan and Deci, 2000; see Figure 1). For our research, two of these categories are most included in our chosen survey instrument: 1) external regulation: students’ behaviors as inspired by a reward or to avoid negative consequences; and 2) identified regulation: behaviors as more internally driven but still enacted toward a goal required by entities external to the student (i.e., the instructors). The other two categories—introjected regulation (i.e., choosing to do something to not feel guilty) and integrated regulation (i.e., when behavior is motivated by coherence with other aspects of self)—are not addressed in this study, as they were not included in the chosen survey instrument (see Methods) in order to minimize survey length (Guay et al., 2000).
Moving across the self-determination continuum, the perceived control that a person has over his or her ability to participate in activities shifts from more external (controlled) to more internal (autonomous) regulation. The more internal the feelings of control are with respect to a task, the more self-determined or autonomous a student is with respect to that task. Autonomous motivation has been shown to be a predictor of persistence toward postsecondary degree completion (Vallerand et al., 1997) and increased retention and depth of learning (Grolnick and Ryan, 1989; Vansteenkiste et al., 2006). Additionally, autonomous motivation is positively associated with academic achievement (Vallerand et al., 1997; Ratelle et al., 2007). In contrast, external regulation and controlled motivation, reflective of low feelings of self-determination, have been associated with negative educational outcomes for students, such as low creativity (Amabile, 1993), anxiety regarding tasks (Ryan and Connell, 1989), lower interest or effort, and lack of personal responsibility for negative outcomes (Ryan and Deci, 2000).

One way in which SSI curriculum may increase motivation is specifically through perceptions of relatedness. There are three major aspects of relatedness that contribute to overall autonomous motivation in classroom contexts, including student perceptions of 1) their relationship with the instructor, 2) their peer relationships, and 3) the relevance or importance of the activities to their lives (Darner, 2012). Students’ perception of curricular relevance to their lives outside the classroom may increase students’ perceptions of social connectedness (i.e., relatedness; Darner, 2007, 2009). Darner (2009, 2014) found that, after participation in an SSI curriculum in a nonmajors biology course, students reported feeling more connected to their communities and were able to relate what they learned to their daily lives. On the basis of these outcomes, the author posited that these students had increased feelings of relatedness. From our perspective, relatedness is of particular interest due to the potential relationship between students’ perceptions of the curriculum and their feelings of relatedness (see Figure 2 for conceptual framework). Fostering relevance for students may increase perceptions of both autonomy and relatedness. The current study assesses not only how the SSI model impacts overall motivation, but also specifically the impact of SSI on feelings of relatedness.

This study adds to the existing knowledge base in a number of ways: 1) by using a rigorous quasi-experimental design with both treatment and control groups analyzed with hierarchical linear modeling techniques; 2) by adding to the limited research studies regarding the SSI approach in postsecondary settings; 3) by exploring a more nuanced notion of motivation with regard to feelings of relatedness; and 4) by investigating of how student motivation changes over the term of a course.

The Current Study
Before determining how SSI might impact student motivation, we sought to determine whether SSI impacted student motivation, particularly motivation to participate in lab activities, compared with a control group. We conducted a quasi-experimental study in three introductory biology courses...
biology courses in which approximately half the laboratory sections were taught using the newly developed curriculum based on the SSI model (SSI treatment) and the other half of the laboratory sections were taught using the traditional curriculum already in place (control curriculum). Specifically, we examined 1) whether and how the motivation in both groups (SSI and control) changed over the course of the term, 2) whether or not the SSI-based curriculum had the potential to cause a shift in student motivation toward the more internally regulated (i.e., autonomous control) side of the SDT continuum for students in the SSI treatment group compared with the control group, and 3) the effect of the SSI-based curriculum specifically on students’ feelings of relatedness to the curriculum, their peers, and their instructors.

We hypothesized that the SSI laboratory curriculum would shift students’ along the continuum toward more internally regulated (autonomous) motivations relative to the control group that received the traditional curriculum over time. More specifically, because of the focus of the SSI curriculum on fostering relevance for students through the contextualization of content with locally and globally relevant SSI, we hypothesized that SSI would shift student motivation to engage in laboratory work toward more autonomous types of motivation by enhancing feelings of relatedness (Figure 2).

