RESEARCH ON LEARNING

Measuring Student Motivation in an Introductory Biology Class

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Abstract

Student motivation is widely regarded as an essential prerequisite for learning and success. To learn more about biology student motivation and how it changes over time, pre/post-surveys were administered to a large introductory biology course during the fall of 2015. These pre/post-surveys contained motivation subscales from the Intrinsic Motivation Inventory (IMI) and the Motivated Strategies for Learning Questionnaire (MSLQ). Although students began the course with high levels of motivation, the pre/post-survey scores revealed that their intrinsic motivation, self-efficacy, and value scores declined during the semester. The value/usefulness (IMI), pressure/tension (IMI), and test anxiety (MSLQ) pre-survey scores were the best predictors of course performance. The implications of these findings and suggestions for improving student motivation are discussed.

Key Words: *Motivation; IMI; MSLQ; biology student; anxiety; value.*

○ Introduction

Motivation is an internal impetus or drive to do a specific action or behavior (Ryan & Deci, 2000). Instructors strive to motivate their students so that they will be interested and engaged during class and will continue valuing the material well into the future. Achieving high motivation in the classroom leads to higher levels of understanding (Vansteenkiste et al., 2005a, b), creativity (Koestner et al., 1984), productivity (Dolmans et al., 1998; Das Carlo et al., 2003), and achievement (Boggiano et al., 1993; Moulaert et al., 2004; Sobral, 2004). Together these positive outcomes make motivation one of the most important elements of learning (Carl Wieman Science Education Initiative, 2013).

Because different motivations are required for student success in different disciplines (Breen & Lindsay, 2002), biology instructors may wish to pay special attention to studies involving biology students' motivation. At the college level, studies have examined both biology majors (Lin et al., 2001; Armbruster et al., 2009; Glynn et al., 2011; Hollowell et al., 2013; Johnson, 2013; Ainscough et al., 2016) and nonmajors (Baldwin et al., 1999; Wilke, 2003; Glynn et al., 2007, 2009, 2011; Lawson et al., 2007; Armbruster et al., 2009; Partin et al., 2011; Ainscough et al., 2016). Studies of biology student motivation have also been performed on primary school (Sturm & Bogner, 2008; Shihusa & Keraro, 2009; Meyer et al., 2015), middle school (Hong et al., 1998), and high school students (Torres, 1994; Sungur & Tekkaya, 2006; Hulleman & Harackiewicz, 2009; Ekici, 2010; Shumow et al., 2013; Walls, 2012). The main goal of these studies was to investigate student motivation and link it to performance and achievement (Torres, 1994; Baldwin et al., 1999; Lin et al., 2001; Glynn et al., 2007, 2009, 2011; Lawson et al., 2007; Partin et al., 2011; Walls, 2012; Hollowell et al., 2013; Johnson, 2013; Ainscough et al., 2016). Several of these studies also evaluated the effectiveness of different teaching approaches (Wilke, 2003; Sungur & Tekkaya, 2006; Armbruster et al., 2009; Shumow et al., 2013) or educational interventions (Sturm & Bogner, 2008; Hulleman & Harackiewicz, 2009; Shihusa & Keraro, 2009; Meyer et al., 2015). When it comes to measuring biology student motivation, most studies have used the Intrinsic Motivation Inventory (Sturm & Bogner, 2008; Meyer et al., 2015), the Motivated Strategies for Learning Questionnaire (Lin et al., 2001; Wilke, 2003; Sungur & Tekkaya, 2006; Partin et al., 2011; Johnson, 2013), the Biology Lesson Motivation Questionnaire (Ekici, 2010), the Biology Self-Efficacy Scale (Baldwin et al., 1999; Ainscough et al., 2016), or the Biology Attitude Scale (Partin et al., 2011).

