The Journal of Undergraduate Neuroscience Education (JUNE), Spring 2017, 15(2):A137-A143

ARTICLE
Redesigning a Neuroscience Laboratory Course for Multiple Sections: An Action Research Project to Engage Students

Hsiao-Wei Tu[1] & Brett D. Jones[2]
[1]School of Neuroscience, Virginia Tech, Blacksburg, VA 24061; [2]Educational Psychology Program, School of Education, Virginia Tech, Blacksburg, VA 24061.

The purpose of our action research project was to improve students' motivation in a multi-section introductory neuroscience laboratory course. In this paper, we present: (a) how we collected data related to students' motivation and engagement, (b) how we analyzed and used the data to make modifications to the courses, (c) the results of the course modifications, and (d) some possible explanations for our results. Our aim is not only to provide the results of our study, but also to explain the process that we used, with the hopes that other instructors can use similar approaches to improve students' motivation in their courses. Our attempts to improve students' motivation-related perceptions were successful in some instances, but not in others. Of particular note was our finding that some of the students' perceptions varied even though the course syllabus was the same across sections. We attributed this variation to the learning environment developed by the teaching assistants (TAs) who taught the different sections. We provide some strategies that faculty instructors can use to redesign courses with high enrollments and help TAs motivate their students.

Key words: student motivation; MUSIC Model of Motivation; laboratory course; instructional design; hands-on experience

Laboratory courses that provide hands-on experience have been an essential and distinctive component in science education (Clough, 2002; Hofstein and Lunetta, 1982, 2004). In particular, inquiry-based laboratory activities foster better science literacy and higher self-confidence, which creates more positive attitudes toward authentic research (Brownell et al., 2012; Gormally et al., 2009). Given that the total undergraduate enrollment in degree-granting postsecondary institutions has been gradually increasing every year (Kena et al., 2016), it seems inevitable that colleges and universities will continue to increase the size of introductory science laboratory courses. As enrollment increases and resources become limited, however, hands-on activities can seem less practical and even unmanageable for instructors with large numbers of students in a single course. Although alternatives, such as remote labs and simulations, have been adopted to supplement or replace "wet labs" in life sciences, the effectiveness of learning is highly dependent on how realistic the exercise is and what the educational objectives are (Ma and Nickerson, 2006; Sauter et al., 2013).

We conducted an action research project to implement hands-on lab modules within a large class in a manner that retained the advantages that these authentic experiences provide in science learning. To do so, we redesigned the instruction to transform a small (14 students) introductory laboratory course into multiple sections of the same material led by graduate teaching assistants (GTAs). This "*Neuroscience Laboratory*" was a two-semester course (1 credit each semester) designed to provide hands-on experiences with a range of experimental strategies and techniques used in neuroscience research. The weekly lab exercises were chosen to help students develop the essential skills to design experiments, collect useful data, analyze the results, and make further speculations. It started as a pilot course in preparation for the development of an undergraduate neuroscience program. After the program was approved and became available to students, it was essential to redesign this course to efficiently accommodate the high enrollment without sacrificing the original learning goals.

During the redesign of the course, we conducted an action research project to document the effects of the redesign on students' motivation and engagement. Action research is defined as "a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives" (Stringer, 2007). This method is highly approachable and practical in educational settings to generate knowledge about teaching and improve the quality of student learning (Altrichter et al., 2008). Through identifying a problem, collecting data relevant to solving the problem, analyzing and interpreting the data, researchers are able to reflect on the challenges of their practice and develop an action plan to cope with the problem (Mills, 2011). One of the key elements in action research is to take action. To do so, we extended our research for three semesters, one semester before the program was officially approved and two semesters after it was approved. This allowed us to modify and apply our redesigned instruction immediately after analyzing and interpreting the data that we had collected.

