Exploring the Relationship Between Course Structures and Student Motivation in Introductory College Calculus

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Abstract

The Mathematical Association of America (MAA) national study of Characteristics of Successful Programs in College Calculus revealed that introductory calculus still occupies a gatekeeper role for STEM majors across the country. Even if students persist through Calculus I, they leave the class with a diminished confidence and enjoyment of mathematics and a decreased desire to continue pursuing further mathematics. Thus, the goal of this research study was to provide a better understanding of the relationship between learning environments and student motivation in introductory college calculus. Results of this work will help guide mathematics faculty and administrators to create environments that are most conducive to fostering students’ motivation, thus supporting their academic achievement in calculus.

The theoretical framework of self-determination theory (SDT) was used to guide this study. SDT is a macro-theory of motivation and has been widely used to study the social factors of an environment under which people thrive. According to SDT, three basic psychological needs are essential to fostering a student’s motivation and engagement: competence, autonomy, and relatedness. Competence refers to students feeling confident and effective in the classroom, autonomy means they have a sense of agency and authority, and relatedness incorporates students’ need to feel a sense of belonging in the classroom. Only when students’ basic psychological needs are supported by the classroom structure can they internalize their motivation to learn.

This paper will report a piece of a larger sequential explanatory mixed-methods design that investigated the interaction of course structures, students’ basic psychological needs satisfaction, and motivation. Three different course types of Calculus I were sampled at a large research university, which included traditional methods, hybrid online, and a large-enrollment active learning classroom. The Basic Psychological Needs Scale (BPNS) and the Situational Motivation Scale (SIMS) were administered to students in the three course types. This quantitative phase involved analyzing survey data from all students in the selected classes to determine if students’ perceptions of their competence, autonomy, and relatedness and motivation types differed between the course structures. Analyses revealed that students’ perceptions of their competence, autonomy, relatedness and autonomous motivation significantly differed between the three course types, with the hybrid online class having significantly lower mean scores than the other two course types. Implications for mathematics faculty will be discussed.
Introduction/Background

The Mathematical Association of America (MAA) national study of Characteristics of Successful Programs in College Calculus revealed that introductory calculus still occupies a gatekeeper role for STEM majors across the country. Bressoud (2013) illustrates this issue with introductory calculus by stating, “this course is famously perceived to be a filter, discouraging all but the very strongest students from pursuing a career in science or engineering”. Gatekeeper courses typically have the highest rate of failures or withdrawals at a university, and students who aren’t successful in these courses tend to switch out of a STEM major (Moore 2005, Suresh 2006). Even if students persist through Calculus I, they leave the class with a diminished confidence and enjoyment of mathematics and a decreased desire to continue pursuing further mathematics. Students at research universities, which are the primary source of our future scientists and engineers, are showing the greatest losses in these factors (Bressoud et al. 2015). This presents a critical issue as our nation is in great need of more STEM graduates entering the workforce (Olson et al. 2012).

These findings become even more discouraging when we take a closer look at the positive characteristics of students entering university calculus. Students have strong academic backgrounds coming into Calculus I, with an average high school math GPA of 3.77. Additionally, 70% of students have taken calculus in high school prior to enrolling at the university level (Bressoud et al. 2015). Recognizing that students are entering calculus with the preparation to succeed, more attention needs to be paid to the learning environment provided to these students; specifically, how pedagogical choices are impacting students’ motivation and performance in calculus. Calculus I course structures with common content and exams, but with differing levels of student-centered instruction, were examined in this study. The framework of self-determination theory (SDT) was used to investigate the social conditions in different course structures that either facilitate or forestall the innate interest and ambition for learning that calculus students possess (Ryan & Deci 2000).

Theoretical Framework

The framework of self-determination theory (SDT) was used to guide this study. Self-determination theory is a macro-theory of human motivation that was developed by psychologists Deci and Ryan. Ryan and Deci (2000) state, “human beings can be proactive and engaged or, alternatively, passive and alienated, largely as a function of the social conditions in which they develop and function” (pg. 68). They stress the importance of doing research on the design of social environments in order to determine the best conditions for optimizing people’s development, performance, and well-being, thus making this an important framework to study classroom structure. As such, SDT has been widely applied in the educational domain. According to SDT, three needs are essential to fostering a student’s motivation and engagement: competence, autonomy, and relatedness. Competence refers to students feeling confident and effective in the classroom. Autonomy refers to students’ sense of agency and authority. Finally, relatedness incorporates students’ need to feel a sense of belonging in the classroom.
Self-determination theory also describes motivation in terms of autonomous versus controlled regulation. These different types of regulations are defined by the extent to which the student has internalized a certain behavior. Controlled regulations include amotivation, where the student completely resists and does not value the classroom activities, external regulation, meaning a student participates in order to get a good grade on exam or avoid looking incompetent, and introjected regulation, in which a student engages in classroom activity in order to avoid shame or feel worthy. On the other side of the spectrum is autonomous regulation, which includes identified regulation, integrated regulation, and intrinsic motivation. Behaviors that are more autonomously regulated have been integrated into a student’s sense of self (Black & Deci 2000). Identified regulation means that the activity is accepted as personally important, such as students studying calculus in order to progress in their major. Integrated regulation is the most autonomous form of extrinsic motivation; as such it is very similar to intrinsic motivation. A student experiencing integrated regulation has fully incorporated a behavior into other aspects of themselves, thus assimilated it into their identity (Deci et al. 1991). For example, a student might study calculus in order to become an engineer and be able to help others, “which is consistent with her abiding values and interests” (Niemic & Ryan 2009).

