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Investigating Student Engagement in First-Year Biology Education: A Comparison of Major and Non-Major Perception of Engagement Across Different Active Learning Activities

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Investigating Student Engagement in First-Year Biology Education: A Comparison of Major and Non-Major Perception of Engagement Across Different Active Learning Activities

Abstract

Educational techniques that improve student engagement have repeatedly been shown to improve performance at the class level at many institutions and in multiple disciplines. However, knowledge of engagement in individual activities in large first-year classes, where there may be several sub-populations of students in different programs reflecting varied interests, is limited. In this study, we examined two large, lecture-based, introductory first-year biology classes to determine whether there were any relationships between specific learning activities and student engagement and performance, both at the class level and as broken down by program of study. Surveys were used to quantify the level of student engagement through four activities: (a) student response systems (clickers), (b) in-class discussions and activities, (c) lab and seminar activities, and (d) interdisciplinary learning. Engagement scores were then compared to students' final grades. Students in all majors who reported higher levels of participation in most activities studied also reported feeling more engaged overall and achieved higher grades than their less-engaged peers; however, students in non-biology majors demonstrated notably weaker relationships between their engagement and performance in biology courses, where such relationships existed at all. In this paper, we discuss the learning activities which are associated with the greatest performance increases in both biology and non-biology majors and suggest how these results may be used to inform instructional techniques to benefit all students, regardless of major, in future course offerings.

Il a été maintes fois prouvé que les techniques éducationnelles qui favorisent la participation des étudiants améliorent également les résultats au niveau de la classe, dans de nombreux établissements et dans diverses disciplines. Toutefois, nous savons que la participation est en fait limitée dans les activités individuelles menées dans les très grandes classes de première année, où il peut y avoir plusieurs sous-populations d'étudiants inscrits dans divers programmes qui reflètent des intérêts variés. Dans cette étude, nous examinons deux grandes classes de première année d'introduction à la biologie enseignées par le biais de cours magistraux afin de déterminer s'il existe des rapports entre des activités d'apprentissage spécifiques et la participation et les résultats des étudiants, tant au niveau de la classe qu'au niveau ventilé du programme d'études. Des sondages ont été employés pour quantifier le degré de participation des étudiants par le biais de quatre activités : (a) des systèmes de réponses des étudiants (clickers), (b) des discussions et des activités en classe, (c) des activités en laboratoire et des séminaires, et (d) l'apprentissage interdisciplinaire. Les pointages de participation ont été ensuite comparés aux notes finales des étudiants. Les étudiants de tous les programmes de spécialisation qui ont affiché des degrés de participation plus élevés dans la majorité des activités étudiées ont également rapporté qu'ils sentaient qu'ils avaient été davantage actifs en participation, en général, et ils ont obtenu des notes plus élevées que leurs camarades qui avaient moins participé. Toutefois, les étudiants qui ne poursuivaient pas une spécialisation en biologie ont fait preuve de rapports considérablement moins forts entre leur participation et leurs résultats dans les cours de biologie, là où il y avait même de tels rapports. Dans cet article, nous discutons les activités

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d’apprentissage qui sont associées aux meilleures augmentations des résultats parmi les étudiants qui se spécialisent en biologie et ceux qui poursuivent d’autres spécialisations et nous suggérons la manière dont ces résultats peuvent servir à informer les techniques pédagogiques afin que celles-ci puissent bénéficier à tous les étudiants, quel que soit leur domaine de spécialisation, pour les cours de l’avenir.

Keywords
engagement, learning, first-year, large class, biology

Student engagement refers to the level of effort and involvement in activities related to their studies (Heaslip, Donovan, & Cullen, 2014) and may be defined as the level of attention, interest, curiosity, and passion that a student has for a subject ("Student Engagement," 2016). In recent years, many institutions have become interested in student engagement as a benchmark of education quality and student development (Carini, Kuh, & Klein, 2006; Pascarella, Seifert, & Blaich, 2010). Self-reporting surveys have commonly been used as a tool to assess engagement, typically at the class or institutional level (Carini et al., 2006; Pascarella et al., 2010). One such survey is the National Survey of Student Engagement (NSSE), which focuses on engagement as defined by the time and effort students direct towards their education (Heaslip et al., 2014). These surveys have consistently demonstrated that an engaging curriculum contributes to student success, both personally and academically (Carini et al., 2006; Pascarella et al., 2010; Heaslip et al., 2014).

The relationship between student engagement and student performance in class has been well established in the literature. Students who reported higher degrees of engagement in their classes tended to achieve higher grades (Carini et al., 2006; Handelsman, Briggs, Sullivan, & Towler, 2005), as well as greater success in educational outcomes, including knowledge retention and critical thinking (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Pascarella et al., 2010; Smith et al., 2005). Notably, students who experienced academic success through high levels of engagement during their first year of study were likely to continue to experience academic success in future years (Kuh et al., 2008; Smith et al., 2005). Given the recognized association between student engagement and academic performance, and the acknowledgement that engagement may be low in traditional large-class lectures, many North American institutions have developed alternative educational approaches to augment or supplement lectures (Armbruster, Patel, Johnson, & Weiss, 2009; Cahill et al., 2014; Husband et al., 2015).

Of particular interest is the implementation of alternative teaching approaches in large introductory biological science classes, which have traditionally been focused primarily on content delivery, at the expense of robust interdisciplinary understanding (Husband et al., 2015; Smith et al., 2005). To combat student disinterest and promote depth of understanding, institutions have explored varying approaches designed to improve student engagement, including the incorporation of case studies (Smith et al., 2005), linking courses in interdisciplinary projects (Husband et al., 2015; Murrant et al., 2015), and utilizing student response systems (Addison, Wright, & Milner, 2009; Heaslip et al., 2014). Although each of these methods has been shown to contribute to increased student engagement, selection of appropriate methods depends on several factors, including student needs, the students' relationships with the lecturer, and the subject material being taught (Heaslip et al., 2014; Husband et al., 2015).

Previous studies have largely focused on courses taken primarily by students in biology majors, addressing the course as a whole (Armbruster et al., 2009; Heaslip et al., 2014). When subpopulations within courses are studied, these groups consist of students with different levels of academic achievement (Addison et al., 2009; Jensen & Moore, 2008). Few studies evaluate engagement of non-biology students in biology courses, where active learning approaches such as discussion-based instruction have also been shown to improve student learning (Bernot & Metzler, 2014; Weasel & Finkel, 2016). Furthermore, these studies are focused on courses specifically for non-biology majors (Bernot & Metzler, 2014; Weasel & Finkel, 2016). Considering that a student's background can affect their response to course material, including their feelings of engagement and how much they learn (Cole, Kennedy, & Ben-Avie, 2009), it is important to understand how students with such different backgrounds and interests that they have chosen different majors will be affected by modern teaching approaches in their biology courses.

In this work, we considered two large, lecture-based, introductory biological science courses that included students from majors in biological science, physical science, and several other disciplines. We examined a variety of different learning activities used to promote student engagement using self-reporting surveys, addressing both students' time and effort as suggested by NSSE (Heaslip et al., 2014) and their attention and interest as suggested by the Glossary of Education Reform ("Student Engagement," 2016). Using results from these surveys, we explored differences between sub-populations within classes, in order to confirm the impact of alternative teaching techniques on the class as a whole, and to identify sub-populations in need of additional consideration in the development of new curricula or instructional methodologies.

Literature Review

Of the many activities used by instructors to promote student learning, we selected four that were used in the biological science courses surveyed herein and which have been explored in previous research. In this brief review, we discuss the current understanding of these approaches and their use in biological science courses in other North American institutions, as well as student perceptions of the activities, both positive and negative.

