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Work in Progress: Design of Mastery-Based-Learning Course Structure to Assess Student Anxiety and Belonging

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WIP: Design of Mastery-Based-Learning Course Structure to Assess Student Anxiety and Belonging

Introduction

Almost 1/3rd (31%) of U.S. adults will experience an anxiety disorder at some point in their lives; with females affected more than males (about 1.5:1) [1]. In 2017, 61% of college students seeking counseling services listed anxiety as the most frequent issue they were facing, and about 23% said it was the problem causing them the most concern (Center for College Mental Health at Penn State [2]). Anxiety can impact physical, cognitive and emotional health, impacting how students perform in their classes and consequently in their careers.

For college students, anxiety is frequently manifested in relation to exams—it is estimated that 10-40% of students are affected by test anxiety. Test anxiety can impact motivation and academic achievement and lead to higher rates of alcohol use and leaving college without a degree [3,4,5,6].

There is a high level of stress among engineering students due to the difficulty of their degree program. Grades and rigor have been identified as some of the most significant stressors for engineering students. High levels of stress can become part of the engineering culture and can be passed on to new students. This cycle of expecting stress can lead to further elevating stress levels for students and can even result in other mental health challenges. One study showed that students enrolled in engineering programs are two times more likely to experience anxiety than their non-engineering classmates. In addition, another study found that engineering students who were experiencing mental health issues sought treatment less often than other students [7].

The engineering culture at a college or university is considered to be an essential aspect of educational success. This culture largely contributes to individuals' sense of belonging. Culture that fosters a sense of belonging has greater student retention. A 2012 study found that lack of belonging was a top reason that engineering students left the program [7].

Competency-based (or mastery-based) course structure allows students to learn at their own pace, so they can complete topics they understand more quickly and focus more time reviewing topics they struggle to understand. Literature suggests that this course structure makes students more autonomous. This leads to higher achievement and motivation since students feel as though they have more control over their education [8]. Mastery-based-learning (MBL) also eliminates the "one-shot" mindset for students taking exams. If students are not able to demonstrate mastery on their first attempt, they are given additional chances and, if they demonstrate mastery, they will receive the same score as students who succeeded on their first attempt [9]. This allows students to learn from their mistakes and try again without any penalties.

Since the curriculum in engineering courses continually builds on itself, it is extremely important that students have an understanding of prerequisite materials. If students are struggling with the more basic content, they will inevitably struggle with subsequent content. Falling behind can lead students to leave the major or their college entirely. Competency or mastery-based-learning structures courses so that students always master basic skills before they can begin to tackle more complex material. With this structure, it is much more difficult for students to fall behind in their courses resulting in a smaller probability that students leave the program. Findings have shown that students performed better, were more knowledgeable, and had more positive/enthusiastic attitudes toward learning when taking competency or mastery-based courses compared with traditional courses [8].

Using MBL has shown an increase in proficiency rates among students [10]. Establishing an ideal curriculum requires finding the proper balance between breadth and depth. While MBL gives students as much time as they need to practice and get assistance with key skills, if they do not complete these essential skills quickly enough they may not reach all the skills that would be covered in a traditional course. On the other hand, when taught in the traditional model, many students did not have enough time to master the fundamental skills of dynamics [10, 11].

The grading structure for MBL evaluates students on the number of skills that they can do well instead of on how well they can do all of the course material. This structure favors proficiency in a few key skills over limited competency in many skills. DeGoede found that the best students were able to complete the course with proficiency in all skills regardless of how the class was structured. The difference between mastery-based and traditional classroom performance is more evident when comparing the proficiency of average students and even more obvious when comparing below average students. Average and below average students perform better using the MBL grading structure than the traditional structure [10].

Many educators have attempted to implement MBL in their classrooms. Feedback from instructors and students has been integral in assessing the success and effectiveness of this course structure. Instructors who utilized mastery-based learning techniques noted that there are benefits including easier grading and better insight into students' progress. They also noted some downfalls such as student's frustration with an unfamiliar pedagogical approach [12]. Additionally, since students work on different topics within the same class, classroom management can become difficult [11].

At Missouri University, MBL was used in an upper-level environmental engineering course. When the class ended, students were given the chance to "suggest improvements" and to point out "strengths" and "weakness" of the course. Using responses from this survey, the following strengths were identified: course structure, grading system, and student motivation. Several weaknesses were also identified. These include time spent learning about the unfamiliar course structure, student motivation, and lack of traditional lecture [12].

