IT'S ABOUT TIME: HOW INSTRUCTORS AND STUDENTS EXPERIENCE TIME CONSTRAINTS IN CALCULUS I

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The goal of this research is to better understand the relationship between how quickly or deeply Calculus material is covered and how this is related to students' instructional experience and their persistence in a STEM major. Specifically, in this report we address the following three research questions using data from a large national survey of Calculus I programs: 1) What is the relationship between Calculus I student and instructor reports of sufficient class time to develop difficult ideas?, 2) What is the relationship between student persistence and student and instructor reports of time to develop difficult ideas?, 3) What is the relationship between students' instructional experience and student and instructor reports of time to develop difficult ideas?

Nationally there is tremendous need to retain more post secondary STEM intending students. The evidence of this need is cogently summarized in the 2012 President's Council of Advisors on Science and Technology (PCAST, 2012) and includes the finding that current approaches to educating STEM majors is insufficient to meet the demands of the workforce. Moreover, the analysis in the PCAST report found that a modest 10% increase in the retention of STEM majors would go a long way to meeting these demands (see also Carnevale, Smith, & Melton, 2011).

Retaining more STEM intending students, however, has been and continues to be problematic and the subject of much scholarly inquiry. One of the most influential studies that examined why students leave STEM majors is the work by Seymour and Hewitt (1997). A primary finding from this work is that students typically do not leave STEM majors for academic or financial reasons. Instead, students are leaving STEM majors because of poor instruction in their mathematics and science courses, with calculus instruction often cited as a primary reason.

The fact that calculus tends to be overstuffed with topics and taught in a manner that does not engage students is something that has been long recognized by the broader mathematical community. Indeed, the calculus reform movement in the 1990's argued for a "lean and lively" approach to calculus, meaning that fewer topics needed to be treated in more depth and in a manner that actively engages students. With the support of the National Science Foundation, the mathematical community developed a number of innovative approaches to calculus, however evidence of lasting or systematic impact of these efforts has been minimal.

The barriers that inhibit faculty from adopting leaner and livelier approaches to instruction are complex and involve the interplay of institutional, cultural, and cognitive factors. For example, the culture of higher education where research is often valued over teaching can impeded an instructor's ability or desire to implement innovative instruction. Student centered instructional approaches are often viewed as taking more time with less material being covered (Johnson, Caughman, Fredericks, & Lee, 2013). Not surprising, concerns about coverage are often cited by faculty as reasons not to implement more student-centered instructional approaches (Christou et al., 2004; McDuffie & Graeber, 2003; Wagner, Speer, & Rossa, 2007). Research, however, continues to find that more active student instruction leads to deeper student understanding, longer retention of knowledge, more positive attitudes, and increased persistence in a STEM major (e.g., Larsen, Johnson, & Bartlo, 2013; Rasmussen & Ellis, 2013; Rasmussen & Kwon, 2007).

In summary, the previous overview points to the need to better understand the relationship between how quickly or deeply Calculus material is covered and how this is related to students' instructional experience and their persistence in a STEM major. Specifically, in this report we address the following three research questions using data from a large national survey: (1) What is the relationship between Calculus I student and instructor reports of sufficient class time to develop difficult ideas? (2) What is the relationship between student persistence and student and instructor reports of time to develop difficult ideas? (3) What is the relationship between students' instructional experience and student and instructor reports of time to develop difficult ideas?

In the first question we examine the extent to which students and instructors report similar pressure regarding the speed at which material is covered in class. We work from the premise that the issue of pacing is one that is experienced by those involved, and hence it is imperative to understand the perspective of both students and their instructor. Previous research has found that the pace in which a course proceeds and well as the nature of the instructional experience are important factors in student decision to either remain or switch out of a STEM major. So, in the second and third questions we examine the relationship between reports of time constraints to adequately develop ideas and student persistence and instructional experience.