In-Class Discussions and Activities

In-class discussions and activities involving active student participation are forms of active learning. These activities differ from traditional lectures, as students personally contribute to their own learning and engage with their peers, rather than passively absorbing material as presented by the lecturer (Armbruster et al., 2009). Research in biological science courses specifically has found that through in-class discussions and activities, students work through problems or case studies and apply learned concepts to find solutions and to make connections (Cahill et al., 2014; Knight & Wood, 2005; Smith et al., 2005). Most biological science curricula do not entirely replace traditional lectures with active learning, but instead integrate opportunities for discussion or activity into instructional time, with students making predictions about new topics and reinforcing previously discussed concepts (Armbruster et al., 2009; Cahill et al., 2014; Knight & Wood, 2005). A groundbreaking meta-analysis by Freeman et al. (2014) showed that when students engage in active learning in the classroom, they achieve greater academic performance in the disciplines of science, mathematics, and engineering; specifically, analysis of grades on examinations and concept inventories revealed a highly significant increase along with a corresponding decrease in failure rates with active learning as compared to traditional lecture.

Student perception of active learning activities, including in-class discussions and other activities, is mostly positive. Most students, particularly those with higher levels of academic achievement, report higher opinions of classes that incorporated these activities as compared to traditional lecture-based courses (Armbruster et al., 2009; Cahill et al., 2014; Smith et al., 2005). Nonetheless, although many students perceive that active learning techniques eventually improve their learning, they are often resistant to using class time for activities other than lectures (Cahill et al., 2014; Knight & Wood, 2005). This may be because less class time is available to cover new concepts when it is also used to actively solve problems, which means that these activities are often combined with self-study so that the same amount of material can be covered in a semester as in a traditional lecture-based class (Cahill et al., 2014; Knight & Wood, 2005; Smith et al., 2005). Interestingly, students who did not enjoy discussion-based learning typically remained strongly opposed, and often resented feeling “forced” to attend class or work in groups (Armbruster et al., 2009; Knight & Wood, 2005). Students who recognized the benefits of active learning typically experienced both higher class performance and a feeling of having learned and retained more useful information than in traditional lecture-based courses (Armbruster et al., 2009; Cahill et al., 2014; Knight & Wood, 2005; Smith et al., 2005).

Student Response Systems (Clickers)

Student response systems (SRSs) such as iClickers are commonly used in biological science courses and in other disciplines to gain immediate student feedback on topics relating to course material, including assessment of background knowledge, verification of understanding, and review of previously covered material (Addison et al., 2009; Terrion & Aceti, 2012). Such rapid feedback has been shown to effectively allow instructors to immediately address concepts with which their students were struggling (Terrion & Aceti, 2012). When using clickers, biological science instructors typically provide brief opportunities throughout each lecture for students to consider and respond using a handheld clicker remote to questions interspersed with lecture (Addison et al., 2009). Although SRSs are classified as an active learning technique, they have been the focus of independent research and can be clearly identified as a distinct engagement activity. Therefore, they will be considered in this study as distinct from in-class discussions and other in-class active learning techniques.

Student perception of iClickers is mostly positive, with most reporting increased feelings of engagement (Addison et al., 2009; Heaslip et al., 2014; Vaterlaus, Beckert, Fauth, & Teemant, 2012) and greater preparedness for examinations (Addison et al., 2009; Vaterlaus et al., 2012). In some cases, instructors develop clicker questions using the same format as exam questions (Addison et al., 2009; Vaterlaus et al., 2012), which would be expected to enhance students' perception of preparedness. The anonymity of SRSs seems to contribute to the positive perception of this learning activity. Students report being more comfortable answering questions when not at risk of being singled out for providing an incorrect answer, which makes them more likely to participate in the activity (Heaslip et al., 2014; Terrion & Aceti, 2012; Vaterlaus et al., 2012). This benefit was noted to be particularly important for shy and anxious students (Terrion & Aceti, 2012; Vaterlaus et al., 2012), although studies have also shown that students who used SRSs anonymously in group activities still shared answers openly in small groups, actively soliciting feedback (Heaslip et al., 2014; Terrion & Aceti, 2012). Research has shown that when clickers are used properly, there is more active class participation and livelier discussions, even though engaging in full class discussion reduced anonymity (Addison et al., 2009; Vaterlaus et al., 2012).

Not all students, however, have a positive perception of SRSs. Although aggregate responses usually show that SRS usage benefits learning and results in improved grades (Vaterlaus et al., 2012), students with lower academic achievement have been shown to be less likely to find clicker use beneficial (Addison et al., 2009). These same low-achieving students saw less significant improvements in grades from use of SRSs (Addison et al., 2009; Knight & Wood, 2005). This finding suggests that improvements in student engagement and performance may be related to the manner in which instructors utilize SRSs, rather than an inherent impact of any SRS implementation (Addison et al., 2009).

Lab and Seminar Activities

Student learning in the small group setting of a seminar or lab may also be considered active learning, as students often engage in more hands-on activities in these environments (Husband et al., 2015; Murrant et al., 2015; Stang & Roll, 2014). Here, however, we are considering labs and seminars independently of in-class discussions and other active in-class activities due to the notable difference in setting, specifically that lab and seminar sessions are much smaller than lecture sessions, and allow students more direct access to their instructor. Many active learning curricula that have been studied involved making changes to both lecture and lab/seminar activities to promote student thinking and development by eliminating overly-prescriptive “cookbook” labs (Knight & Wood, 2005; Smith et al., 2005). In previously-studied biological science courses, active-learning labs and seminars placed a focus on problem solving and application of knowledge, as well as development of skills which would be useful in future courses and careers (Husband et al., 2015; Murrant et al., 2015; Stang & Roll, 2014). Rather than guiding students through the steps of a specific experiment, these active labs involve more self-directed activities, where students participate in developing the process as well as performing the experiment (Murrant et al., 2015; Stang & Roll, 2014).

Due to personnel limitations, teaching assistants (TAs) often instruct lab and seminar sessions in biological science courses. Interactions between TAs and students have been found to influence learning and promote student engagement in these small group settings, with TA interactions often providing the impetus for students to ask additional questions and further develop their understanding of the material (Murrant et al., 2015; Stang & Roll, 2014). Although different TAs for the same course may interact with students in different manners, the key factor in promoting student engagement appears to be the frequency of TA interactions, which significantly increases student engagement (Stang & Roll, 2014). As discussed previously, student engagement is related to student performance, and the positive effects of the aforementioned TA interactions on student performance in lab activities were also observed (Stang & Roll, 2014). Although there is less support in the literature for these benefits in seminar activities, similarities between lab and seminar environments lead us to expect similar benefits from small-group seminars.

Interdisciplinary Learning

Much like hands-on lab work, interdisciplinary learning has been strongly correlated with increased student success (Husband et al, 2015). Interdisciplinary learning refers to the practice of bringing together students from a range of fields or encouraging students to form links between various fields with which they are familiar (Husband et al., 2015; Murrant et al., 2015; Sawtelle & Turpen, 2016). Students may integrate concepts from various disciplines of biological science (Husband et al., 2015; Murrant et al., 2015) or connect concepts in biology to other fields, such as physics (Sawtelle & Turpen, 2016). Interdisciplinary learning often explores relatively complicated problems or scenarios, as these issues allow opportunities for many varied approaches based on different fields or backgrounds (Husband et al., 2015; Sawtelle & Turpen, 2016; Murrant et al., 2015). Interdisciplinary learning also allows students to make otherwise overlooked connections between fields (Sawtelle & Turpen, 2016; Murrant et al., 2015). Such curricula often include many elements of active learning, such as class discussions and small-group activities (Murrant et al., 2015).

