Characteristics of Successful Programs in College Calculus: Pilot Case Study

Sean Larsen Portland State University
Estrella Johnson Portland State University
Steve Strand Portland State University

Abstract

The CSPCC (Characteristics of Successful Programs in College Calculus) project is a large empirical study investigating mainstream Calculus 1 to identify the factors that contribute to success, to understand how these factors are leveraged within highly successful programs. Phase 1 of CSPCC entailed large-scale surveys of a stratified random sample of college Calculus 1 classes across the United States. Phase 2 involves explanatory case study research into programs that are successful in leveraging the factors identified in Phase 1. Here we report preliminary findings from a pilot case study that was conducted at a private liberal arts university. We briefly describe the battery of interviews conducted at the pilot site and discuss some of the themes that have emerged from our initial analyses of the interview data.

Key Words: Calculus, Explanatory Case Study, STEM Student Retention

Issues Explored & Relation to Research Literature

The CSPCC (Characteristics of Successful Programs in College Calculus) project is a large empirical study investigating mainstream Calculus 1 to identify the factors that contribute to success, to understand how these factors are leveraged within highly successful programs. Calculus 1 is *the* critical course on the road to virtually all STEM majors. However, while more students are taking more advanced mathematics in high school than ever before—including over half a million each year who study calculus while in high school (Bressoud, 2009)—the percentage of all college students in 4-year undergraduate programs who are enrolled in mathematics at the level of calculus or above has decreased steadily from 8.93% in 1990 to 6.36% in 2005, a decrease of 29% (Lutzer *et al*, 2007). In Seymour's (2006) testimony to Congress, she noted that, contrary to what is commonly assumed, students do not leave STEM majors primarily for financial or academic reasons. Instead, they leave STEM majors because of poor instruction in their mathematics and science courses, with calculus instruction and curriculum often cited as a primary reason for students' discontinued STEM course taking (Thompson *et al.*, 2007).

Phase 1 of CSPCC entailed large-scale surveys of a stratified random sample of college Calculus 1 classes across the United States. Phase 2 involves explanatory case study research into programs that are successful in leveraging the factors identified in Phase 1. This second phase will lead to the development of a theoretical framework for understanding how to build a successful program in calculus and in illustrative case studies for widespread dissemination. Sixteen institutions have been selected as case study schools based on the results from the survey phase. The set of case study schools includes four community colleges, four bachelors granting institutions, four masters granting institutions, and four PhD granting institutions. In preparation for this case study phase of the project, the team assigned to the bachelors granting institutions conducted a pilot case study at a private liberal arts university. This university was selected because the bachelors degree was the highest mathematics degree offered by the university and because the institution's calculus pass rate was comparable to (actually higher than) the

institutions identified as successful during the survey phase. Note that he institution was not part of the sample that participated in Phase 1). In this preliminary report, we will share some of the findings from the ongoing analysis of this pilot study.

Research Methodology & Conceptual Framework

While crafting the proposal for the CSPCC project, the PI's developed initial hypotheses as to the factors that could impact student success in Calculus I:

Instructor attributes: professional status (e.g. rank), professional preparation to teach calculus, awareness of common difficulties and misconceptions, and attitude toward institution, students, and teaching.

Departmental focus: placement exams, explicit learning goals, use of standardized exams, professional development opportunities, monitoring of student retention.

Classroom variables: size of class, text and curriculum, use of recitation or laboratory sections, incentives for attendance, format and mix of presentation (lecture, small group interaction, question/answer), use of calculators, frequency and nature of assessments, use of pedagogical strategies to increase active participation by students.

Out of class expectations: homework policy (including use of web-based tools to grade and/or provide feedback on homework), hours spent studying each week, encouragement of study groups, use of Learning Center, writing assignments, group projects.

Starting from these hypotheses, the CSPCC team worked collaboratively to develop a series of interview protocols. The data collection plan calls for interviews of instructors, calculus coordinators, administrators, students, tutor center personnel, and representatives of client disciplines. Additional data collection includes collection of assessment and program evaluation documents, exams, and placement tests. The data collected (not including collected documents) for the pilot case study is detailed in Table 1.