Existing motivation research has done much to advance the field, but it also offers several caveats for biology instructors who wish to measure and improve motivation in their classrooms. First, motivation has been shown to vary within and between classes (Crede & Phillips, 2011). While there exists a rich and growing body of research on biology student motivation, additional studies are needed to gain a more complete understanding of student motivation in certain classes, including undergraduate introductory biology classes for biology majors. Second, it can be challenging for instructors and researchers to select a motivation instrument, as existing motivation instruments are based on different theories

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and measure different aspects of motivation. Although these instruments measure similar or partially overlapping metrics, it is unclear whether different instruments would yield different results if applied to the same student cohort. Lastly, most motivation studies survey student motivation only once during the semester, so it is unclear how student motivation changes over time.

The present study was designed to address these issues by using multiple motivation instruments on the same biology students two times during the semester. The instruments used were the Intrinsic Motivation Inventory (IMI) and the Motivated Strategies for Learning Questionnaire (MSLQ). These instruments were selected because they address multiple metrics related to motivation (e.g., self-efficacy, value, anxiety), have similar subscales that could potentially be compared, and have been thoroughly validated and in widespread use for decades. This is the first study that directly compares results from these two motivation instruments.

The primary goal of this study was to measure biology student motivation over the course of the semester and see whether motivation scores were correlated with student performance. This goal was accomplished by assessing student motivation during the first and last weeks of the semester to monitor any changes in motivation and to determine whether any motivation subscales predicted student performance. A secondary goal was to compare the results from two well-known, well-validated motivation instruments, the IMI and the MSLQ. If these instruments were found to be comparable, it could make it easier to compare data sets from IMI and MSLQ studies and form generalizations about the latent variables that underlie student motivation. If the instruments produced different results, biology instructors and researchers could weigh the pros and cons of each for use in their classrooms.

Course Context

This study's cohort consisted of biology majors (n = 112) enrolled in an introductory biology course at a large Midwestern R1 university during the fall of 2015. The class was 56% female and 71% white. Most of these students were in their second semester of college. The course meets in an active-learning classroom (see http://www.classroom.umn.edu/projects/alc.html) for three two-hour sessions each week. During the semester students explore diverse topics including the nature of science, biomolecules, cells, the central dogma of biology, evolution, genetics, and biotechnology.

○ Methods

The Instruments

The IMI (Ryan et al., 1983) is based on self-determination theory and is primarily used to assess self-reported motivation and self-regulation. The full inventory contains 45 items distributed across seven subscales. Experimenters are encouraged to use only subscales that relate to their experiments (Ryan, 1994), and they are also able to modify individual items in order to fit the needs of their particular study (Choi et al., 2010).

In contrast to the IMI, social cognitive learning theories (McKeachie et al., 1986; Crede & Phillips, 2011) were used to design the MSLQ to assess undergraduate motivation and learning strategies. The MSLQ contains 31 items designed to assess college students' motivation and an additional 50 items to assess their learning strategies (Pintrich et al., 1991). As with the IMI, subscales can be used either together or in isolation and experimenters are encouraged to use subscales that are most relevant or practical for their research questions (Pintrich et al., 1993; Duncan & McKeachie, 2005).

Creating the Survey

Studies on motivation routinely measure several motivation-related metrics, including intrinsic motivation, extrinsic motivation, self-efficacy, and value (Pintrich et al., 1991; Ryan, 1994). Intrinsic motivation involves internal interest, satisfaction, curiosity, and fun (Deci et al., 1991; Pintrich et al., 1991). By contrast, extrinsic motivation involves external rewards or punishments such as grades, extra credit, prizes, and deadlines (Deci et al., 1991; Pintrich et al., 1991). *Self-efficacy* refers to a student's belief that they can succeed at a given task, whereas *value* represents the student's judgment about the usefulness of a given task (Pintrich et al., 1991; Partin et al., 2011).