Participation in interdisciplinary learning has been shown to yield learning benefits. Students who engaged in interdisciplinary learning often demonstrate an improved understanding of key concepts in all fields involved (Husband et al., 2015; Murrant et al., 2015). Furthermore, these students were demonstrably aware of their improved understanding, and showed greater confidence in answering questions relating to connections between fields (Husband et al., 2015; Sawtelle & Turpen, 2016). Some students even changed their field of study based on a successful interdisciplinary project that gave them newfound respect for a field or problem (Husband et al., 2015). Students have also been observed to use their understanding in biology to improve understanding of physics concepts (Sawtelle & Turpen, 2016), and their understanding of one discipline of biology to make connections to other disciplines (Husband et al., 2015).

Academic Interests and Students' Attitudes Toward Engagement Activities

There seems to be little in the literature specifically addressing how students' academic interests affect their response to various engagement activities. Although some studies have commented on the particular benefits of various engagement activities to particular groups (Sawtelle & Turpen, 2016; Vaterlaus et al., 2012), there have been no specific studies on undergraduate students of different academic interests in any discipline, much less of students pursuing different majors within the same class. However, what does exist in the literature hints towards a link between students' interests, background, and engagement. Students with experience in internships or undergraduate research are generally more engaged in their studies than students without these experiences, with students putting more effort into activities they find more engaging (Miller, Rycek, & Fritson, 2011). Furthermore, graduate students coming from different universities, or in different areas of study, may have very different attitudes towards group learning activities (Donohue & Richards, 2009). With a wide variety of students present in large, introductory first-year classes, there is a clear need to investigate how to best engage students in these environments.

Summary

All four of the aforementioned learning activities have been found to be associated with many positive outcomes, including improved student performance and positive perceptions of the experience. Some of these approaches, including use of SRSs and in-class discussions and activities, can be implemented in courses without need for a complete overhaul of the curriculum (Addison et al., 2009; Knight & Wood, 2005; Vaterlaus et al., 2012), although others, including incorporation of labs, seminars, and/or interdisciplinary learning, may require greater effort to implement. Despite ample support for the value of these engagement activities, there remains a gap in the literature regarding how students' academic interests affect their responses to these activities, specifically as implemented in biology classes. In this study, we will address the question of student engagement in greater detail in order to determine which learning activities are associated with engagement and performance in both biology and non-biology majors and will suggest how these results may be used to inform instructional techniques to benefit all students, regardless of major, in future course offerings.

Research Questions

In this study, we aim to address the following questions:

1) How are the engagement strategies currently being used in first-year biology courses differentially and cumulatively associated with:

    a. Student perception of engagement in the courses?
    b. Student performance (final grades) in the courses?

2) Are there differences in engagement (overall and broken down by individual strategies) between biology and non-biology majors in first-year biology courses?

We hypothesized that each of the engagement activities investigated will be positively correlated with student perception of engagement, and consequently, with student performance as well. We expect that patterns in non-biology majors may differ from those in biology majors, due to the differences in academic interests between these groups.

Method

Participants

We collected data from students enrolled in two large first-year introductory biology courses at the University of Guelph during the Fall 2016 semester. BIOL 1070 was an introductory biodiversity course, with a focus on evolution, ecology, and organismal biology. BIOL 1070 was co-taught by a pair of instructors in a single lecture section, accommodating 563 students for two 50-minute classes per week. Both instructors were involved in the delivery of course material in each class, frequently transitioning back and forth in lecturing or facilitating activities. BIOL 1090 was an introductory molecular and cell biology and genetics course, with a focus on relationships between structure and function, energy and regulation, and the interrelatedness of life. BIOL 1090 was taught in two six-week segments, with the first six weeks of genetics taught by one instructor, and the second six weeks of molecular and cell biology taught by a second instructor. This course was delivered to 1040 students in two lecture sections, also at two 50-minute classes per week. This study was approved by the Research Ethics Board at the home institution.

Both BIOL 1070 and BIOL 1090 scheduled one 50-minute session per week of small group seminar activities, although this time was not utilized every week. In BIOL 1070, these activities were hands-on and included fieldwork, while BIOL 1090 seminars were exclusively classroom-based. BIOL 1070 classes had a strong focus on active learning techniques, with frequent use of clicker questions and class discussions, while BIOL 1090 classes were run using a traditional lecture style. In the last three weeks of the semester, both BIOL 1070 and BIOL 1090 seminars were used for the interdisciplinary project (IDP), as part of the linked course model described by Husband et al. (2015). In the IDP, students were placed into small groups with participants from other courses, typically consisting of one BIOL 1070 student, one BIOL 1080 (health and physiology – not included in the present study) student, and two BIOL 1090 students. In the IDP, students from all three courses worked together to address a real-world problem relating to the impact of artificial light on humans and the environment from the unique perspectives taught in each class, integrating cell/tissue-, organism-, and ecosystem-level considerations.

Students in BIOL 1070 and BIOL 1090 were evaluated similarly. In BIOL 1070, two multiple-choice midterm examinations (totaling 25%) and one multiple-choice final exam (35%) comprised the majority of students' grades. The IDP was weighted 10%, and the remaining 30% was assessed through seminars, assignments, workshops, and weekly online quizzes. BIOL 1090 was assessed through one midterm (30%) and a final exam (40%), consisting of multiple choice and short answer questions. The IDP was similarly weighted at 10%, and the remaining 20% was assessed through seminars, assignments, and workshops.

Both BIOL 1070 and BIOL 1090 are part of the core curriculum for first-year science majors, of which BIOL 1080 is also a part. Students in biology majors will take all three core 1000-level courses, while students in physical science majors will take at least two of these courses, most commonly BIOL 1090 and one of BIOL 1070 or 1080. These courses are also commonly taken by Engineering majors and non-science majors, in order to fulfil the science electives required by these programs. While the majority of students in both BIOL 1070 and BIOL 1090 are enrolled in a biology program, a significant group of students take these courses to meet requirements, whether that requirement is for the specific course, or simply for a science elective.

Assessment of Student Engagement and Performance

We approached students in BIOL 1070 and BIOL 1090 during the final week of the Fall 2016 semester to introduce the study and invite their participation. Students received a 5-minute presentation during class time and were given the opportunity to ask any questions after class. A 27-question survey was distributed to all students by email and by posting on the BIOL 1070 and BIOL 1090 course websites. To encourage non-biology students enrolled in these courses to complete the survey, we also approached students in IPS 1500, taken exclusively by physical science students, and specifically discussed the relationship between the study and their experience in biology courses. The same survey was sent by email to all students in IPS 1500 and posted on the course website, with instructions for students concurrently enrolled in BIOL 1070 or BIOL 1090 to complete the survey as it pertained to their biology course that semester. The survey accepted responses during the Fall 2016 exam period (Dec. 2 to Dec. 20) and early during the Winter 2017 semester (Jan. 18 to Jan 27). Participants were offered a 1 in 60 chance to win a $25 gift card for on-campus dining halls.

As in previous research, our survey relied on students self-reporting their participation in various engagement activities (Carini et al., 2006; Pascarella et al., 2010). The first five questions in the survey collected basic demographic information, including students' major, course, and student number. We later used student number information in conjunction with class lists to gather the final grades of participants. The next 21 questions asked students to quantify their participation in various engagement activities. Many of these questions used a five-point Likert-like scale to quantify participation, using the categories "always," "usually," "sometimes," "rarely," and "never." Specific questions tracking time spent did not use the Likert-like scale, as this data was already inherently quantitative. Survey questions were designed to capture students' engagement in a similar fashion to the NSSE (Heaslip et al., 2014). The final question asked students to quantify their feelings of engagement on a scale of 1 to 10 for the entire course, using a definition of engagement seen in the Glossary of Education Reform ("Student Engagement," 2016). The complete set of survey questions is included as Supplementary Material.