Research Questions
1. What types of motivations are salient for undergraduate students in an undergraduate introductory biology course?
   a. How do the levels of the different types of motivation change over the course of the term?
2. What was the effect of an SSI-based laboratory curriculum on undergraduate biology students’ levels of autonomous and controlled motivations with respect to engaging in laboratory work compared with the control group?
   a. How did these levels of autonomous and controlled motivations change over the course of the term?
3. What was the effect of an SSI-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 the relevance of the learning activities?
   b. What were the differences between the SSI and control groups in student perceptions of their relationships with their instructors?
   c. What were the differences between the SSI and control groups in student perceptions of their relationships with their peers?

METHODS
Educational Context
SSI and Control Curricula. Students in the SSI sections were taught concepts (genetics, evolution, and ecology) similar to those presented in the previously existing traditional curriculum, but via new modules that integrated the SSI approach, based on recent biology education research, practitioner publications, or new activities developed “in-house” (see the Supplemental Material). The SSI curriculum was designed to address both global and local topical issues assumed to be relevant to most students and to help develop biology literacy, such as genetic testing, genetic modification of crops, and local invasive species. The SSI curriculum (a compilation of laboratory modules) conformed to the guidelines for SSI-based instruction based on the model by Lenz and Willcox (2012). Each SSI laboratory module aligned with biological concepts deemed important to the course within a larger sequence of three courses. In the SSI model, the curriculum must initially motivate students by providing a socio-scientific issue or problem to help contextualize their learning. To meet this goal in the SSI curriculum, students were required to individually watch and/or read and answer questions about various videos and news and scientific articles addressing a specific socio-scientific issue before coming to lab. At the beginning of each laboratory period, graduate teaching assistants (GTAs) then led a 20- to 30-minute group discussion related to the socio-scientific issue that engaged students in active learning (think–pair–share, jigsaw, write and pass, minidebate, role plays, etc.). Following the discussion, students completed inquiry-based laboratory activities that allowed them to develop hypotheses and interpret results with a set of prescribed methodologies or that encouraged them to develop the hypotheses and methodology and interpret results for predefined research questions (Hofstein and Lunetta, 2004). At the end of each laboratory period, students reflected back on the socio-scientific issue and were asked to determine whether their opinions or viewpoints had changed or whether they were inspired to consider a new approach to addressing the socio-scientific issue. Hewitt et al. (2014) present one module of the SSI curriculum that uses the socio-scientific issue of invasive species management to contextualize animal behavior concepts.

The control laboratory curriculum consisted of modified activities from a widely used laboratory manual concerning the same biological content as the SSI curriculum. In the control curriculum, activities were not contextualized to provide real-world relevance or relate to SSI. Students completed pre-labs with questions related primarily to biological content and concepts, and, at the beginning of the lab, GTAs gave a short lecture to introduce the lab activities. Following this introductory lecture, students engaged in the prescribed lab activities with outcomes that students could easily anticipate (i.e., “cookbook labs”). For example, the animal behavior pre-lab would introduce some relevant concepts and ask a series of questions to ensure students read the laboratory introduction. The in-lab activities consisted of observing behaviors with different organisms and answering questions in the laboratory manual to ensure activities were completed. Some questions would relate to predicting behaviors in different contexts, but students were not required to consider an issue or engage in activities designed for problem-solving of real-world issues.