To create the motivation survey used in the present study, items were pulled from several subscales of the IMI and MSLQ. The subscale pairs compared here include intrinsic motivation (IMI) and intrinsic goal orientation (MSLQ), self efficacy (IMI) and perceived confidence (MSLQ), value (IMI) and task value (MSLQ), and pressure/tension (IMI) and test anxiety (MSLQ). All Likert items within each subscale were included. A total of 22 items were pulled from the IMI and 23 items were pulled from the MSLQ. Example items and the number of items in each category can be seen in Table 1. Answer choices for each item were scored on a seven-point Likert scale that ranged from "not at all true" to "very true." All items were slightly altered from the originals so that they focused on the molecular and cellular biology parts of the class. In addition, item tense was altered to make a pre-survey and a post-survey. For example, the "I enjoyed doing this activity very much" IMI item became "I will enjoy doing Molecular and Cellular Biology very much" on the pre-survey and "I enjoyed doing Molecular and Cellular Biology very much" on the post-survey. Minor alterations such as these are allowed and encouraged to meet the needs of the instructor (Ryan, 1994; Duncan & McKeachie, 2005; Muis et al., 2007; Choi et al., 2010). The complete pre/post-surveys are available in the Supplemental Material with the online version of this article.

Data Collection

Students were informed via email and in class that the pre/post-surveys would help the course instructors to better understand their motivations. The surveys were completely voluntary and anonymous. Students who completed both surveys were awarded seven extra credit points, regardless of whether they consented to include their data in this study. Students were told that their answers would not negatively affect their grade, as the data would not be analyzed until after final grades were submitted. The pre/post-surveys were administered online during the first and last weeks of class, respectively. Students were asked a control question to help ensure they were not answering randomly. The survey items were presented in a random order for each student. All student data were collected, stored, and analyzed per the recommendations of the university's Institutional Review Board.

Table 1. Example items for each subscale, taken verbatim from the original Intrinsic Motivation Inventory (IMI) and Motivated Strategies for Learning Questionnaire (MSLQ) surveys, with total number of items (n) asked from that subscale on the pre/post-surveys.

	IMI		MSLQ	
Subscale	Example	n	Example	n
Intrinsic	I enjoyed doing this activity very much.	7	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	4
Self-efficacy	I think I am pretty good at this activity.	6	I'm confident I can do an excellent job on the assignments and tests in this course.	8
Value	I think this is an important activity.	4	It is important for me to learn the course material in this class.	6
Anxiety	I felt very tense while doing this activity.	5	I feel my heart beating fast when I take an exam.	5

Preparing the Data

The collected student pre/post-survey data were linked with student cumulative GPA, ACT scores, and demographics data (sex, ethnicity, year in school, age, and major). Data were analyzed only for students who gave consent, answered the control question correctly, and completed both surveys in their entirety. Of the 130 students in the class, 112 met these criteria. IMI items 11, 12, 21, 22, and 24 needed to be reversed before subscale totals could be calculated; this was done as previously described (Ryan, 1994). A 0–6 Likert scale was used for all items so that a completely unmotivated student would receive a zero.

Aggregated variables were created representing four IMI and four MSLQ subscales mentioned above. Student data for each subscale were aggregated, averaged, and converted to a percentage for ease of interpretation. Many students were acutely aware of their course performance at the time the post-survey was conducted, so the perceived confidence (IMI) and self-efficacy for learning and performance (MSLQ) subscales were left out to avoid confounding this analysis.

Reliability

Cronbach's alpha statistics were calculated for each of the IMI and MSLQ dimensions (Table 2). These Cronbach alpha values indicate that the internal consistency within these scales ranged from acceptable ($0.8 > \alpha \geq 0.7$) to excellent ($\alpha \geq 0.9$).

Table 2. Cronbach's alpha statistics for each of the Intrinsic Motivation Inventory (IMI) and the Motivated Strategies for Learning Questionnaire (MSLQ) dimensions.