Data Analysis

In our survey, two to four questions addressed each of the engagement activities examined in this study: clicker questions, activities and discussions during lectures, seminar activities, and the IDP. Each question was scored on an integer scale from zero to four. For questions using the Likert-like scale, each quantifier was directly tied to a numeric value (i.e., "always" = 4, "never" = 0). For questions that did not use the Likert-like scale, higher values were assigned to answers which indicated a higher degree of time was spent on a particular engagement activity. The raw survey results for each student were grouped into four sets of values (student response systems, in-class discussions and activities, lab and seminar activities, or interdisciplinary learning), based on which engagement activity each question was evaluating. The mean value of each set was defined as the engagement score for the associated engagement activity. Students who indicated they did not participate in an engagement activity, or did not answer the associated questions, were assigned a score of 0 for that activity. A total engagement score was also calculated for each student by summing their four individual engagement scores. Note that this total engagement score captures students' participation in activities only and is distinct from the perceived engagement score, which students provided directly using the 1-10 scale.

We defined three groups for our analyses. Like previous studies, we examined trends at the class level (Armbruster et al., 2009; Carini et al., 2006), while also separately examining students who self-identified as biology majors, and those who self-identified as other majors, including physical science majors (chemistry, physics), engineering, and non-science majors. For each group, we performed ten sets of analyses, comparing the four individual engagement scores and the total engagement score to students' perceived engagement and final grade. We also performed an additional analysis, comparing students' perceived engagement to their final grade. Each set of analyses consisted of linear regression to visually determine the strength and direction of correlation, as well as calculation of a correlation coefficient and p-value to quantify the correlation. If the two data sets being correlated were both normally distributed, as determined by the Kolmogorov-Smirnov test, we used Pearson's product-moment coefficient as our correlation coefficient. If one or both of the sets being correlated were not normally distributed, we instead used Spearman's rank-order coefficient. We also performed a Mann-Whitney U test to compare the individual engagement scores, total engagement score, and final grade between the biology and non-biology majors. For all analyses, we used $\alpha = 0.05$, with significant results at $p < 0.05$.

Results

Demographics

In total, 197 students (13% of 1559 invited) completed the survey. Of the respondents, 61% ($n = 120$) identified as biology majors, with the remaining 39% ($n = 77$) identifying as non-biology majors (see Table 1). 47% ($n = 93$) of respondents were enrolled in BIOL 1070, and 53% ($n = 104$) were enrolled in BIOL 1090. 98% ($n = 193$) of respondents answered the final survey question and provided a perceived engagement score, while only 93% ($n = 184$) of respondents provided a student number and had their final grade determined. No significant differences were found between students' participation in engagement activities ($0.42 < p < 0.87$) or their final grades ($p = 0.83$) based on differences in major.

Table 1
Results of Mann-Whitney U Tests[1]

Measure	*U*	*Z*	*p*
Seminar Engagement Score	4290.0	0.26	0.80
IDP Engagement Score	4119.5	0.80	0.42
Clickers Engagement Score	4233.0	0.51	0.61
Class Activities Engagement Score	4359.0	0.17	0.87
Total Engagement Score	4273.0	0.40	0.69
Final Grade	3846.5	-0.21	0.83

[1]No values were significant at $p < 0.05$.

Students' Perception of Engagement

Based on survey data, all of the engagement scores with the exception of the IDP score were significant predictors ($p < 0.05$) of students' perception of engagement (see Table 2), both at the class level (Figure 1) and for individual majors (biological science Figure 2, non-biology Figure 3). The best predictor of students' perception of engagement at the class level was the total engagement score ($r = 0.60$, $p < 0.00001$). The best predictor of perceived engagement differed between majors, with biological science students' engagement being best predicted by the total engagement score($r = 0.69$, $p < 0.00001$), and non-biology students' engagement being best predicted by class activities ($r = 0.50$, $p < 0.00001$).

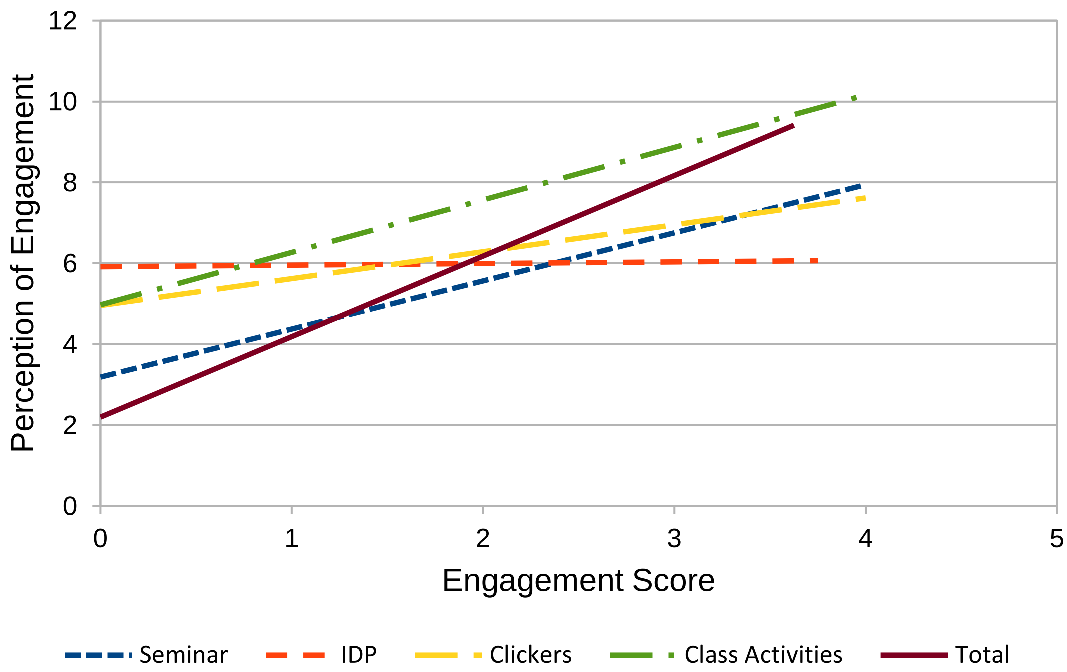

Figure 1. Relationships between engagement scores and student perception of engagement at class level (*n* = 193).