THEORETICAL BACKGROUD

Embedded in our research questions are issues regarding the expectations of students and faculty. These expectations relate to who is responsible for learning, where learning occurs, and how much material is reasonable to cover. Theoretically, we see these types of expectations as part of the didactical contract (Brousseau, 1997). The notion of didactical contract refers to the set of reciprocal expectations and obligations between the instructor and the students, most of which are implicitly formed through patterns of interaction. For example, at the secondary school level students do not expect to have to cover large amounts of material on their own at home. Much of learning therefore occurs in class and students and their teacher are mutually responsible for learning. At the university level, however, these expectations and obligations may shift - the material covered increases, instructors tend to lecture more compared to secondary school teachers, and instructors expect students to learn more on their own at home. Students are often left feeling that their calculus course is overstuffed and taught in an uninspiring and unresponsive manner (Seymour & Hewitt, 1997). It is precisely these aspects of the didactical contract that we aim to unpack at institutions with more successful calculus programs.

METHODOLOGY

In order to answer our research questions, we will draw on data collected during the Characteristics of Successful Programs in College Calculus (CSPCC) project. CSPCC is a large empirical study designed to investigate Calculus I. While Calculus I is offered at nearly every college and university across the nation, and taken by approximately 300,000 students every fall, prior to CSPCC very little data had been collected about what happens in Calculus I. The primary focus of the CSPCC project is to identify factors that contribute to student success and understand how these factors are leveraged within highly successful programs. However, in addition to addressing these primary research goals, the CSPCC project has also amassed a wealth of data on the nature of Calculus I courses across the nation. In this report, we will draw on survey data collected during the CSPCC project. Surveys were sent to a stratified random sample of students and their instructors at the beginning and the end of Calculus I.

At the end of the term, both students and instructors were asked if they felt there was enough time for difficult ideas. Instructors were asked to respond to the prompt: When teaching my Calculus class, I had enough time during class to help students understand difficult ideas. Instructors were asked to provide a response ranging from 1 to 6 on a Likert scale, with 1 meaning “not at all” and 6 meaning ‘very often”. Students were asked to respond to the prompt: My calculus instructor allowed time for me to understand difficult ideas. Students were asked to provide a response ranging from 1 to 5 on a Likert scale with 1 meaning “strongly disagree” and 5 meaning “strongly agree”. Instructor and student responses were linked, so we could match students’ responses to their instructor’s responses. Matched responses to these prompts will be analyzed for our first research question.

To answer our second question, pertaining to persistence, we used multiple questions across surveys to classify students into four categories: Persisters, Switchers, Culminaters, and Converters. Persisters are those students who initially intended to take more Calculus and did not change from this intention at the end of the term. Switchers, on the other hand, were those students that started Calculus I intending to take more calculus, but then by the end of the term changed their plans and opted not to continue with more calculus. Culminaters are those students who began and ended the course not intending to take Calculus II. These students typically only need Calculus I for their major and hence are not STEM intending. Finally, Converters were those students who initially did not intend to take more calculus but by the end-of-term changed their mind and wanted to continue taking more calculus.

In order to understand the relationship between students' instructional experience and student and instructor reports of time to develop difficult ideas, we analyze i*nstructional practices* as reported by students. Students were asked to report the frequency of 8 instructional activities: (a) show students how to work specific problems; (b) have students work with one another; (c) hold a whole-class discussion; (d) have students give presentations; (e) have students work individually on problems or tasks; (f) lecture; (g) ask questions; and (h) ask students to explain their thinking. Students were prompted to provide a response ranging from 1 to 6 on a Likert scale, with 1 meaning "not al all" and 6 meaning "very often".

RESULTS AND DISCUSSION

To make the comparison between instructor and student reports, we computed a new value to indicate what quadrant the student would be in when graphing their response against their instructor's response, as shown in Figure 1. Throughout this paper, we use this classification to demarcate students and to understand the calculus persistence and instructional experience of students in each quadrant.

Students in Quadrant I report having enough time to understand difficult ideas and their instructors agree. Students in Quadrant II report not having enough time to understand difficult ideas but their instructors reported having enough time. Students in Quadrant II report not having enough time to understand difficult ideas and their instructors agree that there wasn't enough time. Finally, students in Quadrant IV report having enough time to understand difficult ideas though their instructors reported not having enough time. From the lens of the didactical contract, students in Quadrants I and III share similar expectations as their instructors regarding the pace of the course and how much material is reasonable. Students in Quadrants II and IV have different expectations than their instructors regarding the pace of the course and different conceptions of the didactical contract within Calculus I.