Instrument	Subscale	Cronbach's α
IMI	Intrinsic motivation	0.918
	Self-efficacy	0.883
	Value	0.885
	Pressure/tension	0.843
MSLQ	Intrinsic goal orientation	0.803
	Confidence	0.903
	Task value	0.885
	Test anxiety	0.717

○ Results

IMI & MSLQ Pre/Post-Survey Results

Student pre/post-survey scores for the eight subscales used in this study are shown in Figure 1. Scores on the pre-survey ranged from 43% on the anxiety subscale (MSLQ) to 82% on the value subscales (MSLQ and IMI). High pre-survey scores were predicted for these students, as this class is the first biology class they take for their major and the students are typically very enthusiastic when they enter the course (B. Gibbens, personal observation). Despite this, student scores on the intrinsic motivation, self-efficacy, and value subscales declined during the semester. The pre/post-survey scores and the amount of decline were both very similar between comparable MSLQ and IMI subscales (Figure 1). For example, student self-efficacy scores declined by 13% on the IMI and by 12% on the MSLQ.

Predictive Analysis

An ordinary least squares (OLS) regression analysis was conducted to determine which motivation scores, if any, predicted overall student performance in the class. Each student's final course percentage was used as a metric for their overall course performance. The regression results show that value/usefulness (IMI), pressure/tension (IMI), and test anxiety (MSLQ) pre-survey scores were the best predictors of course performance (Figure 2). Scores on the value/usefulness (IMI) subscale positively predicted course performance, whereas scores on the pressure/tension (IMI) and text anxiety (MSLQ) subscales negatively predicted performance.

Separate regression models were constructed to explore the relationship between overall course performance and changes in levels

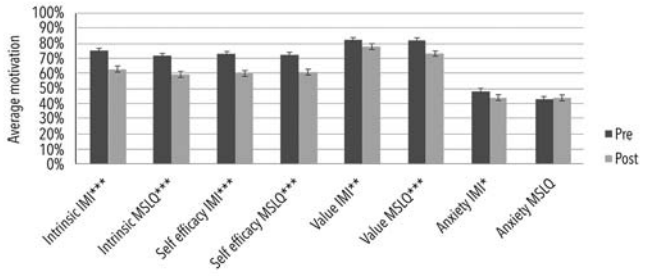

Figure 1. Pre/post-survey scores for the Intrinsic Motivation Inventory (IMI) and the Motivated Strategies for Learning Questionnaire (MSLQ) subscales (100% represents the maximum possible score and 0% the lowest possible score for each subscale). Error bars represent standard error. Asterisks denote significant differences between pre/post-survey scores as determined by paired t-tests (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

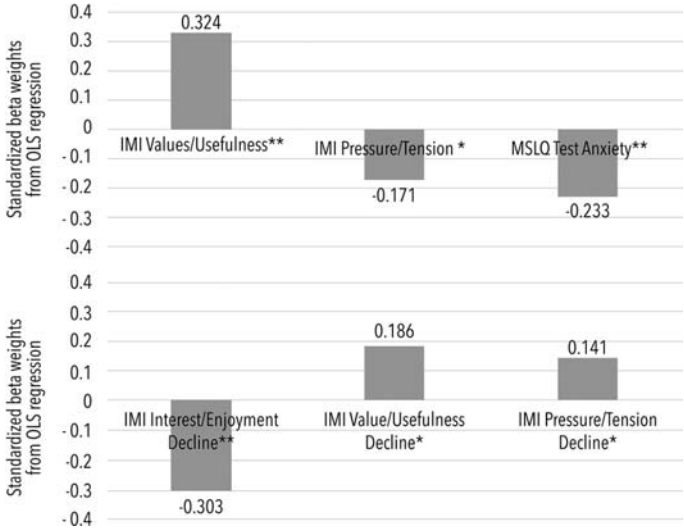

Figure 2. Predicting course outcomes with motivation data: standardized beta weights from ordinary least squares (OLS) regression analyses of student pre/post-survey data. Only subscales that were significantly predictive of course outcomes are shown. (**A**) Pre-survey motivation subscales found to be predictive of student course outcomes. Data were obtained from two separate OLS regression analyses, one conducted using the dimensions of the Intrinsic Motivation Inventory (IMI) as predictors, the other conducted using the Motivated Strategies for Learning Questionnaire (MSLQ) dimensions. (**B**) Changes in the depicted subscale scores (i.e., post-survey scores minus pre-survey scores) either positively or negatively predicted student outcomes. Relative significance is indicated (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

of student motivation over the semester. As expected, declines in the interest/enjoyment (IMI) and pressure/tension (IMI) subscales predicted performance negatively and positively, respectively. Surprisingly, the analysis also showed that the more a student's value/usefulness (IMI) score declined, the better they did in the class. In contrast to the observed IMI pre/post-survey differences, MSLQ pre/post-survey differences did not predict the final course percentage.