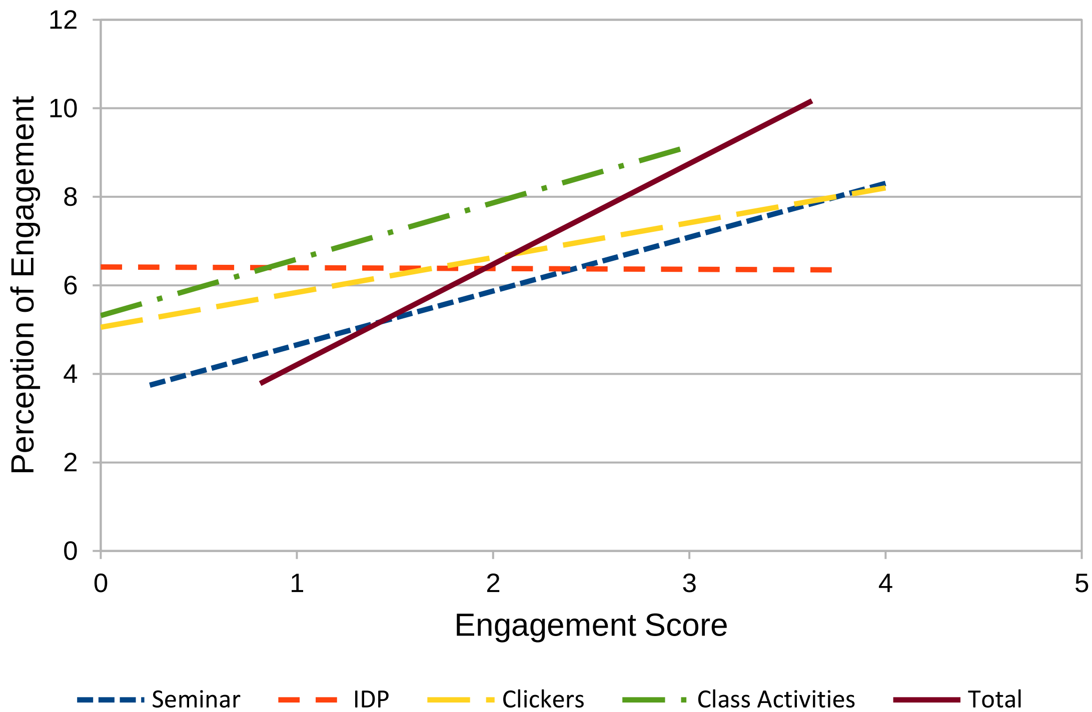

Figure 2. Relationships between engagement scores and students' perception of engagement at for biology students only (*n* = 118).

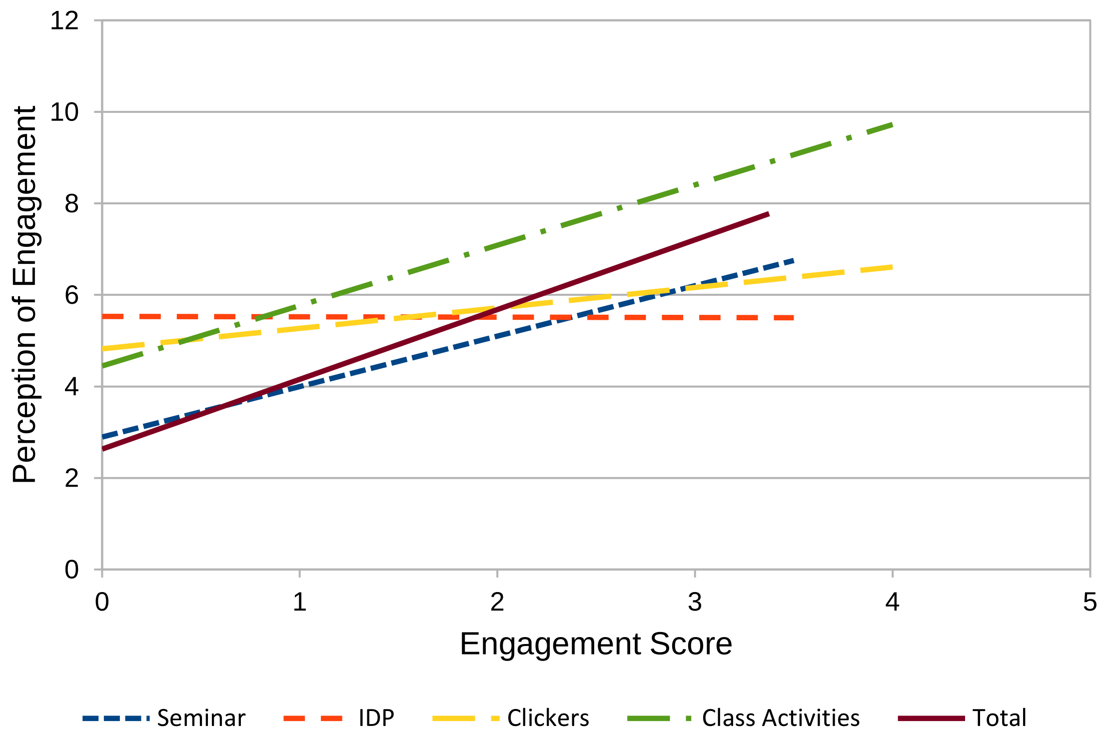

Figure 3. Relationships between engagement scores and students' perception of engagement for non-biology students (*n* = 75).

Table 2
Results of Correlation Analysis for Engagement Scores with Perceived Engagement[1]

Entire Class (*n* = 193)			
Score	*r*	R^2	*p*
Seminar	**0.33**	**0.11**	**< 0.00001**
IDP	0.05	< 0.01	0.49
Clickers	**0.53**	**0.28**	**< 0.00001**
Class Activities	**0.50**	**0.25**	**< 0.00001**
Total	**0.60**	**0.36**	**< 0.00001**

Biology Majors (*n* = 118)			
Score	*r*	R^2	*p*
Seminar	**0.31**	**0.10**	**0.00049**
IDP	0.05	< 0.01	0.62
Clickers	**0.64**	**0.41**	**< 0.00001**
Class Activities	**0.50**	**0.25**	**< 0.00001**
Total	**0.69**	**0.47**	**< 0.00001**
Non-Biology Majors (*n* = 75)			
Score	*r*	R^2	*p*
Seminar	**0.29**	**0.08**	**0.013**
IDP	0.04	< 0.01	0.70
Clickers	**0.36**	**0.12**	**0.00168**
Class Activities	**0.50**	**0.25**	**< 0.00001**
Total	**0.45**	**0.20**	**0.00005**

[1] Values significant at $p < 0.05$ in bold.

Student Performance

All engagement scores, with the exception of the IDP score, were significant predictors ($p < 0.05$) of student performance as measured by their final grade in the course in at least two of the three groups studied (see Table 3). All scores were significant at the class level (Figure 4), while for the biological science students (Figure 5) the seminar engagement score was not a significant predictor of performance ($r = 0.16$, $p = 0.08$), and for the non-biology students (Figure 6) the class activities engagement score was not a significant predictor of performance ($r = 0.22$, $p = 0.06$). The best predictor of student performance was the clicker engagement score, having the strongest correlation with performance at the class level ($r = 0.41$, $p < 0.00001$), for biological science students ($r = 0.41$, $p = 0.00001$) and for non-biology students ($r = 0.42$, $p = 0.00024$).

Table 3
Results of Correlation Analysis for Engagement Scores with Students' Final Grades[1]

Entire Class (n = 184)			
Score	r	R^2	p
Seminar	**0.18**	**0.03**	**0.01**
IDP	0.06	< 0.01	0.42
Clickers	**0.41**	**0.17**	**< 0.00001**
Class Activities	**0.24**	**0.06**	**0.00126**
Total	**0.39**	**0.15**	**< 0.00001**
Biology Majors (n = 112)			
Score	r	R^2	p
Seminar	0.16	0.03	0.08
IDP	0.05	< 0.01	0.62
Clickers	**0.41**	**0.17**	**0.00001**
Class Activities	**0.24**	**0.06**	**0.00973**
Total	**0.40**	**0.16**	**0.00001**
Non-Biology Majors (n = 73)			
Score	r	R^2	p
Seminar	**0.26**	**0.07**	**0.03**
IDP	0.06	< 0.01	0.62
Clickers	**0.42**	**0.18**	**0.00024**
Class Activities	0.22	0.05	0.06
Total	**0.37**	**0.14**	**0.00143**

[1]Values significant at $p < 0.05$ in bold.