In the Engineering and Physics Department at Elizabethtown College, a mastery-based approach to foundational engineering courses has been employed to boost student learning and success. Students are somewhat self-paced but provided active coaching by the professor during class times. Because students have increased autonomy in relation to the pace of the course [8], and because the skill tests cover smaller sections of material and may be retaken as often as needed, a mastery-based approach may reduce anxiety associated with testing. Additionally, frequent skill tests provide instructors with additional feedback so they can help each student individually, at their level which may also lead to increased confidence and belonging.

We hypothesize that:

(1) Students will have less test-related anxiety and anxiety related to the course in general when compared with a traditional assessment (2 during the term exams and final exam). This could occur due to a greater sense of accomplishment through the mastery-based approach, as well as the frequent testing and retesting freedom available to students.

(2) Students will have a greater sense of belonging in the course and program compared with a traditional assessment. This could occur from a greater sense of accomplishment with mastery. However, a lesser sense of belonging could arise as students that are not excelling see others moving through the coursework at a faster pace.

To study the effect of MBL on classroom anxiety and belonging, surveys will be given to students enrolled in circuit analysis courses delivered with a traditional or MBL structure. Data has been collected from the students who were taught using the traditional structure. Those being taught with MBL will be sampled in the next academic year.

Methods/Data Analysis

<u>Grading Structure</u>

In order to convert the course from traditional to MBL, the grading structure and course schedule had to be redesigned. In a class with traditional grading structure, a few exams are given at various checkpoints throughout the semester. These exams make up some predetermined percentage of a student's overall grade and a lot of pressure is placed on doing well on these exams. For example, when this course was graded in a traditional format, four exams made up 60% of a student's grade (see Table 1).

Table 1: Grading Structure for Traditional Circuit Analysis Course

Pre-class preparation	5% (two preps will be dropped)
In-class participation	5% (two participations will be dropped)
Homework	10% (one lowest will be dropped)
Partial exams	35% (three partial exams)
Final Exam	25%
Lab	20%

To convert the course to MBL, key skills for the course were selected. These skills were then divided into fundamental, essential, and advanced skills. The fundamental (F) skills are the ones that students need to understand to succeed in future courses and in their career. The essential (E) and advanced (A) skills are still important, but they are not pre-requisite material for other courses. If a student is able to master all the fundamental skills, they will have a C- and they will pass the class as shown in Table 2. While students who only pass the fundamental skills may not get as much practice with the essential and advanced skills, they will still be exposed to these skills on instruction days and through homework and laboratory exercises. By achieving mastery on the fundamental skills, students should have a full understanding of these topics which they can apply to future engineering courses. This is where mastery based learning and traditional grading differ—mastery-based learning prioritizes mastery of some skills above others, where in a traditional structure, students may have a partial understanding of many topics without a complete understanding of the most important topics.

Table 2: Mastery-based learning grading structure for Circuit Analysis

<table>
<tr><td>Pass any 2 F skills</td><td>F</td><td rowspan="5">F1: Use Ohm's law to calculate power in sources and loads
F2: Demonstrate conceptual understanding of and use equivalent resistance to simplify circuits
F3: Use KVL and KCL and Ohm's law to calculate V, I or R in circuits with unknown variables.
F4: Use voltage dividers, current dividers and equivalent R's to find V, I or P in circuit with several loads and 1 source.
F5: Use Nodal analysis to find V, I and/or P in complex circuits with multiple sources.
F6: Apply Thevenin theorem to simplify a complex circuit into its equivalent of a voltage source and series resistor (Independent Sources only)</td></tr>
<tr><td>Pass any 3 F skills</td><td>D-</td></tr>
<tr><td>Pass any 4 F skills</td><td>D</td></tr>
<tr><td>Pass any 5 F skills</td><td>D+</td></tr>
<tr><td>Pass all 6 F skills</td><td>C-</td></tr>
<tr><td rowspan="7">1/3 of a grade increase for each additional skill passed</td><td>C</td><td rowspan="7">*** Must pass all F skills to earn credit for E and A skills ***
E1: Apply Thevenin theorem to simplify a complex circuit into its equivalent of a voltage source and series resistor (Dependent Sources included)
E2: Identify common op-amp circuits, find the output voltage (or gain) for several cascaded amplifiers.
E3: Find the analytical solution describing the voltage (and current) in a RC or RL circuit as a function of time.
E4: Use Mesh analysis to find V, I and/or P in complex circuits with multiple sources.
E5: Use source transformation to simplify and then analyze a circuit to find the V, I, P or a R.
A1: Design an op-amp circuit project to transform input signal to meet specified output criteria – hands-on project/circuit
A2: Find the analytical solution describing the voltage (or current) in a series or parallel RLC circuit as a function of time.</td></tr>
<tr><td>C+</td></tr>
<tr><td>B-</td></tr>
<tr><td>B</td></tr>
<tr><td>B+</td></tr>
<tr><td>A-</td></tr>
<tr><td>A</td></tr>
</table>