SDT posits that extrinsically motivated behaviors, such as taking a calculus class, can only become autonomously regulated, meaning that the behavior has been integrated into their sense of self, if the social context promotes feelings of competence, autonomy, and relatedness. In other words, students’ individual motivation is constrained by the norms of the classroom (Goldin et al. 2016). When students’ basic psychological needs are supported by the classroom structure, they are more likely to internalize their motivation to learn (Niemec & Ryan 2009). Many prior studies in education, ranging from elementary school to college, have shown the importance of promoting autonomous regulation in the classroom (Deci et al. 1991). In general, more autonomous forms of motivation have been linked to increased interest, excitement, and confidence. This has been shown to lead to higher performance and persistence, even among students with the same level of self-efficacy (Ryan & Deci 2000).

Context

To study the relationship between course structures and student motivation, we sampled three different course types of Calculus I in the Fall 2018 semester: large active learning, hybrid online, and traditional methods. Calculus I at our university is a coordinated course, with every section covering the same material, using the same online homework, and taking the same exams. We sampled two sections of each course type, with the same instructor teaching both sections of a course type, with a total sample size of 340 students.

The large active-learning course was held in a large computer lab. There were around 90 students in each section, and students attended class four days a week. This course structure involved a mixture of lecture and group activities. Each student had a computer
and was able to follow along with the instructor’s slides during the lecture portion of the class. Two graduate teaching assistants, the instructor, and an undergraduate TA assisted students and answered questions during the active learning part of the class.

The next course type was hybrid online, which consisted of around 40 students in each class. These hybrid sections involved students watching online lectures and attending class face-to-face two days a week. One day was used for quizzes over the content covered that week, and the other day involved students working in groups on a learning activity. The quizzes and group activities took place during the first half of class, and the TA worked example problems during the second half of class. This classroom was set up with round tables, with a projector screen at each end of the room.

The last course type in this study was a traditional methods class. Like the hybrid class, students sat together at round tables, with around 45 students in each section. The instructor lectured throughout the class period with an interactive approach, stopping to ask students questions or get their ideas about how to solve a problem. There were no consistent group activities in this class like the other two course types, and this course type did not have any TAs in the classroom.

Methods

The Basic Psychological Needs Satisfaction Scale (BPNS) and the Situational Motivation Scale (SIMS) were administered twice to all students in the six selected sections, once at the beginning of the semester and once at the end. The BPNS was developed by Deci and Ryan (2000) and contains 21 items that measure participants’ perceptions of their autonomy (7 items), competence (6 items), and relatedness (8 items) as defined by self-determination theory. This scale has been adapted for use in an undergraduate classroom, and prior studies have shown internal reliabilities ranging from $\alpha=.77$ to $.86$ for the three subscales (Filak & Sheldon 2003, Levesque-Bristol et al. 2010).

The Situational Motivation Scale (SIMS) was developed by Guay et al. (2000) and contains 18 items designed to measure the six types of motivation proposed by self-determination theory. This scale has been previously validated with college students and was shown to be reliable with internal consistencies ranging from $\alpha=.77$ to $.95$ for the six subscales of intrinsic, integration, identification, introjection, extrinsic, and amotivation (Guay et al. 2000, Levesque-Bristol et al. 2010). In addition to the BPNS and the SIMS, the survey included items to determine if students have previously taken calculus, and student demographic data such as gender and ethnicity was also collected.

The sample size and response rates for each course type are given below:
Results

The following analyses were conducted on students’ post survey scores.

RQ 1) What is the difference in student perceptions of their basic psychological needs satisfaction between the course structures?

A multivariate analysis of variance (MANOVA) model was developed to determine if students’ combined means of the BPNS components (competence, autonomy, and relatedness) differ based on course structure. The MANOVA allows for comparison of a multivariate mean response between groups (Rencher 2002). This model included terms for course structure (the treatment) and student demographic groups (the blocking factor). Use of a blocking factor allows for a comparison of course structures that is not masked by pre-existing differences among students based on the demographics (Ott & Longnecker 2010).

