Identifying Instructional Autonomy Approaches in Calculus and its Connection with Student's Perceived Classroom Climate

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Calculus courses are an integral component for STEM degree attainment yet are historically attributed to high attrition rates and lowering student confidence. Although prior research identified coordination of instruction as a successful characteristic of Calculus programs, there is a need to further examine the role of Instructor Autonomy (e.g., decision making on content and instruction) and its potential impact on student perceptions of the climate. We analyzed data from two national studies of introductory math courses focusing on instructor (N=321) reports of course decision making and student (N=14,488) reports of climate. Preliminary results indicated a great deal of variability in Instructor Autonomy across the Precalculus to Calculus 2 sequence within our sample and even within a department. Narrowing our focus to Calculus 1, variability in Instructor Autonomy persisted and student perception of climate was not unified; however, courses that utilized team-based decision making promoted higher student perceptions of climate.

Keywords: course coordination, calculus, instructor autonomy, student voice

Research indicates Calculus 1 is effective in lowering student's confidence, their enjoyment of mathematics, and their desire to continue in a discipline or future course where mathematics is needed (Bressoud & Rasmussen, 2015). Globally, Calculus 1 courses are associated with high failure rates and attrition (Cavalheiro & Grebot, 2021; Hagman et al., 2017). In the United States, Calculus 1 averages a 22 percent DFW rate, the percentage of students who receive a grade of D, receive a grade of an F, or withdraw from the course (Rasmussen et al., 2019)—about one out of every five students. As such, efforts have increased towards the recruitment and retention of students (Calleros & Zahner, 2021; Patrick & Borrego, 2016) through the improvement of introductory math courses.

From 2009 to 2015, a national study of college Calculus 1 courses was conducted to measure what characteristics of Calculus 1 influenced student success. The Characteristics of Successful Programs in College Calculus (CSPCC) study aimed to improve retention rates for students in Science, Technology, Engineering, and Mathematics (STEM) majors (Bressoud & Rasmussen, 2015). The CSPCC study launched a national survey (n=212) to two- and four-year institutions and conducted case studies of 16 institutions identified as having successful programs in Calculus. The study identified seven characteristics of successful Calculus programs: 1. Regular use of curricular and structural modifications; 2. Attention to the effectiveness of placement procedures; 3. **Coordination of instruction, including building communities of practice**; 4. Construction of challenging and engaging courses; 5. Use of student-centered pedagogies and active-learning strategies; 6. Effective training of graduate teaching assistants; 7. Proactive student support services.

As identified by the CSPCC study, coordination of instruction is a characteristic of successful Calculus programs. Course coordination, as defined by Rasmussen and Ellis (2015), consists of two features, uniform course elements and regular instructor communication. Uniform course elements are elements of a course that are the same for every student across a multi-section course (e.g., textbook, topics, common homework, common tests). Regular instructor communication are moments when instructors contact and support each other regarding aspects of the course. With these two features, course coordination aims to reduce variation across multiple sections of a course by providing consistent experiences (Rasmussen & Ellis, 2015). When it comes to the uniform elements implemented and the frequency of communication with instructors, there is not one blueprint for implementation (Apkarian et al., 2019).

Methods

Data from this analysis comes from two national studies of college Calculus, the Progress through Calculus (PtC) study and the Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) study. PtC cataloged departmental efforts in improving student success and documenting the effectiveness of implementation efforts (Rasmussen et al., 2019), while SEMINAL researched systematic change in mathematics departments towards the use of active learning in introductory mathematics courses (Smith et al., 2021). Both studies conducted in-depth case studies at 20 universities and implemented the X-PIPS-M Survey suite (Apkarian et al., 2019) for instructor, student, and teaching assistants (both graduate students and undergraduate students) across several academic terms.

Through a case study approach with constant comparative methods, we explored and evaluated instructor autonomy and student reports of the perceived classroom climate. The PtC and SEMINAL data sets have three categories of courses namely, Precalculus, Calculus 1, and Calculus 2. All institutions were coded according to their institutional characteristic as a Historically Black College or University (HBCU), as a Hispanic Serving Institution (HSI), or as a Predominantly White Institution (PWI) to both anonymize the institution as well as provide another way to compare institutions and trends. In total we had instructor and student data from 20 institutions with a total response of 321 instructors and 14,488 students. For the 9 institutions that had teaching assistants there were a total of 328 responses.