As shown in Figure 1, almost 60% of students and their instructors agreed that there was enough time in class for them to understand difficult ideas, and around 6% of students and their instructors agreed that there was *not* enough time for them to understand difficult ideas. Nearly 15% of students felt that there was not enough time while their instructors thought there was, and almost 20% of students felt there was enough time while their instructor thought there was *not* enough time.

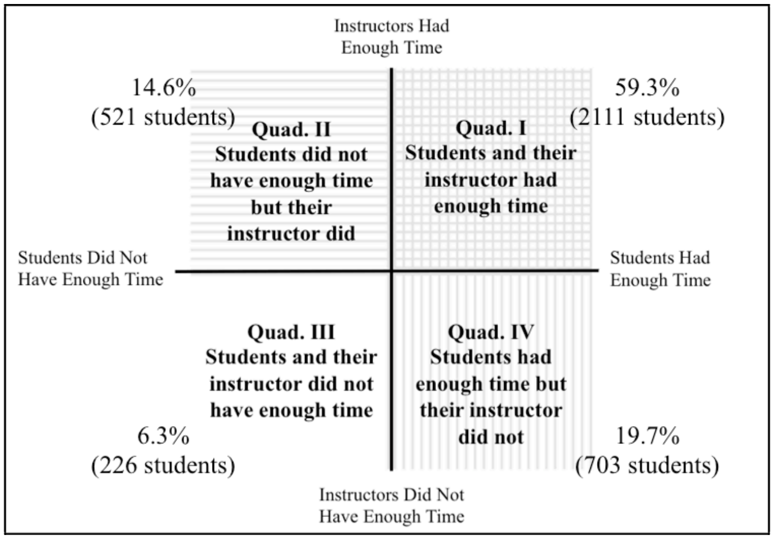

Figure 1: Classification of students based on agreement with instructor.

This data indicates that while the majority of students were in agreement with their instructors that there was enough class time to understand difficult ideas, there are many students that perceive the pacing of the class differently than their instructors, either as having more or less time than their instructors report. While this is an interesting finding on its own, we are more interested to know how the agreement or disagreement with ones instructor on the pacing of the course is related to student persistence. Do students who report not having enough time to understand difficult ideas while their instructors think there is enough time switch Calculus II intentions more often than other students?

In Figure 2 we report the percentage of students who switched their Calculus II intentions after taking Calculus I for each type of student described above. In the sample of students involved in this analysis, 11.6% overall were determined to switch their Calculus II intention.

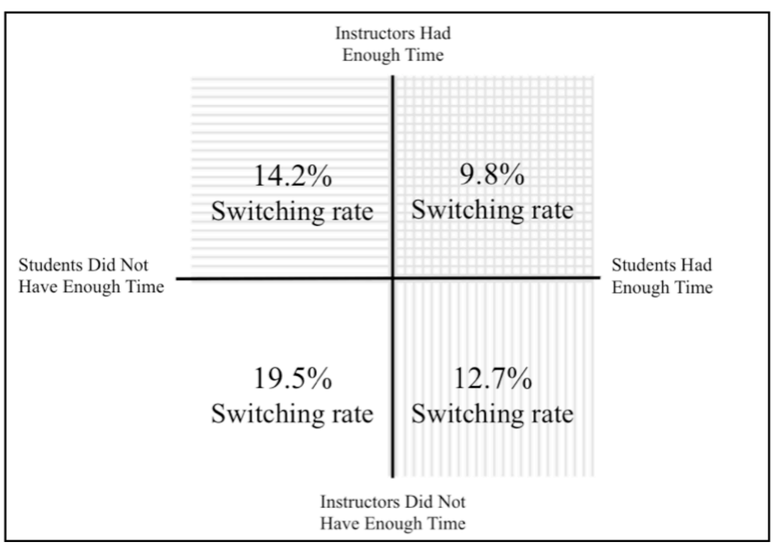

Figure 2: Relationship between persistence and reports of pacing.