After this, any essential or advanced skill that a student passes will allow the student to increase their grade by 1/3 of a letter. For example, if a student masters all the fundamental skills and achieves the C- needed to pass the class, then they pass three additional exams, they will end the class with a B-.

The grading structure in Figure 1 does not include homework, labs, or participation. Since the grading structure is not percentage-based, adjustments need to be made to account for things such as homework, labs, and attendance. The following adjustments will be made to the students' grades: (1) there will be a 1/3rd letter grade deduction for a homework grade below 80%, (2) students must get a final lab grade of 80% to achieve a C- or above in the class, an 85% to achieve a B- or above, and a 90% to achieve an A- or above, and (3) there will be a 1/3rd letter grade deduction for more than three unexcused absences. In the fall 2021 semester, all but one student fell in the 80% or above category for lab. Almost all of these students were above the 90% threshold. Even though these three adjustments can only hurt a student's grade, the adjustments are meant to help students by incentivizing them to practice the course material.

<u>Course Schedule</u>

In the course with a traditional grading scheme, the classroom was flipped, requiring students to watch 15-20 minutes of video prior to class and come to class with filled in notes (i.e., 'gap-notes'). Because of the increase in assessment, the MBL course schedule (see Table 3) included adjustments from a traditional course schedule. Instead of having instruction every day with occasional tests, there will be formal instruction and practice once a week with one day reserved for coaching and testing. On an instruction day, students are still required to watch videos and come to class with the required notes for that skill. Then the professor does a brief review before guiding the students through several problems related to that skill. On a coaching and testing day, students work together on practice problems related to any skill of their choice while the instructor provides informal coaching (about 50 minutes). During the last 30 minutes of class, students have the option to take skill exams for mastery. Since there are more testing opportunities than the number of skill exams, students have an opportunity to learn from the assessment process instead of simply being evaluated by it.

Table 3: Course Schedule for Mastery Based Learning Structure

	Tuesday	Thursday	Friday
Aug.	22 Introduction/F1 Instruction	24 F2 Instruction	25 Homework Due
Aug.	29 F1 and F2 Coaching/Testing	31 F3 Instruction	1 Homework Due
Sept.	5 Coaching/Testing of F skills	7 F4 Instruction	8 Homework Due
Sept.	12 Coaching/Testing of F skills	14 F5 Instruction	15 Homework Due
Sept.	19 Coaching/Testing of F skills	21 F6 Instruction	22 Homework Due
Sept.	26 Coaching/Testing of F skills	28 E1 Instruction	29 Homework Due
Oct.	3 E2 Instruction	5 **Fall break, no class**	6 Homework Due
Oct.	10 Coaching/Testing of F skills and E1	12 A1 Instruction	13 Homework Due

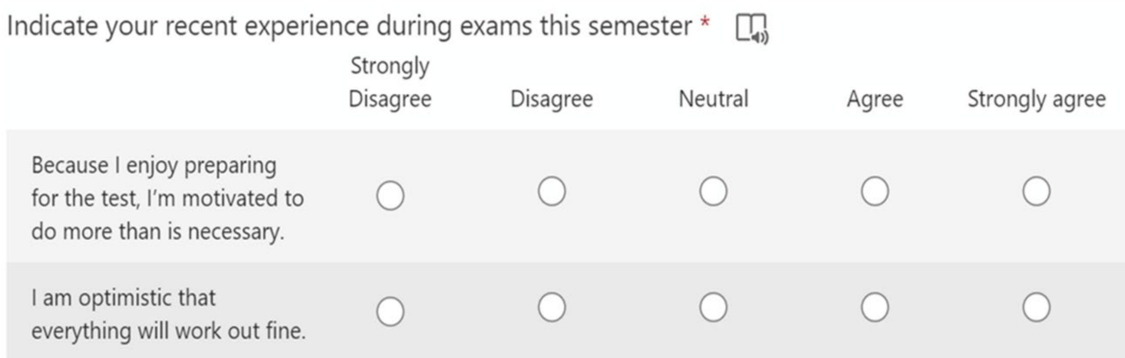
	17 Coaching/Testing of F skills and E2	19 E3 Instruction	20 Homework Due
	24 Coaching/Testing of F skills and E1-E3	26 E4 Instruction	27 Homework Due
Nov.	31 Coaching/Testing of F skills and E4	2 E5 Instruction	3 Homework Due
	7 Coaching/Testing of F skills and E5	9 E6 Instruction	10 Homework Due
	14 Coaching/Testing of F skills and E4-E6	16 A2 Instruction	17 Homework Due
	21 Coaching/Testing of F skills and A2	23 **Holiday Break - No Class**	24 Homework Due
	28 Coaching/Testing Any Skill	30 Coaching	1 Homework Due
Dec.	Final Exam will be used as a chance to retest on any skills you still need to master		