Given that our goal of this present study was to redesign instruction to effectively motivate students in a large lab course, we used the MUSIC® Model of Motivation (abbreviated as the MUSIC model; Jones, 2009, 2015) to gauge students' level of motivation and to make appropriate adjustments in instruction. Based on current theory and research, the MUSIC model consists of five components that quantify students' perceptions related to their instructional environment. Specifically, we ensured that students: (1) felt *eMpowered* by having the ability to make decisions about their learning, (2) understood why the topic was *Useful* for their goals, (3) believed that they could *Succeed* in the course, (4) were *Interested* in the course content and activities, and (5) believed that the instructor and others in the learning environment *Cared* about their learning (MUSIC is an acronym for these key concepts; Jones, 2009, 2015). Other researchers have also used the MUSIC model to examine the motivation of students in higher education courses of various disciplines and formats. For example, the five MUSIC components were measured to identify instructional strategies for improving an online personal health course (Jones et al., 2012), to evaluate students' motivation in problem-based learning capstone engineering courses (Jones et al., 2013), to examine the effects of instruction on students motivation in a psychology course (McGinley and Jones, 2014), and to design courses in an online nuclear engineering curriculum (Hall et al., 2013).

In addition, research has shown that student motivation and class engagement mutually increase each other, leading to higher academic achievement (Jang and Kim, 2012; Reeve and Lee, 2014). To better predict the effects of our redesign on students' engagement, we included measures of behavioral engagement and cognitive engagement. Behavioral engagement includes students' effort related to academic tasks (e.g., persistence, attention), whereas cognitive engagement involves aspects of self-regulation and thinking strategically (Fredricks et al., 2004). In sum, we conducted an evaluation of the course redesign by considering students' motivation-related perceptions and their engagement in the course.

MATERIALS AND METHODS

Context of Study

"*Neuroscience Laboratory*" was a 2000-level, one-credit required course that emphasized creative experimental design, data collection, analysis, and interpretation of the results. A variety of hands-on and simulation exercises were carefully designed to introduce strategies and techniques commonly used in neuroscience research. A brief description of the lab activities can be found as Supplementary Materials. In particular, the lab activities focused on neuroanatomy, electrophysiology, and cellular neuroscience in the fall semester. In the spring semester, the content was more related to behavioral neurobiology, neuroendocrine, and higher level cognitive processes. The lab met once for approximately 3 hours every week. Each lab period began with a 40-minute lecture of relevant concepts, after which students worked in groups of 2-4 to complete the exercise in the remaining time. Informal discussions were carried out during the lab to keep track of students' progress and to brainstorm possible interpretation of the results. Students were graded on attendance, participation, lab cleanup, pre- and post-lab assignments, and a final exam.

The focus of our action research project included 3 semesters (Spring 2015, Fall 2015, and Spring 2016), all designed and taught by the same instructor. The instructor was assisted by 3 graduate teaching assistants and 3 undergraduate teaching assistants (UTAs) in Fall 2015 and Spring 2016 with 1-3 of the TAs assisting in each section. The GTAs were recruited by the Neuroscience Program Director from the Translational Biology, Medicine, and Health Program at Virginia Tech, whereas the UTAs were former students in this course who volunteered in exchange of course credits. None of the teaching assistants had prior teaching experience and all of them were trained by the instructor.

Participants

Students enrolled in the *Neuroscience Laboratory* courses completed the survey during the last lab period in each semester. Demographic information of the students is summarized in Table 1. After being informed of the purpose of the survey, 14 students in Spring 2015 (100% response rate), 92 students in Fall 2015 (94% response rate), and 78 students in Spring 2016 (100% response rate) finished the survey voluntarily and anonymously.

	Spring 2015 (N = 14)	Fall 2015 (N = 92)	Spring 2016 (N = 78)
Major			
Neuroscience	0	80	76
Non-neuroscience	14	11	0
Not specified	0	1	2
Class standing			
Freshman	1	1	1
Sophomore	3	56	48
Junior	4	26	19
Senior	6	8	8
Not specified	0	1	2
Gender			
Female	6	57	49
Male	8	33	27
Not specified	0	2	2
Ethnicity			
White		58	54
Black or African-American		7	4
Hispanic		4	1
Asian or Pacific Islander		11	7
American Indian		0	0
Mixed or Other		8	9
Not specified		4	3

Table 1. Demographic information of the students. The neuroscience degree program was not available in Spring 2015, therefore all students were "non-majors." We did not collect ethnicity data in Spring 2015.

Measures

All items measuring the MUSIC components, cognitive engagement, and behavioral engagement were rated on a 6-point Likert-format scale with the following descriptors: 1 = *Strongly disagree*, 2 = *Disagree*, 3 = *Somewhat disagree*, 4 = *Somewhat agree*, 5 = *Agree*, 6 = *Strongly agree*. The ratings for the items in each scale were averaged to create the total score for each scale.