Since the MANOVA model suggested course structure was significant ($p <0.0001$), univariate ANOVA models were used to determine which of the individual components of the multivariate mean response in the BPNS differed between the course structures. Since the univariate ANOVA tests were significant for each BPNS component, all pairwise comparisons were conducted to determine which of the course types had significantly different autonomy, competence, and relatedness scores. For each BPNS component, the hybrid online course had significantly lower mean scores than the traditional and large active learning courses.

<table>
<thead>
<tr>
<th>BPNS Component</th>
<th>ANOVA</th>
<th>Course Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p-value</td>
</tr>
<tr>
<td>Autonomy</td>
<td>3.62</td>
<td>0.0284*</td>
</tr>
<tr>
<td>Competence</td>
<td>9.63</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Relatedness</td>
<td>6.77</td>
<td>0.0014*</td>
</tr>
</tbody>
</table>

Figure 2. BPNS by Course Type
RQ 2) What is the difference in student motivational types between the course structures?

The six subscales of the SIMS were collapsed into two factors: autonomous motivation (intrinsic, integration, identification) and controlled motivation (introjection, extrinsic, amotivation). Next, the same process used for RQ 1 above was followed. Since the MANOVA was significant (p=0.0055), univariate ANOVA models were developed for each factor. The ANOVA for autonomous motivation was significant; therefore, all pairwise comparisons between the course types were conducted. Results showed that the hybrid online course had a lower mean autonomous motivation score than the traditional and large active learning courses.

<table>
<thead>
<tr>
<th>SIMS Component</th>
<th>ANOVA</th>
<th>Course Type</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p-value</td>
<td>M</td>
<td>SE</td>
<td>M</td>
<td>SE</td>
</tr>
<tr>
<td>Autonomous Motivation</td>
<td>7.45</td>
<td>0.0007*</td>
<td>4.19</td>
<td>0.16</td>
<td>4.37</td>
<td>0.13</td>
</tr>
<tr>
<td>Controlled Motivation</td>
<td>0.69</td>
<td>0.5018</td>
<td>4.00</td>
<td>0.12</td>
<td>3.95</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Figure 3. SIMS by Course Type**

**Conclusions**

Overall, analyses revealed that students’ perceptions of their competence, autonomy, relatedness and autonomous motivation significantly differed between the three course types, with the hybrid online class having significantly lower mean scores than the other two course structures. In order to get a better idea of what aspects of each course structure could be contributing to these results, follow-up student interviews were conducted. Preliminary qualitative analysis of the interview data is pointing to a few aspects of a hybrid course that mathematics faculty should consider when implementing this course type.

Students in the hybrid class expressed some frustration with balancing the amount of work that was expected to be completed outside of class:

“*I think I'd rather learn the lectures in class definitely, because I get behind on watching the lectures, just because I have to do the all these math assignments... just outside work. And then I have to watch a lecture outside of class, which I should be learning in class... So it's like, this is time taken away from my homework and studying that I could be having in class.*” - Katie

Another aspect of the hybrid class that students struggled with was not being able to ask a question in real-time during the lectures:

“*It's very different. In high school, I was able to ask a lot more questions while going through the lecture. So, if I didn't understand something, I could just ask in that instant...*”
and not have to remind myself to ask about it later… it's different in person when you ask someone, because it's easier for them to explain it to you when you're sitting right in front of them…” –Katie

“Well I don't think I wanna do another hybrid class just 'cause I like having someone actually in front of me and being able to see it done in front of me. Instead of on a screen where ... if I have a question, I can't just raise my hand and be like, 'I don't understand'.” –Betty

**Implications**

One way faculty could combat student frustrations similar to Katie’s is being more explicit about how students should manage their time for the out of class component. Students in this hybrid course only attended class face-to-face two days a week, whereas the other courses met four days. This provides an opportunity to reframe students’ thinking about the workload of a hybrid course, by explaining that they have more choice in when their work is getting done by not having to come to class an additional two days. By faculty maximizing student perceptions of having a voice in when they choose to watch the lectures, students’ feelings of autonomy could be better supported (Niemic & Ryan 2009).

A possible way that instructors of hybrid courses could address students’ frustration of not being able to ask questions during the online lecture is to provide a discussion board for students to pose questions. Students could answer each other’s questions, and an undergraduate or graduate TA could also help facilitate the discussions. By providing this extra source of feedback and interaction through the discussion board, students’ competence and relatedness perceptions could be better supported in a hybrid environment.

While these preliminary results are just a piece of a larger mixed-methods study, these findings can start to shed some light on the interaction of course structures and student motivation in introductory calculus courses. Results of this work will help guide mathematics faculty and administrators to create environments that are most conducive to fostering students’ motivation, thus supporting their academic achievement in calculus.
References