MBL curriculum is more flexible on coaching days since students choose which skills they would like to spend time practicing, and they can decide when they are ready to attempt the exam. This means that some students will be learning about advanced topics during instruction days while practicing skills from previous topics during coaching days. While this could be confusing, one could argue that not having mastery of basic concepts (e.g., Ohm's Law and Kirchhoff's Laws) while covering advanced material can be equally confusing. Thankfully, interleaving instructional topics has been shown to improve understanding and retention so while it may be challenging in the moment, students learning could actually improve. Furthermore, one-on-one (or small group) interaction with the instructor during coaching days will also help to address individual student concerns and help them learn material specific to their situation.

In preparation for the course to be taught using MBL, homework assignments and exams were created for each skill. Homework assignments were made to consist of 15-25 questions. When homework assignments were created, diverse questions were selected so students will be required to apply their knowledge to a variety of circuits. Test banks for the exams were created from these homework assignments. Each test bank consists of questions from the homework assignments that can be used as an exam question for students to demonstrate their mastery. This way, if students are comfortable doing the homework problems, they should excel on their exams. Additionally, using the homework questions as test problems will provide students with an incentive to do their homework (test bank questions will be a numerical variation of the homework question so students cannot simply memorize the numerical answers). A limitation of this approach is that students may attempt to memorize the steps of solving the homework problems instead of truly learning how to approach the problems. Including more design skills (e.g. skill A1 in Table 2) could help address this shortcoming. ability. The large number of homework problems will hopefully dissuade students from taking this approach.

Survey Questions

Two introductory circuit analysis courses will be given a survey to assess student anxiety and belonging. In the fall 2022 semester, students taking the course with a traditional grading structure were given the survey three times: week 6 (after the first exam), week 11 (after the second exam), and week 15 (after the third exam and before the final exam). The next time the class is taught, in fall 2023, the class will be taught using MBL. These students will be given the same survey at the same intervals to determine how the new MBL course structure impacts student anxiety and sense of belonging. Survey questions were selected from the Achievement Emotions Questionnaire that focused on anxiety, enjoyment, hopelessness, hope, pride, and shame. This questionnaire wasn't used in its entirety due to its length. When students take the survey, they will answer questions by selecting the amount that they agree with a given statement. For example, students will be given the statement "I am optimistic that everything will work out fine" in reference to taking exams. Then they can select an answer between strongly agree and strongly disagree (Figure 1).



Indicate your recent experience during exams this semester *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
Because I enjoy preparing for the test, I'm motivated to do more than is necessary.	○	○	○	○	○
I am optimistic that everything will work out fine.	○	○	○	○	○

Figure 1: Sample survey questions given to students

There were also several survey questions selected from the Belonging Uncertainty Scale that focused on student belonging. These questions also allowed students to select the amount that they agree with a given statement by choosing an answer between strongly agree and strongly disagree.

<u>Data Processing</u>

A data processing pipeline has been created to analyze data. The Likert data will be tested for normality and analyzed with parametric or non-parametric, as appropriate, statistics. The survey results are downloaded as excel files and uploaded into MATLAB®. MATLAB will convert the survey responses into useable data. Each student's score will be calculated and combined into one of the following categories: anxiety, enjoyment, hopelessness, hope, shame, pride, and belonging. Once the data has been collected from the MBL course, a two-way ANOVA will be used to analyze levels of anxiety and sense of belonging over the factors of week-of-the-semester (weeks 6, 11, 15) and course structure (traditional vs MBL).

Results

The data gathered during the semester with traditional course structure does not show any significant difference between the students' levels of anxiety, enjoyment, hopelessness, hope, shame, or pride with relation to the class (Figure 2).

