Student, Teacher, and Institution Effects on Student Achievement and Confidence in College Calculus

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Using the Mathematical Association of America's Characteristics of Successful Programs in College Calculus dataset (CSPCC) of 13,965 students from a variety of institutions nationwide, student characteristics and experiences were analyzed via pre- and post-course survey responses. This research evaluated the effect of student background, student-reported teaching behaviors, and institutional environments on academic achievement and student confidence. The findings of this research could lead to a better understanding of the impact of calculus teaching practices and the implications of retaking calculus for students of all experience levels.

Keywords: post-secondary calculus, pedagogical behaviors, student confidence

Approximately 61% of students taking Calculus I in a postsecondary school have already taken a calculus course in high school (Bressoud, 2015), with students of all demonstrated proficiency levels who took calculus in high school receiving higher grades in post-secondary Calculus I than their counterparts (Sadler & Sonnert, 2018). Existing research has explored the relationships between previous calculus experience and performance, as well as the relationships between different types of instructional strategies in postsecondary calculus classes (Bressoud, Mesa, & Rasmussen, 2015; Ellis, Fosdick, & Rasmussen, 2016; Ellis, Kelton, & Rasmussen, 2014; Mesa, Burn, & White, 2015; Sonnert & Sadler, 2015). However, the interaction of these instructional strategies with students' confidence remains underexplored.

Using the Characteristics of Successful Programs in College Calculus dataset (CSPCC), this study contributes to the existing knowledge of college calculus by examining the impact of previous calculus experience on students' confidence in a post-secondary Calculus I class.

Calculus I in the Postsecondary Setting

The choices made by instructors regarding in-class behaviors and homework have arguable impacts on student confidence and performance. Different categories of teaching behaviors have emerged from the CSPCC dataset. Three factors defined as 'good' teaching, technology, and ambitious teaching were found to have differing impacts on students' attitudes towards math; 'good' teaching had a positive impact, technology had no significant impact, and ambitious pedagogy had a negative impact (Sonnert & Sadler, 2015). These impacts varied further when students were grouped by performance. High performing students responded to progressive behaviors more positively than low performing students (Sonnert & Sadler, 2015). Other research expanded on these three factors and broke 'good teaching' behaviors into three categories: Classroom Interactions that Acknowledge Students, Encouraging and Available Faculty, and Fair Assessments (Mesa et al., 2015). Approximately half of Calculus I homework is submitted on paper, though homework that is graded is most often done so via on online homework system (Bressoud et al., 2015). However, the use of online homework has uncertain effects on student outcomes (Bressoud et al., 2015). This study builds upon the categories previously created by Sonnert and Sadler (2015). and Mesa, et al. (2015) with an exploration of homework categories and textbook choice as teaching behaviors and an additional focus on confidence as a student outcome.

This study contributes to an existing body of literature that has used CSPCC to identify elements of calculus instruction that impact student outcomes such as performance and confidence. These student outcomes are influenced by a student's characteristics and prior experiences as well as the post-secondary Calculus I instruction they receive. In particular, we ask:

- What are the effects of previous math background, classroom interactions, and institutional environments on student outcomes such as student confidence and performance in post-secondary calculus education?

Conceptual framework

This research draws on the framework for instruction as interaction framework (Cohen, Raudenbush, & Ball, 2003), which focuses on the dynamic between students, teachers, and learning environments. Our quantitative study utilizes categorical and numeric variables that fall into different domains of the framework: student, instructor, and institutional levels. In particular, we focus on student and teacher interactions within the institutional environment; analyze the impact of teacher behaviors, we take into consideration other influences on student outcomes at the institution, instructor, and student levels.

Research Methodology and Results

Sample

Our sample draws from the CSPCC dataset, which was comprised of pre- and post-course survey responses from 13,965 students and 496 instructors, at 169 institutions of varying types across the United States. For our analysis, we retained students who had complete data on the variables of interest, resulting in a final sample of 2,831 students. The demographics of the analytic sample closely mirror those of the full sample (Table 1).