Perceptions of the MUSIC model components. We measured students' perceptions of the MUSIC model components (i.e., empowerment, usefulness, success, interest, and caring) using the MUSIC® Model of Academic Motivation Inventory (MUSIC Inventory; Jones, 2016). The five MUSIC Inventory scales measure the extent to which a student perceives that: he or she has control of his or her learning environment in the course (empowerment scale, 5 items), the coursework is useful to his or her future (usefulness scale, 5 items), he or she can succeed at the coursework (success scale, 4 items), the instructional methods and coursework are interesting (interest scale, 6 items), and the instructor cares about whether the student succeeds in the coursework and cares about the student's well-being (caring scale, 6 items). An example item from each scale follows: "I had control over how I learned the course content" (empowerment), "In general, the coursework was useful to me" (usefulness), "I was confident that I could succeed in the coursework" (success), "The coursework was interesting to me" (interest), and "The instructor cared about how well I did in this course" (caring). As a measure of the scales' internal consistency reliability, Jones and Skaggs (2016) reported excellent Cronbach's alpha values for each scale: 0.91 for empowerment, 0.96 for usefulness, 0.93 for success, 0.95 for interest, and 0.93 for caring.

Behavioral engagement. We used three of the five items from the Behavioral Engagement scale of the Engagement vs. Disaffection with Learning measure (Skinner et al., 2009) to measure students' behavioral engagement. An example item is: "I tried hard to do well in this course." Reeve and Lee (2014) used these same three items in their study and reported Cronbach's alpha values of 0.82 and 0.80 at two time points.

Cognitive engagement. We measured students' cognitive engagement with the 3-item Metacognitive Strategies scale used by Reeve and Lee (2014) that was based on items by Wolters (2004) and Pintrich et al. (1993) Motivated Strategies for Learning Questionnaire. This scale assesses students' use of metacognitive strategies and an example item is: "In this course, I kept track of how much I understood the work, not just if I was getting the right answers." Reeve and Lee (2014) reported Cronbach alpha values of 0.77 and 0.80 for the scale at two time points.

Instructor and course ratings. One item was used to assess students' overall perceptions of their instructor ("My overall rating of the instructor for this course") and one item was used to assess their overall perceptions of their course ("My overall rating of the course"). Students responded to these items using the following Likert-format scale: 1 = *terrible*, 2 = *poor*, 3 = *satisfactory*, 4 = *good*, 5 = *very good*, 6 = *excellent*. These items are similar to the items included on the mandatory course evaluation forms used at the participants' university and have been used in other studies (e.g., Jones, 2010).

Other items. We included 18 other items in the survey: 8 items assessing students' feedback on general instruction (e.g., "The objectives of each lab were clearly presented."), 5 items for the TAs' performance (e.g., "The graduate TA was helpful during the lab."), and 5 items for the grading system (e.g., "Grading criteria are clear and reasonable."). These items were also rated on a 6-point Likert-format scale like that used for the MUSIC Inventory.

Analysis

Each semester, we calculated descriptive statistics for the five scales in the MUSIC Inventory, the engagement measures, the overall instructor and course ratings, and the other 18 items in the survey. We computed Cronbach's alpha values as a measure of the internal consistency reliability of the scales. We conducted ANOVAs and post-hoc Tukey analyses to compare among the five sections in Fall 2015 and Spring 2016, and we used *t*-tests to determine if there were any differences between consecutive semesters. Because the primary goal of our action research was to redesign instruction to effectively motivate students in a large course, we interpreted the results from each semester and made adjustments accordingly in the following semester, in an attempt to improve the lower scores and change students' perceptions.

RESULTS

Spring 2015

In the Spring 2015 semester, students were asked to respond to only the items in the MUSIC Inventory (no ratings of engagement, instructor, course, and other items). The scores on all five MUSIC Inventory scales were higher than 5 (*Agree*) on a 6-point Likert-format scale (see Table 2). Cronbach's alpha values were all acceptable and ranged from 0.84 to 0.91 (α = 0.88 for empowerment, 0.89 for usefulness, 0.84 for success, 0.85 for interest, and 0.91 for caring). During informal conversations with the instructor, students reported that they found the lab manuals informative and the hands-on activities challenging but enjoyable. Students were able to establish good relationships with each other through the class activities that required data sharing and the open discussions that occurred during lab time. However, about half of the class reported that the grading system was unclear because they were not given a rubric and that they wanted more guidance on their weekly assignments.