○ Discussion

Pre/Post-Survey Results

The primary goal of this study was to measure biology student motivation and see how it changed over the course of a semester. The observed overall decrease in motivation was surprising given the results of previous studies that showed either little change (Tsigilis & Theodosiou, 2003) or an increase in different aspects of motivation (Sungur & Tekkaya, 2006; Cheang, 2009; Van Vliet et al., 2015). One possible explanation is that students simply may not have been as intellectually stimulated by the class as predicted. If students were not interested and engaged in the class, their motivation would be expected to decrease. However, this explanation runs counter to end-of-the-semester evaluations in which most students indicated that the course stimulated their interest in the subject matter (data not shown). A second possibility is that students may enter this course with unrealistic expectations; as students become aware of the class specifics and expectations (e.g., structure, difficulty, work load), they may lose some of their initial enthusiasm. This is especially true for students who are very interested in topics that are not covered in the class. A third possibility is that students have lower scores on the post-survey because it is given during a very stressful time of the semester when students are turning in final projects, giving presentations, and preparing for final exams. This final possibility seems especially likely, as many students feel overworked and fatigued during this time (B. Gibbens, personal observation).

Overall student scores were highest on questions related to value and lowest on anxiety items. This indicates that students cared deeply about the subject matter and that pressure/tension levels were manageable. While student pre-survey scores related to intrinsic motivation, self-efficacy, and value were high for both the IMI and the MSLQ, no ceiling effect was observed.

Biology student scores on different motivation subscales are comparable to what has been seen in other studies done on undergraduate populations. For example, Pintrich et al.'s (1993) study found that students score high on intrinsic goal orientation and self-efficacy subscales (i.e., >5 on a 1–7 point Likert scale) and lower on test anxiety (e.g. 3.63 on a 1–7 point Likert scale). By contrast, the subscale scores in the present study were markedly different from those in studies done on primary and high school biology students. For example, scores on IMI and MSLQ subscales related to intrinsic motivation, value, and self-efficacy were 11–42% higher for the present study's undergraduate cohort than they were for sixth-grade (Sturm & Bogner, 2008) or tenth-grade (Sungur & Tekkaya, 2006) biology students. These differences highlight the importance of academic level, classroom context, and student cohort differences when doing motivation studies. Because motivation is expected to differ in different disciplines (Breen & Lindsay, 2002) and in different classes (Crede & Phillips, 2011), it is recommended that instructors administer motivation instruments on their own student cohorts to establish local norms for comparative purposes (Pintrich et al., 1991).

Student scores on comparable IMI and MSLQ subscales were very similar (Figure 1), suggesting that either survey could be used

effectively to measure biology student motivation and its related metrics. These data also suggest that it may be possible to compare other existing IMI and MSLQ data. However, caution should be taken when comparing results between different IMI and MSLQ studies, as each has its own unique student cohort and each instrument has its own history, uses, and theoretical underpinnings (Pintrich et al., 1991; Ryan, 1994; Duncan & McKeachie, 2005).