Course Structure and Curricular Implementation. We implemented the SSI curriculum and the control curriculum simultaneously in 25 laboratory sections of three introductory biology for life science majors courses during a 10-week Spring term at a large research university in the Pacific Northwest (Figure 3). The lectures associated with these laboratory sections did not utilize an SSI framework in curriculum or instruction. Because the SSI curriculum was implemented in the laboratory sections only, students were randomized at the laboratory section level.
The majority of the students ($n = 832$) were enrolled in two team-taught lectures (lectures A and C in Figure 3), which were taught identically by the two instructors, with one instructor teaching the first 5 weeks and the other instructor (L.K.) teaching the second 5 weeks of the 10-week term. A smaller lecture section ($n = 200$) was taught by a different single instructor for the entire term (lecture B in Figure 3). The laboratory sections were taught by GTAs who were assigned to lab section and curriculum (either SSI or control) based on their availability. Both curricula had a mix of male and female GTAs, with similar average teaching and teaching professional development experiences. GTAs were trained in a similar manner on curricular implementation, regardless of being assigned to teach the SSI or control curriculum.

Sample and Participant Assignment

The participants in this study were undergraduate students ($n = 1032$) enrolled in the introductory life science majors’ biology course. Students were told during the first lecture of the course that the biology program was implementing different curricular sections of a lecture/lab combined course with three different lectures and 25 lab sections. The SSI and control curricula were divided approximately evenly within each lecturer or lecturer team. The SIMS was offered to all students three times (at the beginning of the term, in the middle of the term, and at the end of term). AM, class taught in the morning; EXT, control group; PM, class taught in the afternoon.

![FIGURE 3. Hierarchical course structure of introductory biology for science majors and laboratory curricular implementation. The study was implemented in the laboratory sections of a lecture/lab combined course with three different lectures and 25 lab sections. The SSI and control curricula were divided approximately evenly within each lecturer or lecturer team. The SIMS was offered to all students three times (at the beginning of the term, in the middle of the term, and at the end of term). AM, class taught in the morning; EXT, control group; PM, class taught in the afternoon.](Image)

The SIMS (Guay et al., 2000) is composed of 16 Likert-scale items, with four questions per each motivational subconstruct assessed, that is, intrinsic motivation (IM), amotivation (AM), and two types of extrinsic motivation, identified regulation (IR) and external regulation (ER). As stated previously, the SIMS does not measure either the integrated regulation or the introjected regulation types of extrinsic motivation, due to a desire to streamline the survey and ensure students responded accurately without survey fatigue (Guay et al., 2000). The SIMS was determined to be the most adequate survey for our research questions per its design to measure situational motivation within a certain context (e.g., in a biological laboratory course). Additionally, there have been extensive studies on the validity and reliability of the SIMS and the relationship of the scale items to SDT (Guay et al., 2000; Standage and Treasure, 2002).

The SIMS was slightly modified to be specific to the context of a biology laboratory course. To this end, minor changes were made to the SIMS response statements to say “for the biology XXX lab” instead of “this activity.” Students responded on a scale of 1 to 7, where 1 corresponds to “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 XXX lab?” Cronbach’s alpha was calculated for the subscales from preterm participant survey scores to ensure reliability of the measure in this study (IM = 0.91, IR = 0.87, ER = 0.83, and AM = 0.91). Analyses included scoring for each one of the four subconstructs for students at each time point.

In addition, as previously described by researchers (Vallerand, 1997; Levesque et al., 2004), we calculated a self-determination index (SDI) using all four subconstruct scores. The SDI has been shown to be a valid metric for self-determination (Vallerand, 1997). It is calculated by weighting the subconstructs of the self-determination continuum, with heavier positive weight for intrinsic motivation (IM) and negative weight for amotivation (AM) to reflect the extreme ends of the motivational continuum described in SDT (see Figure 1 again for reference). Calculating SDI enables the analysis of a single score on the SIMS, which was important for the hierarchical quantitative analyses discussed in Data Analysis. SDI was thus calculated as

$$\text{SDI} = 2 \times \text{IM} + \text{IR} - \text{ER} - 2 \times \text{AM}$$
SDI scores can range from −18 to +18, with the more negative values representing lower feelings of self-determination (i.e., controlled motivations).

Open-Response Survey Questions
To qualitatively assess the impact of relatedness need fulfillment on situational motivation, we included three open-response questions in the survey. The questions were designed to allow deeper investigations into why the SSI curriculum might promote a shift on the SDT motivation continuum. The questions were as follows:

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.