Table 1. Full and Analytic Sample Demographics

CSPCC Full Sample			Analytic Sample		
	N	%		N	%
Institutions	169		**Institutions**	131	
Associate's	40	23.67	Associate's	25	19.08
Bachelor's	41	24.26	Bachelor's	30	22.90
Master's	21	12.43	Master's	15	11.45
PhD	67	39.64	PhD	61	46.56
Instructors	496		**Instructors**	333	
Students	13,965		**Students**	2,831	
White	6,947	70.69	White	2125	75.06
Black	456	4.64	Black	67	2.37
Asian	1,340	13.63	Asian	365	12.89
American Indian or Alaska Native	128	1.30	American Indian or Alaska Native	34	1.20
Hispanic	957	9.74		240	8.48
Male	5,688	56.36	Male	1,556	54.96
Prior Calculus Experience	6,837	65.77	Prior Calculus Experience	2,018	71.28

Creation of Composite Variables

The CSPCC dataset has numerous instructional variables and prior work has studied student perception of specific instructor behaviors (Ellis et al., 2014). However, we hope to expand upon this work by considering confidence as a student outcome and by further stratifying types of pedagogical behaviors. To create our instructional composites, we used pre- and post-course survey responses of the students. These variables were created first by combining survey questions that, on a conceptual level, addressed teaching behaviors of distinct types. This was an iterative process that went through conceptual and then statistical testing. The initial instructional categories were: Encouraging students, Fair exams, Interpersonal interaction, Student use of technology (Graphing calculator), Instructor use of technology, Student use of technology (CAS), Cognitively challenging homework, and Valuing students.

Once categorized, we analyzed these collections of questions with a principle component analysis (PCA) to determine the questions with the strongest correlation. After running a PCA on each composite and eliminating survey questions that did not load on the same factor as the others or were not conceptually compatible with other questions, we were left with composites of 3 to 9 items, all with Cronbach alpha scale reliability coefficients greater than .75. After this process was complete, we decided to remove the Student use of technology, Fair exams, and Cognitively challenging homework composites as the factor reports had low scale reliability coefficients. The Valuing students composite was removed because we determined, after additional scrutiny, that it was encompassed by the Encouraging composite.

Analysis

For our analysis, we used hierarchical linear modeling (HLM) with three levels, with students working under instructors who are operating within an institution. We ran a series of HLM models, adding covariates in blocks of related variables. Every model clusters on the three levels. In addition, this model, and all others, are weighted by institution type, as the original data over-sampled universities and under-sampled community colleges (Bressoud, 2015). The sample weight was created using the CBMS (Blair, Kirkman, & Maxwell, 2013) distribution of Calculus I students by institution type. When evaluating student outcomes, performance is measured on a 0-4 scale while student confidence is measured on a 0-5 scale.

Results

Table 2. Course Grade

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Student Variables						
ACT/SAT		2.108***	2.001***	2.315***	2.198***	2.187***
Prior Calculus		0.253***	0.252***	0.333***	0.314***	0.315***
Race						
Black			-0.228	-0.204	-0.182	-0.188
Asian			0.142**	0.159***	0.127**	0.130**
P.I., A.I., or A.N.			-0.04	-0.041	-0.062	-0.075
Hispanic			-0.118	-0.099	-0.093	-0.097
Gender			0.045	0.044	0.026	0.029
Parent Educ. Level						
Some College			-0.071	-0.027	0.003	0.01
College			-0.138*	-0.047	-0.028	-0.023
Graduate School			-0.058	0.02	0.044	0.052
Instructor Variables						
Homework Type						

Physical				0.319*	0.17	0.171
Online				0.256+	0.155	0.154
Student Use of Tech.				0.088	0.103	0.159+
Instructor Use of Tech.				0.148	0.017	-0.04
Class Size[a]						
30-70				0.108+	0.07	0.109+
70+				0.127+	0.110+	0.173*
Textbook						
Hughes Hallett				-0.193**	-0.199***	-0.255***
Thomas				-0.057	0.007	-0.001
Rogawski				-0.155+	-0.023	-0.029
Anton				0.013	-0.037	-0.081
Other				0.007	0.056	0.015
Retaking Ratio				-0.628***	-0.467**	-0.522**
Encouragement					1.496***	1.503***
Interpersonal					-0.111	-0.119
Institution Type						
BA						0.125
MA						-0.049
PhD						0.003
Constant	3.136***	3.016***	3.071***	2.972***	1.994***	1.976***

*+ p<0.10, * p<0.05, **p <0.01, ***p< 0.001*

[a] Class size was estimated from the averages of instructor reports of enrollment.