Fall 2015

Modifications. Because of a large increase in enrollment in Fall 2015, the class was divided into five sections with about 20 students in each section (*N* = 20, 18, 20, 20, and 20). The general structure and the instructor's teaching style remained the same as in Spring 2015, but specific TAs were assigned to each section. The TAs were trained intensively by the instructor for five days immediately prior to the semester, during which they were familiarized with the learning goals, the experimental procedures, and the grading criteria of each lab exercise. Based on the feedback from the previous semester about the unclear grading system, a general rubric was created and applied to all post-lab assignments, in an attempt to provide more guidance for the students. Specifically, four grading categories were given with descriptions (content: whether you answered all questions; logic: whether your answers make sense; clarity: whether your answers are clear and specific; creativity: whether you think critically and creatively), and each category was worth 15 points (1-3: poor; 4-6: fair; 7-9: average; 10-12: good; 13-15 excellent). Examples of excellent assignments were demonstrated in the first two weeks of the semester. Additionally, the pre-lab assignments were changed from homework to in-lab quizzes on the content of each week's lab exercise to provide students with an incentive to read the lab manual and understand the objectives before working in the lab.

	Spring 2015 (N = 14)	Fall 2015 (N = 92)	Spring 2016 (N = 78)
MUSIC model components			
Empowerment	5.53 ± 0.55	4.43 ± 0.81	4.14 ± 0.98
Usefulness	5.64 ± 0.46	5.13 ± 0.76	4.84 ± 0.67
Success	5.54 ± 0.53	4.48 ± 0.83	4.41 ± 1.11
Interest	5.48 ± 0.59	4.69 ± 0.76	4.32 ± 0.79
Caring	5.65 ± 0.61	4.60 ± 1.16	4.63 ± 1.00
Engagement measures			
Behavioral	NA	5.08 ± 0.72	4.96 ± 0.83
Cognitive	NA	4.71 ± 0.72	4.72 ± 0.68
Other ratings			
Instructor	NA	4.77 ± 1.08	4.91 ± 0.94
Course	NA	4.87 ± 0.71	4.57 ± 0.75

Table 2. Mean and standard deviation (M ± SD) for the study variables.

MUSIC model components. The mean score for each MUSIC model component in Fall 2015 is summarized in Table 2. Cronbach's alpha values were acceptable at 0.82 for empowerment, 0.90 for usefulness, 0.87 for success, 0.84 for interest, and 0.94 for caring. When compared with the previous semester (Spring 2015), the mean values for all five MUSIC scales were significantly lower in Fall 2015, ts > 2.43, ps < 0.05, with the largest decrease evident in the empowerment scale score. When we compared the scale scores across all 5 course sections in Fall 2015, only the usefulness score was significantly different among the five sections, $F(4, 87) = 3.11$, $p < 0.05$, and the difference in the interest score was marginally significant, $F(4, 87) = 2.44$, $p = 0.05$. There was no significant difference in empowerment $F(4, 87) = 0.63$, $p = 0.65$, success $F(4, 87) = 1.61$, $p = 0.18$, or caring $F(4, 87) = 2.03$, $p = 0.10$.

Engagement measures and other ratings. Both engagement measurements were relatively high (Table 2), with behavioral engagement significantly higher than cognitive engagement, paired $t(91) = 4.96$, $p < 0.01$. Cronbach's alpha values were acceptable at 0.78 for behavioral engagement and 0.67 for cognitive engagement. Other ratings, including overall instructor and course ratings, were all higher than 4.5 on a 6-point Likert-format scale, except for the following three items regarding grading: the average was 4.11 for the item "Pre-labs helped me think about the experiments critically," 3.93 for the item "Grading criteria are clear and reasonable," and 4.21 for the item "Comments on the post-labs help me better understand the material."