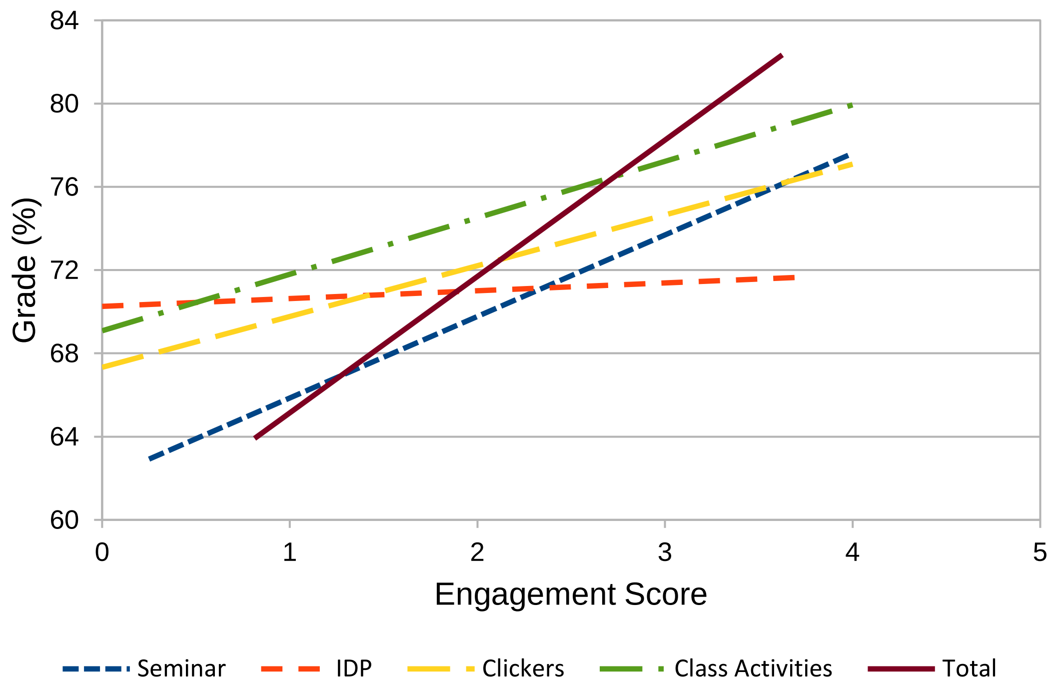

Figure 4. Relationships between engagement scores and students' final grades at class level (*n* = 184).

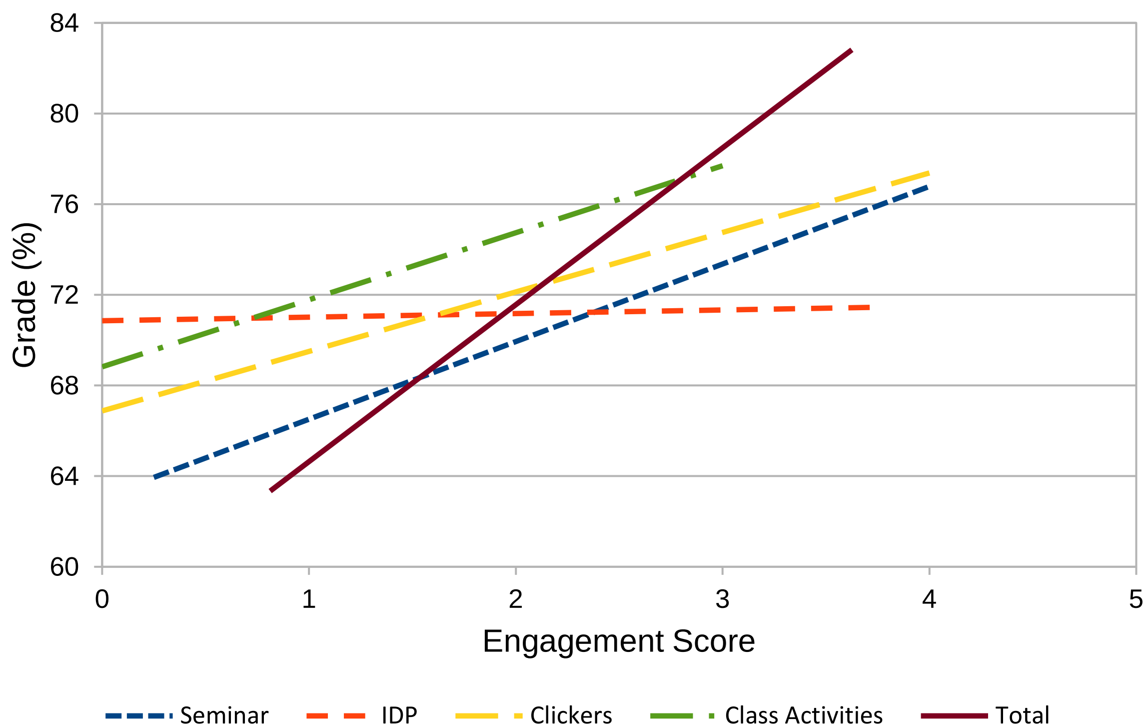

Figure 5. Relationships between engagement scores and students' final grades for biology students only (*n* = 112).

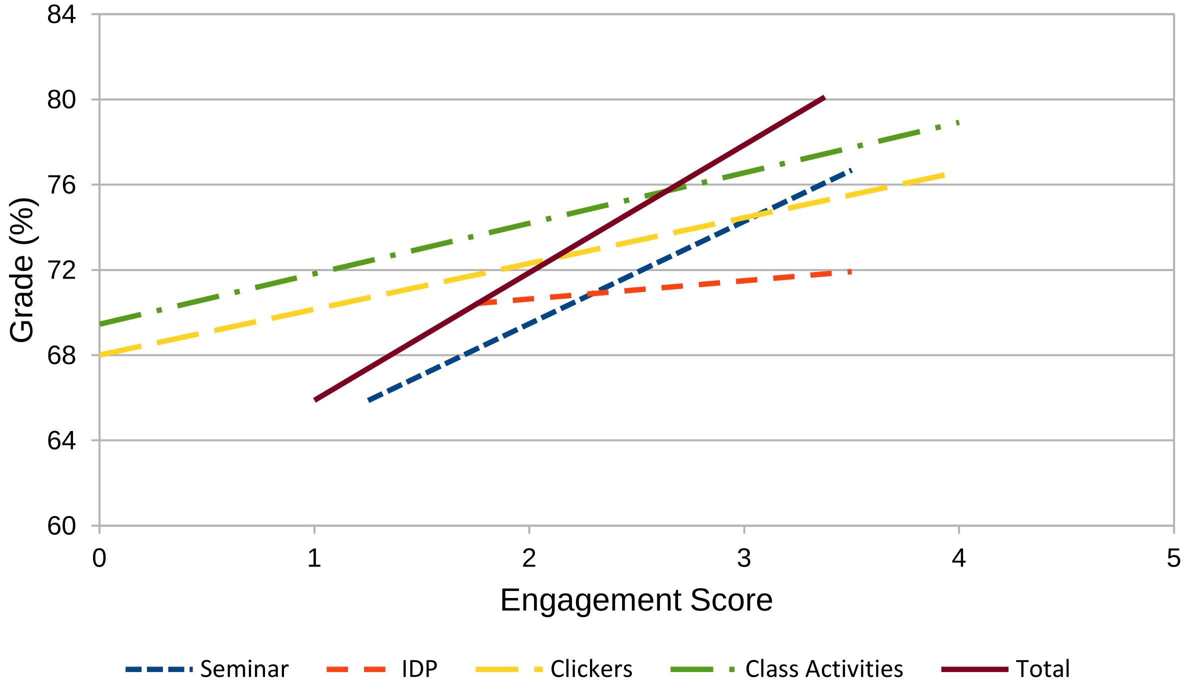

Figure 6. Relationships between engagement scores and students' final grades for non-biology students only (n = 73).

For biological science students, the seminar engagement score was not a significant predictor of student performance; however, a non-significant positive correlation was apparent ($p = 0.08$). Similarly, class activities were not a significant predictor of performance for non-biology students, although a positive correlation is again evident ($p = 0.06$).