As shown in Figure 2, there was a significant relationship between student and instructor agreement on reports of pacing and student persistence in calculus (χ^2 (3, N = 3561) = 24.85, $p < .001$). Specifically, 9.8% of students in Quadrant I switched their Calculus II intentions, 14.2% of students in Quadrant II switched their Calculus II intentions, 19.5% of students in Quadrant III switched their Calculus II intentions, and 12.7% of students in Quadrant IV switched their Calculus II intentions.

As reported by Rasmussen and Ellis (2013), 11.6% of students in this sample were determined to be switchers (i.e., switched their Calculus II intention). We see that students in Quadrant I, who reported having enough time to understand difficult ideas and their instructors agreed, switched at a lower rate than the sample proportion. Students who did not feel like they had enough time (in Quadrant II and Quadrant III) switched at a much higher rate that the sample proportion. This implies that feeling rushed to cover difficult material is a factor in losing STEM intending students, consistent with Seymour and Hewitt's (1997) findings.

These findings indicate that students who switch their Calculus II intention are most likely to come from classes where they feel there is not enough time to understand difficult ideas and where their instructors agree. Concerns about pacing and coverage are often pointed to as reasons not to implement student-centered pedagogy, although the literature consistently points to the benefits of this instruction on students. Next, we investigate the relationship between students' instructional experiences and reports of time to develop difficult ideas. Table 1 shows the results of the ANOVA comparing student reports of the eight instructional practices within each quadrant. All differences were significant at the $p = .001$ level.

How frequently did your instructor:	QI (N~2419)	QII (N~621)	QIII (N~301)	QIV (N~854)
show how to work specific problems?	5.18+ (.923)	4.48^(1.309)	4.39^ (1.423)	5.14+ (.941)
have students work individually…?	3.98+ (1.574)	3.18^ (1.679)	3.22^ (1.711)	3.87+ (1.692)
lecture?	4.86^ (1.298)	4.92^ (1.479)	5.40+ (1.102)	5.38+ (.923)
ask questions?	4.89+ (1.019)	3.75^ (1.343)	3.68^ (1.336)	4.80+ (1.118)
have students work with one another?	3.65+ (1.921)	2.87^ (1.867)	2.32^ (1.545)	2.96^ (1.774)
hold a whole-class discussion?	3.84+ (1.770)	2.74^ (1.688)	2.22^ (1.556)	3.27^ (1.788)

have students give presentations?	2.04+ (1.527)	1.53^ (1.063)	1.28^ (.819)	1.63^ (1.293)
ask students to explain their thinking?	4.23+ (1.501)	2.89^ (1.611)	2.37^ (1.379)	3.73 (1.586)

Note. +=Values higher than overall average by .05, ^=Values lower than overall average by .05

Table 1: Student reports of instructional practices by Quadrant.

These analyses paint four very different classroom images. In Quadrant I, where students and their instructors agree that there was enough time to understand difficult ideas, there are higher than average reported frequencies of all instructional activities except for lecture. So, in classes where the students and instructors felt like there was enough time for understanding difficult ideas, there were more student-centred activities. In Quadrant IV, where students had enough time but their instructors did not, there are higher than average reported frequencies of showing students how to work specific problems, having students work individually on problems, lecture, and asking questions, and lower than average or average on the other practices. This indicates that when instructors felt some pressure to cover material, student-centered teaching practices were jettisoned.

Quadrant II is populated by students who did not have enough time but whose instructor did. This quadrant is characterized by lower than average reported frequencies of all pedagogical activities, as compared to the other quadrants. Finally, in Quadrant III students and their instructors agree that there was not enough time in class to understand difficult ideas. In these classes, students reported higher than average levels of lecture and lower than average levels of all other practice. This environment appears very traditional and is consistent with the literature indicating that when there is a pressure for time, student-centered practices are sacrificed.

CONCLUSION

These results indicate that we are most likely to lose STEM intending students in classes in which they do not feel like they have enough time to learn difficult material. We saw especially large rates of students who changed their plans and opted not to continue with more calculus when both the students and their instructor felt that they did not have enough time. Interestingly, these classes are also characterized as very traditional, with high levels of lectures and low levels of any other instructional practice. These results are contrasted with results from classes in which students and instructors both feel that they have enough time. In these classes, where there is a variety or traditional and student-centered instruction, students are more likely to continue with their intentions of taking further calculus courses.

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