Data Analysis
Hierarchical Analyses. While all data were analyzed on the student level, the curricular treatments were implemented at the lab-section level. Thus, there is a clear hierarchical nature in the experimental design; students were nested in labs, which were nested in section(s), creating a clustering of groups (Figure 3). Current literature has argued for the need to account for the variance between lecture sections and for differences in lecturers. Additionally, we accounted for the temporal correlation between time-point observations from the same student who took part in all three surveys (preterm, midterm, and postterm) through repeated-measures methods.

To assess the effect of the SSI lab curriculum on student self-determination scores, we tested the fixed effects of the curriculum treatment and the time by curriculum treatment interaction. The latter fixed effect examines how the effect of the curriculum treatment on students’ motivation changed throughout the term. Data were analyzed using SAS PROC MIXED (SAS Institute, 2008). We used 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.

The following is the complete saturated statistical model:

\[ Y_{ijklmnop} = \mu + \alpha_i (\text{curriculum}) + \beta_j (\text{time}) + (\alpha \beta)_ij + \gamma_k + \delta_{l(k)} + \xi_{m(k)} + \eta_{n(lkm)} + \theta_0 + t_p + e_{ijklmnop} \]

• \( Y_{ijklmnop} \) = measure of motivation (subconstruct or SDI) of the nth student nested in the mth lab nested in the lth section nested in the kth lecture at the jth time receiving ith curricular treatment
• \( \mu \) = the overall mean
• \( \alpha_i \) = fixed effect for the ith curricular treatment
  o \( i = 1, 2 \), where control curriculum is 1 and SSI curriculum is 2
• \( \beta_j \) = fixed effect of the jth time measurement
  o \( j = 1, 2, 3 \)
• \( (\alpha \beta)_ij \) = fixed interaction of the ith curriculum treatment and the jth time
• \( \gamma_k \) = random effect of kth lecture
  o \( \gamma_k N(0, \sigma^2_{\gamma}) \)
• \( \delta_{l(k)} \) = random effect of the lth section nested in the kth lecture
  o \( \delta_{l(k)} N(0, \sigma^2_{\delta}) \)
• \( \xi_{m(k)} \) = random effect of the mth lab nested in the lth section nested in the kth lecture
  o \( \xi_{m(k)} N(0, \sigma^2_{\xi}) \)
• \( \eta_{n(lkm)} \) = random effect of the nth student nested in the fth lab nested in the mth section nested in the kth lecture
  o \( \eta_{n(lkm)} N(0, \sigma^2_{\eta}) \)

Analysis of Open-Response Data. The students’ answers to the open-response questions were analyzed within QSR International’s NVivo10 software (v. 10; QSR International, 2012). Analysis was primarily theory driven, with SDT in mind (Krippendorff, 1980; Weber, 1990; Namey et al., 2007). Analysts also used thematic analysis of students’ responses when appropriate (Auerbach and Silverstein, 2003), allowing for some emergent themes grounded in the data (Glaser and Strauss, 1967; Namey et al., 2007).

Coding of all data was done by one researcher using a blinded coding process. Before being coded, data were de-identified (K.H.) in terms of the relevant curriculum (SSI or control) associated with students’ responses in an attempt to prevent coding bias. Codes were later segregated by corresponding curriculum once all coding was complete. Another researcher coded 5% of the data, and interrater scoring demonstrated good interrater agreement (73%). As an additional measure, the coding
processes and emerging codes were discussed with multiple external researchers (Patton, 2002, pp. 465–466).

Although these were qualitative data from open-response questionnaires, we chose a quantitative analysis due to the large number of small units of texts (1–3 sentences long). Converting qualitative data into quantitative data for analysis is a common practice, especially when data from many participants are collected (Bernard, 1996). Upon completion of the coding, NVivo was used to generate code frequency reports. These reports uncovered coding themes in the data for each question on the questionnaires, separated by curriculum (SSI and Control). Specifically, frequencies were determined “on the basis of the number of individual participants who mention[ed] a particular theme” (Namey et al., 2007, p. 143). Nonparametric two-sample proportion tests were used to compare the frequencies of each code for each question between the two curricula. Differences were deemed significant at \( p < 0.05 \). To highlight the most prevalent themes, we omitted any code that represented less than 5% of the total responses to a particular question for both curricula combined.