Spring 2016

Modifications. In the Fall 2015 semester, the empowerment scale (M = 4.43 ± 0.81) and the success scale (M = 4.48 ± 0.83) were the lowest rated among the five MUSIC components, probably because the students were concerned that the TAs' feedback on their assignments was less helpful and that the grading criteria was still unclear, making it difficult to improve their post-lab write-ups. Given these findings, several changes were made in the Spring 2016 semester in hopes of improving students' motivation, including (1) redesigning the questions in both pre-lab quizzes and post-lab assignments to make them less open-ended; (2) specifically tailoring each grading rubric for each weekly write-up (e.g., "Present the mean (2 points) and the standard deviation (2 points) of your data in a table with clear column titles (3 points)"); and (3) retraining GTAs to focus on background reasoning and provide more specific comments in addition to a numerical grade. See the Discussion section for more details on the changes and the students' response.

MUSIC model components. Table 2 summarizes the average score for each MUSIC component in Spring 2016. All five MUSIC scales were still significantly lower than those measurements in Spring 2015, ts > 3.69, ps < 0.01. Surprisingly, despite our modifications, students felt significantly less empowered, $t(168) = 2.13$, $p < 0.05$, and less interested, $t(168) = 3.11$, $p < 0.01$, in the lab compared to the previous semester (Fall 2015). They also felt the material was significantly less useful for their goals, $t(168) = 2.67$, $p < 0.01$. However, the success scale, $t(168) =0.45$, $p = 0.65$, and the caring scale, $t(168) = 0.18$, $p = 0.86$, did not differ significantly between the two consecutive semesters. There was also no significant difference in the MUSIC scales across sections, Fs < 2.26, ps > 0.07. Cronbach's alpha values were acceptable at 0.89 for empowerment, 0.89 for usefulness, 0.94 for success, 0.88 for interest, and 0.91 for caring.

Engagement measures and other ratings. Compared to the Fall 2015 semester, we found no significant difference in students' ratings of behavioral engagement, cognitive engagement, and overall instructor rating, ts < 1.03, ps > 0.30. However, the overall course rating was significantly lower in Spring 2016 than in Fall 2015, $t(167) = 2.64$, $p < 0.01$. Within the current semester, behavioral engagement, cognitive engagement, and overall course rating were not significantly different among the five sections, Fs < 0.42, ps > 0.79, but overall instructor rating was significantly different, $F(4, 73) = 3.03$, $p < 0.05$. Behavioral engagement was still significantly higher than cognitive engagement, paired $t(77) = 2.90$, $p < 0.01$. Cronbach's alpha values were acceptable at 0.79 for behavioral engagement and 0.71 for cognitive engagement.

Moreover, students believed that the objectives of each lab were more clearly presented, $t(167) = 2.44$, $p < 0.05$, and lab manuals were more well-organized and well-prepared, $t(168) = 3.10$, $p < 0.01$. However, four out of five items assessing the TAs' performance, as well as one item regarding the effectiveness of post-lab assignments, were significantly lower in this Spring 2016 semester, ts > 2.13, ps < 0.05.

DISCUSSION

The purpose of this action research project was to redesign a large introductory neuroscience laboratory course to improve students' motivation. The instruction was modified over three consecutive semesters based on students' feedback and ratings on several measures. Major changes, such as the addition of TAs and grading rubrics, made it possible to retain most hands-on lab activities, but at the same time, lowered motivation-related ratings. In addition, some of the students' perceptions varied across sections even though the instructor's teaching style remained the same.

Overall, the quantitative measures (i.e., scores on the MUSIC Inventory and engagement measures) indicated that the course redesign *lowered* students' motivation-related perceptions and engagement instead of increasing them. In essence, the redesigned course appears to have had the opposite effect of what was intended. To explain these unexpected findings, we consider several factors that varied from semester to semester that could have had more of an impact on students' MUSIC perceptions and engagement than the factors included in the course redesign, including: the contribution of the teaching assistants, the feedback to students, and the student composition.