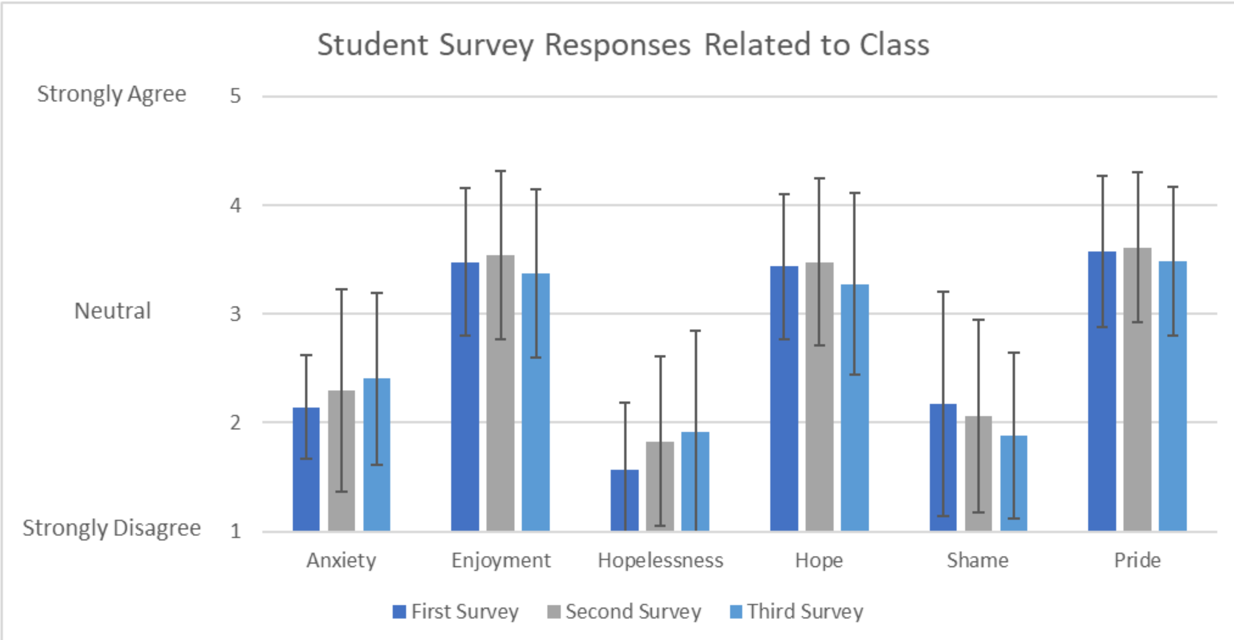


Figure 2: Average student responses related to anxiety, enjoyment, hopelessness, hope, shame, and pride about class when taught with traditional course structure

The data was also analyzed to look at students' levels of anxiety, enjoyment, hopelessness, hope, shame, or pride with relation to the testing while the course was taught with traditional structure (Figure 3). Similarly, there was no significant difference across the weeks of the semester.