**RESULTS**

**Student Demographics**

There were similar numbers of student responders in each curriculum (SSI curriculum: \( n = 443 \); control curriculum: \( n = 418 \)) with similar demographics. The majority of the students reported being between ages 18 and 22 years. The majority of students were female (SSI: 58%; control: 59%) and European or white (SSI: 67%; control: 72%) in both groups. The next most frequently reported ethnicity was Asian or Asian American (SSI: 17.2%; control: 13.9%), while all other race/ethnic origin categories represented less than 10% of the total enrollment in both curricula.

**Response Rates**

The HLM analysis included only those who participated in all three surveys (\( n = 698 \)) in order to assess individuals’ motivation over time. The response rate for completing all three surveys was 72% with no statistically significant differences regarding completion between SSI and control groups. Individual lab section response rates varied from 56 to 86%, with similar low and high rates in both SSI and control groups. Of the 968 students enrolled in the classes at the end of the term, 861 participated in the postterm survey, with an overall response rate of 89% for the three questions on relatedness.

**Curricular Effects Using the Self-Determination Index**

Students in the SSI curriculum had an increased score on the SDI motivational index that was, on average, 1.394 higher \( (F = 12.16; p = 0.005) \) than those in the control curriculum (see Figure 4). This higher score in the SSI curriculum indicates a shift toward more autonomous forms of motivation.

The difference in SDI scores between the SSI and control groups was determined from an average of the lab section scores. Many of the lab sections in the SSI groups had significantly higher SDI scores than the control groups. While there was no difference in SDI scores between SSI and control groups in the preterm surveys, students in the SSI group had significantly higher SDI scores than the control group in both the midterm and postterm surveys (Figure 4). There was a significant effect of time on SDI score over the course of the term \( (F = 13.42; p < 0.001) \), in that students’ motivation in both treatment groups decreased over the course of the term. There was not a significant curriculum by time interaction \( (F = 2.24; p < 0.1073) \).

**Curricular Effects Broken out into Subconstructs**

We also investigated the differences between the SSI and control groups in the four subconstructs 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.

**Autonomous Regulation.** For intrinsic motivation, there was strong evidence of an effect of curricular treatment \( (F = 27.85; p < 0.0001) \) and an interaction between curricular treatment and time \( (F = 2.20; p < 0.01) \). These results indicate that, at the end of the term, intrinsic motivation was significantly higher in the SSI group than in the control group. Compared with the preterm survey, intrinsic motivation was lower in both the control and the SSI groups at both the midterm and the postterm surveys. However, the decrease is significantly less for the SSI group than for the control group. For identified regulation, there is similarly strong evidence of an effect of curricular treatment \( (F = 11.13; p < 0.005) \) but no interaction between curriculum and time \( (F = 2.20; p > 0.1) \). It appears that identified regulation decreased for both treatment groups throughout the term; however, there was a larger decrease in the control group between preterm and midterms in comparison with the SSI group. At the end of the term, students in the SSI group had higher internal regulation than those in the control group.

**Controlled Regulation.** There is strong evidence that there is an effect of curricular treatment on external regulation \( (F = 45.86; p < 0.05) \) but no evidence of an interaction between
curricular treatment and time ($F = 0.82; p > 0.4$). It appears that external regulation changes very little throughout the term for the control group. On the other hand, as time goes by, the external regulation for the SSI group decreases. The SSI group had lower external regulation than the control group at the end of the term.

Amotivation. In general, over time, amotivation increases for both groups. However, the increase is greater for the control group compared with the SSI group. There is strong evidence of an effect of curricular treatment for amotivation ($F = 4.28; p < 0.05$). However, there is no evidence of an interaction between curricular treatment and time on amotivation ($F = 0.53; p > 0.5$). The SSI group had lower amotivation scores than the control group at the end of the term.