Data Collection Protocol	Interview Subject
Department Chair Interview	Chair of Mathematics Department
Instructor Interview	Instructor A, B, and C
Calculus Coordinator	Instructor A
Placement Sub-Interview	Instructor B
Student Focus Group Interview	Students of Instructor A (n=3) and B (n=7)
Dean Interview	Dean of the College of Arts and Sciences
Client Discipline Interview	Associate Dean – School of Engineering
Learning Center Interview	Tutor Center Director
(Modified) Learning Center Interview	Freshman Resource Center Director
Tutor Interview	Undergraduate Tutor
Teaching Center Interview	Director of Center for Teaching and Learning
Classroom Observation Protocol	Classroom of Instructor A, B, and C

Selected Preliminary Results of the Research

Analyses (of audio recordings) of interviews are being guided by the initial hypotheses described above and by a set of analytic codes that emerged during an initial open coding phase. Note that the goal of the study is to produce explanatory case studies. Our preliminary analysis is an initial step toward this goal and has resulted in the identification of several factors that the pilot study participants consider to be crucial to the success of their calculus program. These include:

- Placement
- Coordination
- Culture
- Resources and Administrative Support
- Faculty
- Freshman Support System
- Regular Auditing and Review of Progress (Resulting in Action)

Here we will briefly discuss placement and culture:

Placement. One year prior to our data collection, the department adopted a placement exam developed by the Mathematical Association of America. Since the adoption of this placement exam, the pass rate in Calculus 1 has increased from 78% to 89%. The exam is taken during the students' senior year of high school and the results are sent to the freshmen scheduler at the university. Every student must take the placement exam, including those who have passed Advanced Placement (AP) exams. The department also recently implemented a rule establishing a C- as the cutoff for passing Calculus 1 (previously it was D-). One important impact of these changes is that the previous stigma attached to taking pre-calculus at the institution has been greatly diminished as pre-calculus enrollment has increased dramatically.

"One of the things that the placement test has done is it's made it ok to take pre-calculus. When I first taught it, I had nine students in pre-calculus. Teaching that class was horrible since all the students felt like it was shameful and they were embarrassed. Now we have two classes of 30 and it's wonderful." –Instructor C

Culture. Teaching is the top priority at the university (even Deans are required to teach a course). The calculus professors (almost always tenure track faculty) have very generous office hours and constantly encourage students to come for help, using strategies such as requiring them to come to office hours to pick up their graded exams. The calculus instructors have semi-regular meetings and frequent informal conversations about teaching and learning. This is an observation that was made by almost everyone that we interviewed including the Dean, the department chair, the faculty and students.

"From what she's mentioned in the class, and the few times I've seen her in office hours, it seems like they're like a little math family. They're a little math community. Everyone's always talking… I've seen them go into other people's rooms and you hear like laughing coming down the hallway sometimes. – Student of Instructor A

Implications for Practice or Further Research

The CSPCC project has aims to have a significant impact on practice by providing models of successful calculus programs. One form these models will take is that of explanatory case studies of programs identified as being successful. The research reported here represents the beginning of this process. In the immediate future, we will need to continue triangulating the various data sources within the pilot study data set. For example, it is mentioned above that informal communication among the calculus instructors was something that was seen as important by

instructors, administrators and students. However, we also identified factors that were mentioned by some interview subjects (e.g. good communication between the client disciplines and the math department) but were not mentioned (and in some cases strongly disputed) by other subjects. This kind of cross-checking across interview protocols will allow us to determine whether given factors actually have a significant presence in the program and the extent to which they are seen to be crucial by program participants. As the project continues to unfold, future research activities will include cross case analyses (across institutions within a single type and across institution types). In particular, such analyses will help the research team to recognize which factors appear to be essential and which may be helpful but are not essential (e.g., those that are not present in a number of successful programs).

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