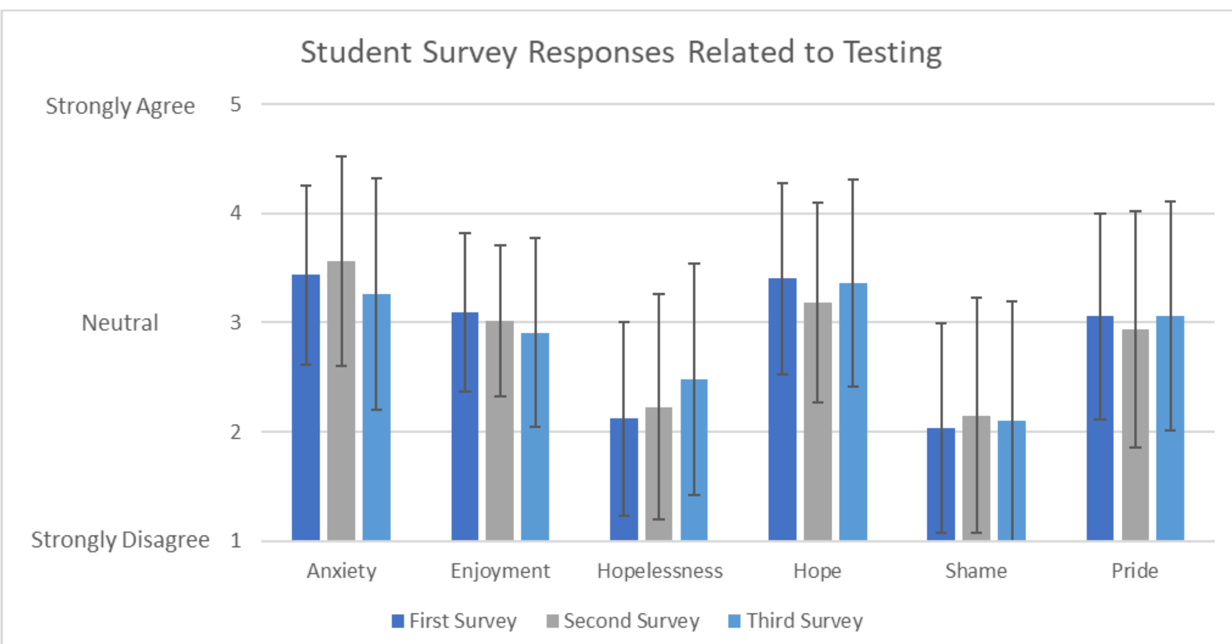


Figure 3: Average student responses related to anxiety, enjoyment, hopelessness, hope, shame, and pride about testing when taught with traditional course structure

Finally, the data for student belonging in the class and the engineering program was analyzed (Figure 4). Once again, there was no significant change in students' feelings of belonging over the course of the semester.

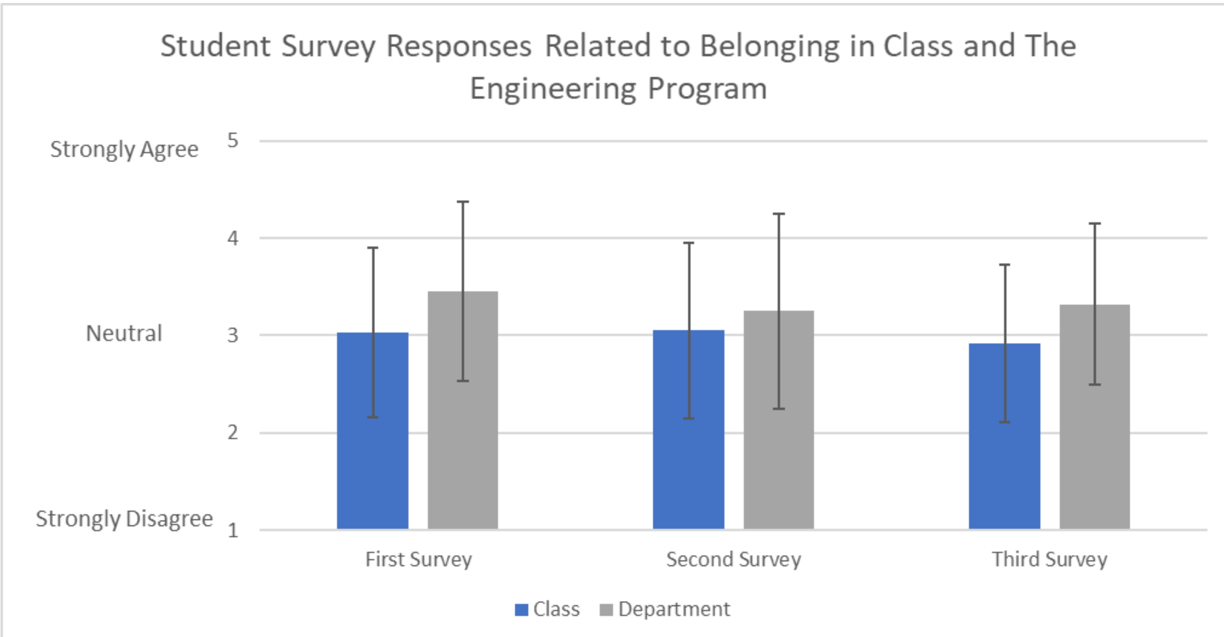


Figure 4: Average student responses related to belonging in class and the engineering program when taught with traditional course structure

Conclusion

Given the data that has currently been collected, there appears to be no statistically significant differences in students' levels of anxiety, enjoyment, hopelessness, hope, shame, pride, or belonging over the course of the semester. Next academic year, when the course is taught using MBL, it is hypothesized that the level of test anxiety and anxiety related to the course in general will be lower than it was with the traditional course model due to the increased frequency of testing opportunities. Students' sense of belonging will also be compared between the traditional and MBL structures to determine if students feel a greater sense of belonging in the course and the program with this course structure.

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