Postterm Open-Response Question Coding Results. In the SSI curriculum, fewer students indicated that the lab activities were not relevant to their daily lives or future careers compared with students in the control curriculum (Figure 5; SSI = 30.1%; control = 39.8%; $p < 0.005$). Additionally, more students indicated real-world relevance (SSI = 18.2%; control = 3.2%; $p < 0.001$) or interest (SSI = 12.4%; control = 6.7%; $p < 0.01$) regarding the laboratory activities in the SSI curriculum than in the control curriculum. Another theme that differed between SSI and control curricular groups was a change or affirmation of career goals (SSI = 2.8%; control = 0.5%; $p < 0.01$).

A significantly higher percentage of SSI students than control students described their GTA as excited to teach (SSI = 41% of responses; control = 33%; $p < 0.05$; Figure 6). There was also significantly higher percentage of positive responses concerning GTA quality from students experiencing the SSI curriculum versus the control curriculum (SSI = 57.2%; control 37.3%; $p < 0.01$). Significantly fewer students ($p < 0.01$) in the SSI group (3.2%) described their relationship with their GTA negatively or as nonexistent compared with the control group (7.5%).

The final open-response questions explored themes related to student–student relationships in the context of the laboratory class. There were no significant differences in coded categories related to student–student relationships between student groups receiving the two different curricula (Figure 7; $p > 0.05$).

DISCUSSION

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 may increase their motivation to learn science (Sadler, 2009). Several studies show that SSI interventions provide motivating contexts for learning from a student perspective (Barber, 2001; Sadler, 2004, 2009). Additionally, of more than 200 empirical education studies in which the SDT framework has been applied to investigate educational outcomes or motivational profiles of students, few have focused on undergraduate introductory courses or the effects of curricular innovation on student motivation (Guay et al., 2008). To date, our study is one of the first to investigate undergraduate biology majors’ motivation with regard to an SSI-based curriculum, and, specifically, in
that students experience less of a decrease in autonomous motivation as the term progressed. Yet, given our findings curriculum groups may have perceived their lab courses in this types of student motivation concerning academic activities evaluative light as the term progressed. Yet, given our findings environment are correlated with more controlled motivate (and regulated motivation) concerning awarding of exam near the end of the term, students may feel more external pressure as the time for evaluation of those activities approaches (Wicker et al., 2004). We conjecture that, as a final exam approaches concerns of relatedness with the curricula and GTAs were different between the two students, as previously documented (Darner, 2009, 2014). SDT researchers have found that autonomous motivations are more likely to occur when a student’s need for relatedness, or social connectedness (in addition to competence and autonomy) is adequately fulfilled (Deci et al., 1991). The need for relatedness has been described as needing to feel a sense of social belonging. In the classroom context, the relevance of the learning and student relationships with peers and instructors are particularly important to fulfilling the relatedness need (Ryan and Deci, 2000). The higher positive perceptions of student—GTA relationships was also not an expected finding. More research is needed to further investigate the nuances in the SSI model’s impact on student—instructor interactions. It is possible that the novel inquiry-based methods associated with the SSI curriculum may have been a confounding variable regarding various findings, and especially with respect to perceived GTA enthusiasm and quality. It is also possible that, despite the randomization of GTAs teaching the different curricula, there were one or two more engaging GTAs in the SSI group than in the control group. There were no differences in student perceptions of peer relationships between the SSI and the control curriculum groups. 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. It is possible that the unique setting of the laboratory climate and requirement in both curricula of cooperative interactions with peers ultimately were more powerful predictors of student relatedness than the curricular nuances.