Note. The baseline student is a white female with an average SAT/ACT score and no previous calculus experience attending a two-year institution. She receives instruction in a small classroom that employs none of the given methods, uses the Stewart text, and does not use homework. Neither of her parents went to college.

Note. Pacific Islander (P.I.), American Indian (A.I.), and Alaskan Native (A.N.) were combined due to sample size.

Note. Models were run using Stata.

Table 3. Student Confidence

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Student Variables						
Prior Confidence		0.569***	0.384***	0.355***	0.354***	0.355***
ACT/SAT			-0.169	0.152	0.152	0.173
Prior Calculus			0.058	0.112**	0.114*	0.115*
Course Grade			0.580***	0.486***	0.490***	0.488***
Race						
Black			-0.033	-0.03	-0.025	-0.022
Asian			-0.191*	-0.212*	-0.203**	-0.195**
P.I., A.I., or A.N.			0.117	0.084	0.068	0.072
Hispanic			-0.098	-0.087	-0.086	-0.077
Gender			0.163***	0.134***	0.132***	0.130***
Parent Educ. Level						
Some College			0.031	0.066	0.055	0.065
College			0.019	0.05	0.046	0.051
Graduate School			-0.035	0.008	0.005	0.018
Instructor Variables						
Retaking Ratio				-0.288*	-0.361**	-0.360*
Encouragement				1.598***	1.566***	1.588***
Interpersonal				0.052	0.146	0.128
Homework Type						
Physical					-0.292+	-0.331+
Online					-0.262	-0.288+
Student Use of Tech.					-0.084	-0.067

Instructor Use of Tech.					-0.105	-0.151
Class Size[a]						
30-70					-0.02	0.006
70+					0.01	0.081
Textbook						
Hughes Hallett					-0.06	-0.06
Thomas					-0.166**	-0.134*
Rogawski					0.007	0.029
Anton					-0.034	-0.077
Other					-0.105+	-0.114+
Institution Type						
BA						0.083
MA						0.138
PhD						-0.022
Constant	1.263***	1.301***	1.471***	0.122	0.604**	-0.233

*+ p<0.10, * p<0.05, **p <0.01, ***p< 0.001*

[a] Class size was estimated from the averages of instructor reports of enrollment.

Note. The baseline student is a white female with an average SAT/ACT score and no previous calculus experience attending a two-year institution. She receives instruction in a small classroom that employs none of the given methods, uses the Stewart text, and does not use homework. Neither of her parents went to college.

Note. Pacific Islander (P.I.), American Indian (A.I.), and Alaskan Native (A.N.) were combined due to sample size.

Note. Models were run using Stata.

Preliminary results indicate that Encouraging students, Homework type, and Student use of technology (graphing calculator) are pedagogical methods that have a significant relationship with student performance. Encouragement and homework also significantly influence student confidence. The overwhelming influence of encouraging behavior paints a clear picture: instructors demonstrating their care for their students can significantly positively impact student confidence and grades. There is an evident need for compassionate Calculus I instruction to boost student morale and achievement.

We also have found students' previous math experiences to be significant in relationship to their confidence; students who have seen calculus before and/or fared well on standardized tests are more confident in Calculus I courses. After observing the influence of previous calculus experience on a student's individual post-secondary calculus experience, we would like to continue our work on the peer effects within Calculus I classrooms and the influence of the ratio of calculus retakers within a classroom as an environmental factor.

The Cognitively challenging homework composite caught our interest despite our inability to include it in our models; we plan to further investigate the influence of homework types, class size, and the student/instructor ratio in future work.

Implications for Teaching Practice and Future Research

This research has implications for the instruction of college calculus courses, specifically encouraging efforts to demonstrate care for students and direct instruction towards students who are taking calculus for the first time. Future work should focus on the effects of homework type and textbook choice as instructor behaviors.

Intended Questions for the Audience

Is there other research that supports this relationship between encouraging behavior and student performance? Any suggestions for a qualitative follow-up study?

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