The Contribution of Teaching Assistants

As we noted previously, the course was taught primarily by the instructor in Spring 2015 and then the TAs had more of an instructional role in the course when multiple sections were added in Fall 2015 and Spring 2016. Given the size of the classes in Fall 2015 and Spring 2016, the TAs were highly relied on for answering questions and helping students troubleshoot throughout the experimental procedure. Therefore, during the limited training time (five days immediately before the semester began in Fall 2015 and 3 hours per month during Spring 2016), the instructor focused on giving a comprehensive interpretation of the material and supervising the TAs went through each lab module in order to identify the difficulties students may encounter. However, it appears that the amount of training was not enough for the TAs to familiarize themselves with the material and for them to be confident when interacting with students; only three of the TAs had enrolled in the course previously, which could have made the others even less confident in their mastery of the course content. Students reported that information given by the instructor and by the TAs was usually inconsistent, which oftentimes confused them and resulted in low success scores in Fall 2015 and Spring 2016, as compared to Spring 2015 when the instructor was the sole source of guidance.

Furthermore, the TAs' lack of prior teaching experience greatly reduced the quality of their interaction with the students. For example, when the students made a procedural mistake or obtained unexpected results, the TAs preferred to directly provide a solution, instead of encouraging the students to think critically and derive their own answer as the instructor had done in Spring 2015. We believe this is the main reason for the low empowerment score observed in Fall 2015 and Spring 2016 when the TAs played a major role in establishing the learning environment. It may have also contributed to the fact that behavioral engagement was significantly higher than cognitive engagement in both semesters. That is, from the students' perspective, it may have been easier to copy what the TAs did and said rather than engaging more deeply cognitively to solve the problem.

We noted several barriers that could have limited the effectiveness of the TAs. First, it was difficult to find times when all of the TAs and instructor could meet to discuss course-related issues. The instructor might have been able to teach the TAs how to respond to students' questions if they had discussed these interactions more often. Second, all of the GTAs had their research labs off campus, which limited students' access to them. Third, when the GTAs received a question through email, they usually needed to double check with the instructor before answering the students, which delayed their responses. Lastly, the instructor was restrained from the GTA selection process by policy, which may have led to the GTAs' misunderstanding of their responsibilities in class and underestimate of the amount of time required to perform well. These barriers could have led to the lower caring scores documented in Fall 2015 and Spring 2016 as compared to Spring 2015.

Feedback to Students

The differences in how students were provided with feedback across semesters may have contributed to the lowered scores reported on the quantitate measures. In Spring 2015, the primary instructor had more control over the type and style of feedback given to students. As more course sections were added in Fall 2015, the TAs became more involved and the feedback varied more substantially, sometimes in ways that might have negatively affected students' course perceptions.

In Spring 2015, the questions on the assignments were designed to stimulate critical thinking, especially when the results were ambiguous or unexpected (e.g., "Can you draw a conclusion with the data you collected? Why or why not?"). The grading goal was to emphasize the importance of logical and clear scientific writing. However, the open-ended questions were difficult for introductory-level students, and more guidance was needed to help them organize their thoughts and structure their answers, which was beyond the scope of this laboratory course. As a result, we modified the questions and offered clear rubrics in Fall 2015 and Spring 2016 (e.g., "Draw a conclusion with your data that support or refute the hypothesis listed in the lab manual [5 points]."). Although these changes helped students identify key concepts more easily and finish the assignment more efficiently (both could contribute to higher scores on the success scale), they could have made students feel less in control of their learning because there were fewer options for data interpretation; thus, decreasing students' perceptions of empowerment.

Another factor that may have influenced students' perceptions is the feedback they received on each assignment. The GTAs tended to focus on the correctness of each answer, which may have indirectly restrained students' creativity and decreased their perceptions of empowerment. When asked to focus more on the background reasoning, some GTAs tried to make every student think alike (to give the "correct" answer), while some simply gave full credit on the assignment for any individualized interpretation. These responses by the GTAs appears to have caused another potential problem: variation in grading style. Because the GTAs graded differently, different learning atmospheres were created across the different sections. Consequently, some students raised concerns about the fairness of the grades. Additionally, the feedback on the assignments from the GTAs tended to be brief and harsh (e.g., "Wrong graph.") compared to the instructor's comments (e.g., "A histogram may be more appropriate here to show the difference between the two groups."). This difference in feedback style may have led to lower scores on the caring scale in Fall 2015 and Spring 2016 as compared to Spring 2015 when the instructor completed most of the grading and provided most of the feedback.