OLS Analysis

Previous studies have shown that many of the motivation subscales measured here can be predictive of student performance. For example, other MSLQ studies on biology student motivation have found that intrinsic goal orientation (Pintrich et al., 1993; Lin et al., 2001), task value (Pintrich et al., 1993; Johnson, 2013), and test anxiety (Pintrich et al., 1993; Partin et al., 2011; Johnson, 2013) were predictive of final course grades. By contrast, a meta-analysis on MSLQ studies found that MSLQ subscales only had a weak to moderate relationship to academic performance (Crede & Phillips, 2011). In the present study, the OLS analysis indicated that student pre-survey scores on value/usefulness (IMI), pressure/tension (IMI), and test anxiety (MSLQ) subscales were the most predictive of student course performance. These findings contrast with those of Pintrich et al.'s (1993) MSLQ study, which showed that intrinsic goal orientation and task value were correlated with students' final grades. However, these findings agree with MSLQ studies indicating that task value (Pintrich et al., 1993; Johnson, 2013) and test anxiety are predictive of student performance (Partin et al., 2011).

One of the more curious results of the present study was the finding that the more a student's value (IMI) score declined, the better they did in class. This is counterintuitive because one might expect students' value scores to be correlated with their performance. One explanation is that some students might enter the class with unrealistically high value scores; if students start with unrealistically high scores, they may experience a large score decline while still leaving the class with a high value score. An alternative explanation is that some students may perform well, or poorly, regardless of how much they value a given topic. For example, some pre-med students might realize that they do not value basic biology, but they still strive to perform well in order to be accepted into medical school.

Limitations & Future Directions

While this study yields new insights about biology student motivation, it is not without its limitations. One limitation is that individual survey items were altered slightly from the originals to focus students on the molecular and cell biology portion of the course, and to allow these instruments to be easily administered in a pre/post-survey format. Although researchers are allowed and sometimes encouraged to make minor alterations to IMI and MSLQ subscales (Ryan, 1994; Duncan & McKeachie, 2005; Muis et al., 2007; Choi et al., 2010), it is possible that these changes altered the validity of the subscales used in the present study. Additionally, while the pre/post-survey format allowed student motivation to be measured at the beginning and end of the semester, it remains unknown how student motivation fluctuated during the semester. It is also unclear which aspects of the course were most closely associated with changes in student motivation. For example, it may be enlightening to measure motivation before and after project deadlines or exams. This could be addressed in future studies by examining motivation several times during the semester. While my results show that biology student motivation decreased overall during the semester, it is unknown whether students experienced similar motivation declines in their other courses. Was the observed motivation decline course-specific or more general? The former could suggest shortcomings within the given course, while the latter could suggest problems with course sequencing, credit load, or end-of-semester stress. Future studies could determine how students' motivation in one class is related to their motivation in other courses they are taking. A final limitation is that the anonymous nature of this study made it impossible to track individual students after the study period ended. Consequently, it is unknown whether the observed motivation declines influenced student retention or persistence within the college or major.

○ Conclusion

My results indicate that biology student motivation changed during the semester. Biology instructors or researchers wishing to measure biology student motivation should do so at least twice per semester to show how a given course affects students' baseline motivation. Adding additional timepoints could also be useful for determining which aspects of a given course have the greatest positive or negative impacts on student motivation.

The fact that value/usefulness (IMI), pressure/tension (IMI), and text anxiety (MSLQ) pre-survey scores were predictive of student performance is exciting because it suggests that targeted interventions could be designed on the basis of pre-survey data to improve motivation in different student cohorts. Some simple interventions have already been developed and used successfully in a variety of disciplines (Yeager & Walton, 2011). Similar interventions could enable biology instructors to build on initial student enthusiasm to reduce or even reverse its observed decline over the course of the semester.

Overall, my results indicate that the IMI and MSLQ subscales provide similar, though not equivalent, measures of student motivation and related metrics. These early results are encouraging as they suggest that valuable comparisons could potentially be made between the rich data sets found in the IMI and MSLQ literature. However, additional studies are needed using different classes, cohorts, and institutions to determine typical results for different classes, disciplines, and student populations, and to determine which IMI and MSLQ subscales exhibit the most overlap. Such comparisons are important for answering the ultimate question about which motivation instruments and theories do the best job of capturing and explaining motivation when given a particular set of students, research questions, and circumstances.

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