Relationship between Perceived Engagement and Performance

Students' perceived engagement was positively correlated to final grade at the class level ($r = 0.33$, $p = 0.00001$) and for biological science students ($r = 0.42$, $p < 0.00001$), as shown in Table 4 and visualized in Figure 7. Although the relationship between perceived engagement and performance displayed a positive trend for non-biology majors ($r = 0.20$), this relationship was not significant ($p = 0.10$).

Table 4
Results of Correlation Analysis for Perceived Engagement with Students' Final Grades[1]

Group	r	R^2	p
Class	**0.33**	**0.11**	**0.00001**
Biology Majors	**0.42**	**0.18**	**< 0.00001**
Non-Biology Majors	0.20	0.04	0.10

[1]Values significant at $p < 0.05$ in bold.

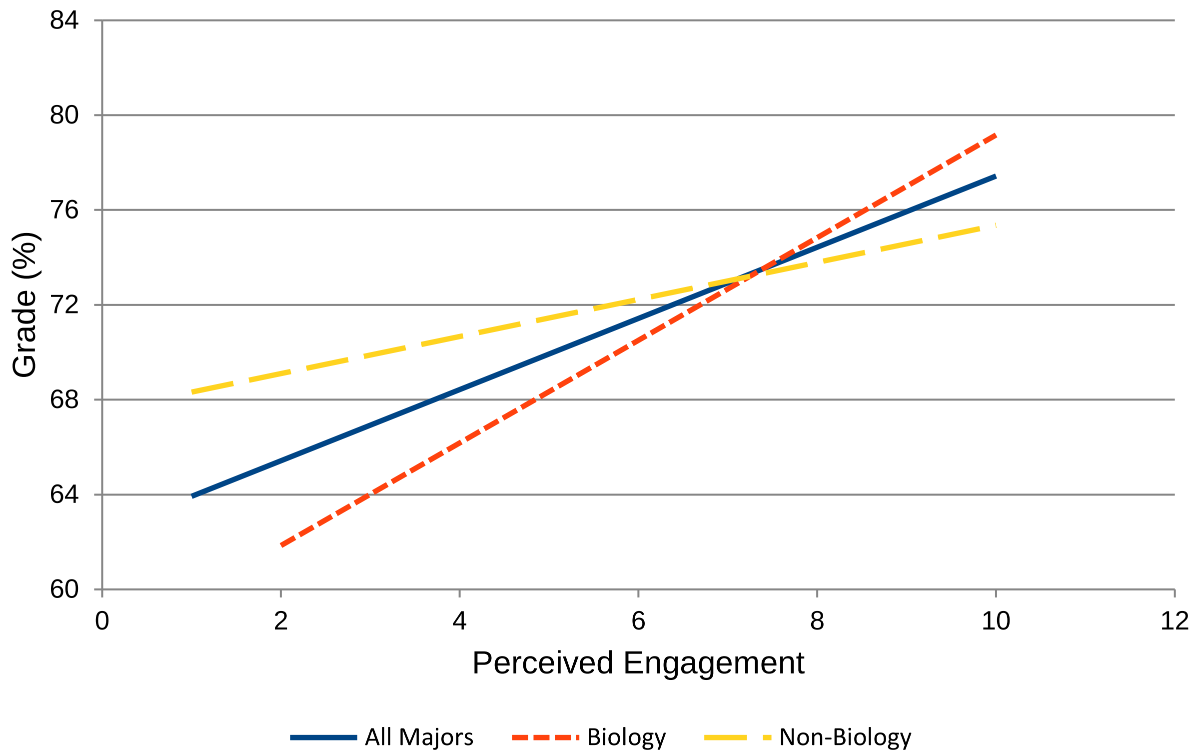

Figure 7. Relationships between perceived engagement and final grade for all three groups.

Discussion

In the present study, we surveyed students in two large first-year introductory biology courses to examine relationships between students' self-reported participation in engagement activities and two outcomes, students' perceived level of overall engagement, and student performance. We also investigated differences in these two outcomes between students in biology and non-biology majors. We found that the majority of our engagement activities were statistically significant predictors of both performance and perceived engagement, with relationships generally being stronger for perceived engagement than performance. We also observed different patterns in non-biology students than biology students, indicating that different subpopulations of students may be best engaged by different instructional techniques, and that relationships in minority subpopulations may be masked by considering only class-level data.

Students' Perception of Engagement

Regardless of major, it is clear from the results of this study that the majority of learning activities investigated herein were significantly and positively correlated with perceived overall engagement in all three groups of students, indicating that these strategies were successful at engaging both biological science and non-biology students. The one exception to this observation was the IDP; here, the activity engagement score consistently failed to display a significant relationship with students' perception of overall engagement. One possible explanation for this discrepancy was the topic of the project. Students in the Fall 2016 semester studied the effects of artificial light on humans and the environment, and it is possible that this group of students simply were not engaged by this topic. Future work should explore multiple IDP topics, in order to control for the effect of the topic on students' perception of engagement.

Since biology majors comprised the majority of students in both courses, it is unsurprising that the best predictors of students' perception of overall engagement were the same at the class level as for biology majors. In both of these groups, we saw that the total engagement score was the best predictor of students' perception of overall engagement, closely followed by the clicker engagement score. We also found a strong correlation between the class activities and discussion engagement score and students' overall perceived engagement. The significant contributions from clickers and class activities indicates that students who regularly attended class and engaged with their lecturer were more likely to also feel engaged by the course material.

The non-biology majors exhibited different patterns than the class level, indicating that patterns in this group may have been masked in previous work that considered relationships at the class level only. For non-biology majors, most engagement scores were weaker predictors of student engagement than at the class level, implying that non-biology students are generally less engaged in biology courses than biology students. Since students in biological science majors typically have stronger interests in biology than non-biology majors, it follows that a less-engaging environment is necessary to allow an interested student to feel engaged. The exception to the pattern of lower engagement scores in non-biology students was the class activities engagement score, which remained a strong predictor of students' perceptions of engagement. These activities are more common in smaller courses, such as physical science and upper-year arts courses at the institution where this study was conducted. Non-biology students who were used to learning through discussion may find these activities more familiar and more conducive to promoting engagement. It should, however, be noted that the inferences drawn from the results of the non-biological sciences group are limited by the small number of subjects in that subsample.

Student Performance and Engagement

As has been well-established in previous work, there is a strong relationship between student engagement and student performance at the class level (Armbruster et al., 2009; Carini et al., 2006). Therefore, it is unsurprising that in this study, most trends at the class level which related activity engagement scores to student performance yielded similar conclusions to those previously discussed for students' perception of overall engagement. Relationships between student engagement scores and class performance were slightly weaker than those between engagement scores and perception of engagement, suggesting that while an engagement score-performance relationship clearly exists, the factors which affect student performance are more complex than simply engagement. Our results are consistent with previous research that showed that student performance was affected by a variety of engagement methods, including active learning, clickers, and group work (Armbruster et al., 2009).

As with the IDP and overall engagement, no group showed a significant relationship between the IDP engagement score and students' final grade. While this finding is initially surprising, as the IDP is directly responsible for 10% of students' grade, the marking scheme for the IDP limits our ability to draw conclusions regarding this association. Since the IDP is a group project, student grades depend not only on how well they understand the material from their own course, but also on the understanding of course material by each of their group members. A student who is very engaged in their own course might perform very well individually on the IDP; however, a less-engaged group member might expend less time and energy on the project, and negatively impact the group mark. With groups of four assigned pseudo-randomly by the teaching team, we expect it to be an uncommon occurrence for all members of a group to be highly engaged in the project. However, we expect that if we were able to compare groups consisting solely of highly-engaged students to groups consisting solely of less-engaged students, that there would be a significant and observable relationship as seen with the other engagement scores.