Student Composition

One interesting finding is that the usefulness scores were significantly different across sections in Fall 2015. Specifically, the section that enrolled the most non-major students (28%) had a significantly lower usefulness score than the other four sections in which only 5-16% of the students were non-majors. This difference disappeared in the following semester (Spring 2016), possibly due to dropout of non-majors (only two out of 78 students were non-majors). This makes sense because non-majors may take the course for their personal interest but find the content irrelevant to their future goals or career.

Unlike other introductory science laboratories, this course was specifically designed for neuroscience majors with inquiry-based instruction. The students might have been overwhelmed by the jargon and concepts used in the lab, which could have resulted in them asking for more guidance. Therefore, more pictures and videos were included in the lab manuals in Spring 2016 to illustrate each experimental procedure. Although students' ratings for the lab manuals and learning objectives became significantly higher from Fall 2015 to Spring 2016, the success scores remained similar. These changes may have led to lowered empowerment scores due to the formalized and structured experimental steps that were required.

IMPLICATIONS AND CONCLUSION

Based on our successes and failures in this action research project, we suggest some strategies that faculty instructors should consider to motivate and engage their students. First, when TAs have important roles in interacting with students, instructors should provide TAs with specific training on both content knowledge and pedagogical skills before the semester begins. It also seems that it would be beneficial to monitor some of these interactions or, at a minimum, provide ongoing training during the semester. Previous studies showed that many undergraduate students described "knowledgeable" and "approachable" as desired qualities of TAs and instructors (Good et al., 2015; Herrington and Nakhleh, 2003). Consistent with the MUSIC model, knowledgeable TAs should help students succeed by empowering them to develop their own understanding of the material instead of passively offering information; and, when TAs are approachable, they show that they care about students' learning by providing comprehensive feedback and responding to their questions in a timely and respectful manner.

Second, although it can be difficult for one individual to grade all of the students when there are multiple course sections, a consistent grading system across different sections can help students understand the expectations and feel as though they are being treated fairly. A detailed rubric can be used to provide consistency and hold students to the same standards, which can help students to believe that they can be successful. For assignments in which the students are encouraged to develop their own experiments, there is likely no uniform procedure and "correct" answer to the assignments. In these cases, TAs should fully understand the student's hypothesis and experimental design during the lab in order to grade the interpretation of the data collected, rather than focusing on the amount of data or the correctness of answers (Marshman et al., 2016). Focusing on the thinking skills involved in the process instead of simply the outcome can lead to higher levels of cognitive engagement.

Third, faculty instructors should be aware of how students' perceptions of success may interact with their perceptions of empowerment and carefully determine an appropriate balance when designing assignments. Although open-ended questions empower students to take control of their learning, these questions may lack the structure that novices or non-majors need to complete the coursework, and thus, have a negative effect on students' perceptions of success. Alternatively, structuring assignments too rigidly in an attempt to ensure students' success may limit their perceptions of empowerment because they have fewer decisions. Therefore, instructors must find the balance needed in their particular course and context to help students reach their optimum motivation and achievement.

Finally, this action research project demonstrates the sometimes messy nature of instructional design within the context of real-world courses. We learned that some wellintentioned course design changes can be offset or moderated by other factors. In our case, what we intended to be positive changes to the assignments were offset by the manner in which TAs provided feedback on and graded the assignments. Although some outcomes can be anticipated, others cannot and may interfere with the intended outcomes. However, through the use of measures such as those implemented in this study, researchers can collect data that can be analyzed and used to make data-driven decisions consistent with best instructional practices.

REFERENCES

Altrichter H, Feldman A, Posch P, Somekh B (2008) Teachers investigate their work: an introduction to action research across the professions (2nd ed). New York, NY: Routledge.

Brownell SE, Kloser MJ, Fukami T, Shavelson R (2012) Undergraduate biology lab courses: comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. J Coll Sci Teach 41:36-45.

Clough MP (2002) Using the laboratory to enhance student learning. In: Learning science and the science of learning (Bybee RW, ed) pp 85-97. Arlington, VA: National Science Teachers Association.

Fredricks JA, Blumenfeld PC, Paris AH (2004) School engagement: potential of the concept, state of the evidence. Rev Educ Res 74:59–109.

Good J, Colthorpe K, Zimbardi K, Kafer G (2015) The roles of mentoring and motivation in student teaching assistant interactions and in improving experience in first-year biology laboratory classes. J Coll Sci Teach 44:88-98.