Instructional Autonomy

To analyze instructor autonomy, we looked at the instructor responses to the Likert scale questions on who was making the decisions about the course content and the instructional approach. Specifically, instructors answered the questions;

1. "How are most decisions about <u>course content</u> (e.g., syllabi, exams, homework, pacing, grading) made for the course? Clarify if you wish." and
2. "How are most decisions about <u>instructional approach</u> (e.g., use of clickers, group work, active learning) made for the course? Clarify if you wish."

with answer options of *1 ("I make most decisions"), 2 ("I am part of a team that makes most decisions"), or 3 ("Someone else makes most decisions")*. To better help understand the data, we developed a classification table to categorize the level of autonomy instructors had in their course, see table 1 (Instructor Autonomy). To classify a site using the Instructor Autonomy table we looked per site per instructor autonomy question. For the two questions we noted which answer choice had the highest percentage of instructor response per site. Given the exploratory nature of this analysis, categorization based on highest percentage allowed for further exploration and reflected the lived reality of instructors but does fail to capture the level of agreement between instructors. Then we combined the classification of the highest percentage of responses for the approach and the content to get the overall instructor autonomy per site for the course. For example, if HSI 1 had 60% of instructors say someone else decides content and 52% of instructors say they are part of a team that decides the approach, the site would be classified as

“Collective Approach Top Down Content”. Due to 1 institution having too much variability and low response rates we chose to exclude PWI 14 from the analysis leaving us with 19 institutions. For analysis, after determining the instructor autonomy classification we compared and contrasted across sites, course levels, and within institutional characteristic groupings.

Student Classroom Climate

To evaluate the perceived classroom climate from the student’s perspective we looked at three 5-scale Likert questions asking the student to describe the overall climate. Questions asked about the intellectual engagement, academic rigor, and atmosphere the student perceived in the Calculus courses as seen below,

“How would you describe the overall climate within [Calculus 1]?

1. Excluding and Hostile (1) _ _ _ _ _ Including and Friendly (5) [Atmosphere]
2. Intellectually boring (1) _ _ _ _ _ Intellectually Engaging (5) [Intellectual Engagement]
3. Academically Easy (1) _ _ _ _ _ Academically rigorous (5) [Academic Rigor]”

For analysis we compared and contrasted institutions across the average of the three climate questions. We then looked for possible trends between the site's instructor autonomy classification and the student’s perceived climate by use of the institutional characteristics. Through grouping institutions by their institutional characteristics we also examined the student data to note any trends within a particular group of institutions that could then be compared to the other institutional characteristics groupings.

Preliminary Results

Initial analysis of looking across course level (Precalculus, Calculus 1, and Calculus 2) revealed that as the sequence of Calculus progressed there was more instructor autonomy. 35% of all Precalculus instructors stated they choose their content whereas 44% of Calculus 1 instructors and 49% of Calculus 2 instructors stated they choose their own content. With decision on approach 67% of Precalculus instructors stated that they choose their own approach whereas 73% of Calculus 1 and 80% of Calculus 2 instructors stated they choose their own approach. With this trend of seeing more individual choice as the Calculus sequence progressed, we still witnessed variation within a course level on the type of instructor autonomy. Meaning that in our data set, Precalculus courses had a larger variety of instructional autonomy approaches (10 variations), compared to Calculus 1 (8 variations) and Calculus 2 (8 variations). It is worth noting that of the 19 analyzed institutions there are 16 institutions with Precalculus, 19 institutions with Calculus 1, and 18 institutions with Calculus 2 responses. Therefore, while Precalculus had the fewest institutions represented, it had the largest number of different instructor autonomy types.

Analysis of looking across courses within an institution determined that most institutions (15 of 19) have differing categories of instructor autonomy across their Calculus sequences. From those 15 institutions, six institutions had the same categorization for two of their courses with most of the same categorization being seen in the Calculus 1 and Calculus 2 courses - highlighting how Precalculus can often be disconnected from the course sequence. The remaining 9 institutions had no categorizations in common across their Calculus sequences. For the remaining four institutions that have the same categorization of instructor autonomy, three of those institutions only had data from two of the courses in the sequence, meaning only one institution (HBCU 1) had the same level of instructional autonomy across the entire sequence.

Given the variation in instructor autonomy within an institution across course level we decided to move forward with our analysis of just Calculus 1 courses across the 19 institutions.