Other than the IDP, there are only two cases in which we do not see an engagement score as a statistically significant predictor of performance. Seminar engagement score for biology majors was not a statistically significant predictor of final grade ($p = 0.08$), although the trendline in Figure 5 does show a positive correlation. Similarly in the non-biology students, the class activities engagement score was not a significant predictor of grade ($p = 0.06$), with a positive correlation shown by the trendline in Figure 6. In both of these cases, we believe that the lack of a significant relationship is due to insufficient sample size, as the magnitude of the correlation coefficient is similar to that of the class level, where both seminar engagement and class activities engagement were significant predictors of student performance.

In all three groups studied, the best predictor of student performance was the clicker engagement score. Clicker questions were similar to the multiple-choice midterm and exam questions featured in both BIOL 1070 and BIOL 1090, and students who spent time and effort on these questions, and used them as a study tool, may have been better prepared to answer similar questions on their examinations. As discussed previously, engagement in clicker questions has also been linked to student interaction with the material and the lecturer, which may have other links to student performance. Since some lecturers used clicker questions as a means of directing their explanations in class, students who participated in clicker questions may have also been more likely to experience benefits from attending class than students who did not participate, demonstrating an indirect link to improved performance. Future work should investigate the role of clicker questions more closely by carefully controlling for variables such as lecture style, course content, and evaluation methods, to more fully understand the link between clickers and student performance.

When we subdivided the class into biology and non-biology majors, we observed a stronger positive relationship between engagement and performance in the biology majors. The non-biology students did not display a significant relationship, despite an observed positive trend. This is unsurprising given the greater discrepancy between the best predictors of engagement and performance in non-biology students: the class activities engagement score, while the best predictor of non-biology students' perceived engagement, was not a significant predictor of their performance. It would be instructive for future work to examine this relationship more closely, and with a larger sample size, to determine if a significant relationship does in fact exist, and to what degree the two measures are correlated.

Practical Applications and Future Research

The data presented clearly indicated that many of the engagement strategies discussed had direct and measurable effects on both student engagement and performance. The consistently high correlation between the total engagement score and both students' perceived overall engagement and performance indicates that a combination of engagement activities was beneficial to students, and that future course offerings should continue to utilize a variety of methods to promote student engagement. Especially in relation to student performance, the clicker engagement score was a significant predictor. Future work should examine the relationship between these engagement activities and students' outcomes, and attempt to determine which of these relationships are causally related.

The single non-significant engagement score, the IDP score, merits further investigation. While it was surprising that there was no observable relationship between IDP engagement and students' perceived engagement and performance, it is important to remember that the key benefits of the IDP and interdisciplinary learning relate to building skills and making connections between fields (Husband et al., 2015). Because the current work examined only a single topic for interdisciplinary learning, and took place so early in the students' academic careers, we cannot conclusively say that the IDP did not impact student learning. Perhaps different results might be seen in winter semester courses, when first-year students have gained greater course experience and are better prepared for interdisciplinary learning, or in upper year courses. And other benefits to IDP participation are possible; for example, the IDP experience may cause students to feel better prepared for their upper-year classes as a result of the strong interdisciplinary basis that the IDP fosters. Further research is needed, following a cohort of students through to their upper year courses, in order to fully understand the impact of the IDP on student learning.

The results of this study have important implications for course design and assessment. As student engagement in the classroom is obviously a priority for the majority of educators, the use of engagement activities is broadly recommended as a means of achieving this goal. However, what the present study demonstrates is that, at least in some contexts, different engagement activities are perceived as resulting in variable engagement by students, although the overall level of engagement seems to reflect an accumulation of engagement in a multitude of activities. Therefore, courses should be designed to incorporate a variety of activities whenever possible, and should prioritize those activities that have been shown to yield maximum engagement, such as clickers. Although future research in this area is warranted, the present study also suggests that labour- and resource-intensive activities, such as the interdisciplinary project, may not need to be included. Moreover, as this study demonstrates that the perception of engagement across different engagement activities may differ between majors and non-majors, the inclusion of a variety of engagement activities may be especially important to engage the broad cohort of students in classes which include students from different majors and with a variety of academic interests.

While the current study has focused only on students in biological science courses, there is no reason to believe that the differences in student responses to engagement strategies are limited to this type of course. It would be quite surprising if such differences between majors and non-majors were limited only to certain courses. Future work should investigate other large first-year courses in other disciplines, such as chemistry, mathematics, physics, and the social sciences, to verify that such differences remain apparent. These investigations in different disciplines would also allow for comparisons between course types – e.g., do biology students always respond in the same way to the same engagement strategies, or does the best way to engage this cohort of students vary depending on the type of material being taught? By building a more complete understanding of how students respond to engagement strategies across a wide range of majors and subjects, such studies have the potential to drastically transform post-secondary education.

Limitations

Although our results were derived from a sample of nearly two hundred students, this comprised only a small proportion of the student enrolment in both biology courses. Furthermore, because our sample was not randomly selected, and consisted entirely of students who chose to complete the survey, there is risk of systemic error due to volunteer bias, where students with certain characteristics, such as good class attendance, are more likely to choose to participate. Future studies might improve student response rate by providing stronger incentives for participation, such as 1-2% of the final course grade being assigned based on study participation, although such incentives are not always allowed by research ethics boards. Previous studies using stronger participation incentives have achieved response rates as high as 80% (Terrion & Aceti, 2012). Another confounding factor exists in our analysis: we grouped BIOL 1070 and BIOL 1090 students together in a single sample for analysis, despite the difference in teaching styles, in order to improve statistical power and produce an aggregate group representative of biology education as a whole, rather than individual courses. A consequence of this aggregation is that BIOL 1070 students were overrepresented in our sample, representing close to half the respondents while only composing one third of the total population. We believe that this overrepresentation was due to greater enthusiasm from BIOL 1070 instructors than BIOL 1090 instructors for study participation. As the incidence of engagement activities was much higher in BIOL 1070 than BIOL 1090, it is possible that increased response rates from BIOL 1070 introduced bias into our results. However, when we examined BIOL 1070 and BIOL 1090 separately, the majority of trendlines were similar to those seen in the aggregate data set (data not shown). Larger data sets derived from an increased response rate would allow us to analyze each course separately and improve the reliability of our conclusions.

As with many educational studies, our observational study design was unable to suggest any causal relationships between engagement activities and students' perception of overall engagement or between engagement activities and student performance. While we do suggest that relationships exist between our variables of interest, we are unable to comment on whether one variable influences another, or whether several variables of interest are influenced by other unstudied variables. Conducting future studies immediately preceding and following changes in course delivery, such as those from curriculum redesigns or changes in instructor, could provide stronger evidence for a causal relationship, if one exists.

Conclusion

From our survey of students in two large first-year introductory biology courses, we found that the majority of engagement activities studied were statistically significant predictors of both performance and students' perception of engagement, with stronger relationships for engagement than performance. Differences in best predictors of engagement between subpopulations of students indicate that students pursuing different majors are best engaged by different instructional techniques, and that no one engagement activity has consistent benefits throughout different student groups. As researchers, this information is important in interpreting the results of previous studies examining engagement at the level of the entire class; class-level benefits may be apparent if a large subpopulation of students is positively impacted by a particular engagement strategy, but this improvement may mask a lack of impact on students in other subpopulations who may be better reached by a different strategy. As instructors, this information is valuable in curriculum and activity planning, encouraging the development and use of a wide variety of engagement activities in the classroom to maximize the benefit to all students. By continuing to build engaging and interactive curricula at all levels of post-secondary education, using a combination of teaching techniques beneficial to students in particular subject areas or programs of study, we can build a stronger foundation for continued success in teaching and learning in the university environment.

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