Gormally C, Brickman P, Hallar B, Armstrong N (2009) Effects of inquiry-based learning on students' science literacy skills and confidence. IJ-SoTL 3:Article 16.

Hall S, Jones BD, Amelink C, Hu D (2013) Educational innovation in the design of an online nuclear engineering curriculum. JET 13: 58-72.

Herrington DG, Nakhleh MB (2003) What defines effective chemistry laboratory instruction? Teaching assistant and student perspectives. J Chem Educ 80:1197-1205.

Hofstein A, Lunetta VN (1982) The role of the laboratory in science teaching: Neglected aspects of research. Rev Educ Res 52: 201-217.

Hofstein A, Lunetta VN (2004) The laboratory in science education: Foundations for the twenty-first century. Sci Educ 88:28-54.

Jang H, Kim EJ (2012) Longitudinal test of self-determination theory's motivation mediation model in a naturally occurring classroom context. J Educ Psychol 104:1175-1188.

Jones BD (2009) Motivating students to engage in learning: The MUSIC Model of Academic Motivation. IJTLHE 21:272-285.

Jones BD (2010) An examination of motivation model components in face-to-face and online instruction. EJREP 8:915-944.

Jones BD (2015) Motivating students by design: Practical strategies for professors. Charleston, SC: CreateSpace.

Jones BD (2016) User guide for assessing the components of the MUSIC® Model of Academic Motivation. Retrieved from http://www.theMUSICmodel.com

Jones BD, Epler CM, Mokri P, Bryant LH, Paretti MC (2013) The effects of a collaborative problem-based learning experience on students' motivation in engineering captone courses. IJPBL 7:Article 2.

Jones BD, Skaggs G (2016) Measuring students' motivation: validity evidence for the MUSIC Model of Academic Motivation Inventory. IJ-SoTL 10:Article 7.

Jones BD, Watson JM, Rakes L, Akalin S (2012) Factors that impact students' motivation in an online course: Using the MUSIC model of academic motivation. JoTLT 1:42-58.

Kena G, Hussar W, McFarland J, de Brey C, Musu-Gillette L, Wang X, Zhang J, Rathbun A, Wilkinson-Flicker S, Diliberti M, Barmer A, Mann FB, Velez ED (2016) The condition of education 2016 (NCES 2016-144). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Ma J, Nickerson JV (2006) Hands-on, simulated, and remote laboratories: a comparative literature review. ACM Comput Surv 38:Article 7.

Marshman E, Maries A, Henderson C, Singh C, Yerushalmi E (2016) From instructional goals to grading practices: the case of graduate teaching assistants. arXiv preprint arXiv:1601.08210.

McGinley J, Jones BD (2014) A brief instructional intervention to increase students' motivation on the first day of class. Teach Psychol 41:158-162.

Mills GE (2011) Action research: A guide for the teacher researcher (4th ed). Upper Saddle River, NJ: Pearson.

Pintrich PP, Smith DAF, Garcia T, McKeachie WJ (1993) Predictive validity and reliability of the Motivated Strategies for Learning Questionnaire (MSLQ). Educ Psychol Meas 53:801-813.

Reeve J, Lee W (2014) Students' classroom engagement produces longitudinal changes in classroom motivation. J Educ Psychol 106:527-540.

Sauter M, Uttal DH, Rapp DN, Downing M, Jona K (2013) Getting real: the authenticity of remote labs and simulations for science learning. Distance Educ 34:37-47.

Skinner EA, Kindermann TA, Furrer CJ (2009) A motivational perspective on engagement and disaffection: conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom. Educ Psychol Meas 69:493-525.

Stringer ET (2007) Action research (3rd ed). Los Angeles: SAGE Publications.

Wolters CA (2004) Advancing achievement goal theory: using goal structures and goal orientations to predict students' motivation, cognition, and achievement. J Educ Psychol 96:236-250.

Received January 06, 2017; revised February 23, 2017; accepted February 28, 2017.

The authors would like to thank Virginia Tech's Open Access Subvention Fund for paying the publication fees for this article.

Address correspondence to: Dr. Brett D. Jones, Educational Psychology Program, School of Education, Virginia Tech, 319 War Memorial Hall, 370 Drillfield Drive, Blacksburg, VA 24061. Email: brettjones@vt.edu.