**Implications, Limitations, and Future Directions**

We believe there is practical utility in using a motivational framework to explore and plan for student success. This study

---

**FIGURE 7.** Participant descriptions of peer relationships. Coded student responses to the question asking students to describe their relationships with their peers for the SSI (n = 435) and the control (n = 415) groups. Categories with significant differences between the two curricula determined by the two-sample proportion tests are indicated with asterisks (*, p < 0.05; **, p < 0.01).
may help practitioners identify ways to create learning environments that support students’ autonomous motivations in large introductory courses, namely via SSI-based curricula. Moving beyond studies that simply assess intrinsic and extrinsic motivation, our study additionally provides educators insight into the worth of SSI curricula for nuanced aspects of motivation shown to be critical for student success (i.e., perceived relatedness to curriculum and instructors). Our results indicate that these more proximate SSI curriculum–related outcomes help accomplish the more ultimate goal of functional biological literacy or students’ ability to understand, problem solve, and communicate with regard to timely and complex real-world biology–based problems. Finally, we hope that our study might serve as a methodological model for others doing discipline-based education research, with the novel nested design allowing researchers to attend to potential confounding factors in quasi-experimental design, such as class sections, instructors, and so on.

However, additional methodological limitations to this study must be acknowledged. Most problematic, and alluded to earlier, is that it is not possible to discern from our data which aspect of the SSI curriculum can be credited with the observed student outcomes. Indeed, a number of curricular and instructional aspects that were part of the SSI treatment are known to be associated with positive student outcomes, including real-world relevance of the curriculum, inquiry-based and problem-solving exercises, and the student reflection exercises at the end of each SSI lab. Also, because students were not surveyed after every lab period, our study design did not allow for the analysis of the impact of individual lab modules on student motivation or relatedness with respect to SSI, GTAs, and peers. Ultimately, in considering our study results, the SSI curricular model that we used must be considered as a whole. At the same time, the coded responses of the open-ended survey questions strongly indicate that the contextualized SSI issues had a potentially isolatable effect on student motivation and perceptions of relatedness. Given the voluminous body of research indicating inquiry-based pedagogy and student reflection are “best practices” in promoting student learning, we are hesitant to suggest that further study should be conducted on the potential of SSI devoid of these other strategies.

Additional study limitations pertain to the results around relatedness. It has been suggested by others that a student’s ability to perceive the value in the learning activities depends on the social connections made in relatedness need fulfillment (e.g., Deci, 1992). Yet, as predicted by SDT, it is highly likely that students also felt a greater sense of autonomy when engaged with the SSI curriculum particularly, due to the inclusion of more authentic science activities. More research is needed to ascertain the relationship between relatedness and autonomy and potential overlap between these two needs in impacting student motivation. Regardless, the results of this study support the conceptual framework guiding the hypotheses and research questions (Figure 2) around the connections between autonomous motivations in SDT, the SSI model, and the importance of relevance to increasing motivation. Although we made no direct assessment of the development of functional biological literacy, we have extrapolated that quotes from students regarding their ability to make connections with content and real-world issues and their daily lives indicate a positive outcome and link in the conceptual framework. Future research studies could identify and implement more direct assessments of functional biological literacy along with motivational constructs of SDT related to SSI.

The fact that this curricular implementation took place at a single institution, and thus the subsequent limits to generalizability, must be also acknowledged. Additionally, “treatment diffusion” could have biased this study, given that it took place in the same institution, and students almost certainly shared their experiences in the laboratory curriculum across the control and SSI groups. To control for treatment diffusion effects, a cohort model design could be used in future studies when a new SSI curriculum is implemented in large courses.

Still, given these limitations, we believe that our study, because it is a large quasi-experimental study with the presence of a control group, added to the literature base regarding undergraduate motivation and relatedness in biology and with respect to SSI curricula specifically. We conclude that the use of an SSI curriculum in large introductory biology laboratory courses may yield positive effects on the motivation of students, including buffering a typical decrease in student motivation over the term of a course. This increased motivation and buffering effect could potentially increase students’ success and persistence in biology courses and programs and in attending to pressing issues of great societal import.

ACKNOWLEDGMENTS

We thank the graduate teaching assistants, faculty, and students who participated in piloting the SSI curriculum and filling out the survey instruments. We also thank David Hubert, Ehern Bentz, and two anonymous reviewers who helped greatly in clarifying and strengthening our paper.

REFERENCES