We began the deep dive into Calculus 1 by categorizing the instructor autonomy (see Table 1), noting that there were many institutions that had a split highest percentage on who was deciding the content in the department.

Table 1. Categorization of Instructor Autonomy Approaches of Calculus 1 Courses

		Decision on Instructional Approach		
		I decide	*Team Decides*	*Someone Else Decides*
Decision on Course Content	*I decide*	Full Individual Autonomy- **PWI 1, PWI 5, PWI 11, PWI 7, HSI 1, HSI 3, HBCU 1**	Collective Approach Individual Content- **PWI 9**	
	Split Individual and Collective	Individual Approach Split Individual and Collective Content- **PWI 4, PWI 12, PWI 15**		
	Team Decides	Individual Approach Collective Content- **PWI 3, PWI 8, HSI 2**	Team Collective Autonomy- **HSI 4**	
	Split Collective and Top Down	Individual Approach Split Collective and Top Down Content- **PWI 10**		
	Someone Else Decides	Individual Approach Top Down Content- **PWI 6, PWI 13**		Top Down Highly Coordinated- **PWI 2**

By organizing the institutions into the Instructor Autonomy table, we can see that the majority of Calculus 1 instructors are getting to choose their own instructional approach but there is a lot of variety in who is deciding the content of the course. We see that 11 of the 19 institutions are experiencing a form of coordination with who is deciding content as there is another voice of a team or more of a top down coordination happening even within the split categories. To better understand what was happening in these varied Calculus 1 courses we analyzed student data about their perceived climate within the classroom.

For the climate questions on atmosphere, intellectual engagement, and academic rigor we looked at the means and standard deviations for instructor autonomy categories. Recall these climate questions are all based on a 5-scale Likert style question with 5 being representative of a more friendly atmosphere, more intellectually engaging, and more academically rigorous. Notice that the individual approaches seem to lead the student perception of the atmosphere to be lower (i.e. less friendly) and are exacerbated by also having top down content, as seen in the Individual Approach Top Down category. The highest ranking of the classroom atmosphere is in the Team Collective Autonomy approach where instructors are working in a team to decide the content and approaches in the classroom. We also see a similar pattern for the engagement question, highest ranking of engagement in the Team Collective Autonomy and lower in the individual approaches with an exacerbated effect when individual approach is paired with a top down content. Within the rigor question there is a less clear pattern which may be a result of the student interpretations of the questions and thus requires further analysis. It is noteworthy that we are not seeing a more unified student experience in the top down courses as the standard deviations are within the same relative range across all categories of courses.

Table 2. Student Perceptions of Climate by Instructional Autonomy Approaches

Instructional Autonomy Classification	Number of institutions	Atmosphere	Engagement	Rigor
		Mean (SD)	Mean (SD)	Mean (SD)
Full Individual Autonomy	7	4.13 (1.01)	3.57 (1.24)	4.07 (.99)
Individual Approach Split Individual and Collective Content	3	4.24 (.91)	3.59 (1.17)	3.93 (.96)
Individual Approach Collective Content	3	4.23 (.92)	3.61 (1.21)	3.62 (1.14)
Individual Approach Split Collective and Top Down Content	1	4.15 (.99)	3.59 (1.20)	3.90 (.99)
Individual Approach Top Down Content	2	3.95 (1.02)	3.49 (1.16)	4.11 (.98)
Collective Approach Individual Content	1	4.03 (.95)	3.57 (1.18)	4.03 (.955)
Team Collective Autonomy	1	4.48 (.80)	4.07 (1.05)	3.70 (1.04)
Top Down Highly Coordinated	1	4.06 (1.06)	3.40 (1.24)	3.74 (.99)

Discussion

From our investigation we found that when looking across the Calculus sequence there is a great deal of variation happening across the 19 institutions, with greater variability in Precalculus, and variability within an institution. It was seen in the student data that there was the same level of variability of reported climate even within the top down courses, but team collective approaches may support the highest levels of reported climate. These findings seem to support prior research on the efficacy of course coordination as a successful characteristic of Calculus programs (Rasmussen & Ellis, 2015). Additional analysis is needed to examine the perceptions of the students who are moving through an institution's Calculus sequence where each level of course has a different category of instructor autonomy. Lastly, we would like to examine institutions that do have the same level of instructor autonomy throughout to explore the instructor perceptions as well as the student experience.

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