Surveying Mathematics Departments to Identify Characteristics of Successful Programs in College Calculus

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This report highlights the completion of the first step of a large national investigation of mainstream Calculus I that aims to identify the factors that contribute to student success in Calculus I. Calculus I is the critical course on the road to virtually all STEM majors. Even students who do well in it often find the experience so discouraging that it leads to a change of career plans. We have very little data on the preparation and aspirations of the students who enroll in this course or of the factors that contribute to success in calculus. This five-year NSF funded project begins to fill this gap in knowledge.

The report provides a brief overview of departmental and instructional factors that influence student persistence and success in college and university calculus. We also describe the processes of developing a suite of six survey instruments to assess the characteristics of calculus instruction at colleges and universities across the nation. Since the six surveys (department chair, calculus coordinator, instructor pre, instructor post, student pre, and student post) followed the same development process we will limit our discussion in this report to the student pre- and post-surveys. The survey development process began with the development of a taxonomy of critical attributes of successful calculus programs that have been reported in the literature. This was followed by cycles of item construction, clinical interviews with survey respondents and item refinement until survey items assessed the intended taxonomy variables and the survey question and answer formats were interpreted consistently with the designers’ intent. The research that guided the item development, including the format choice and validation cycles will be described with findings that reveal items that are effective for gaining information about calculus instruction and its impact on students. Pre-course surveys have been administered to over 10,000 students across the nation and post-survey data will be available at the end of the fall, 2010 semester.

Brief Summary of the Literature

Over the last 25 years, various studies about student persistence in college in general and in STEM studies in particular have converged on a nearly common set of clearly identifiable factors that contribute to student persistence. Broadly, these factors pertain to (a) a strong sense of community and self-perception of identity with that community, (b) departmental or institutional supports for learning, and (c) instructional behaviors that meet students’ intellectual needs, promote greater learning and develop student self-confidence. In the area of college calculus as well as secondary mathematics leading to calculus, research findings also highlight the effect of pedagogical issues that affect students’ understanding of the key ideas of the course (e.g., limit, derivative). Numerous studies have also highlighted the importance of students’ development of problem solving behaviors and habits of mathematical thinking that are consistent with ones held by acting mathematicians and scientists. Yet another vast area that has been shown to affect students’ learning and mathematical self efficacy include the quality of interactive engagement within the
classroom and intellectual demand put on students in homework and within the classroom. (e.g., homework, explanations). Other areas that have been particularly influential in affecting student persistent include: i) student self-efficacy relative to mathematics, ii) student and teacher beliefs about the nature and methods of mathematics, and iii) student self-identity with the culture of mathematics.

Research findings reveal many more variables than are feasible to include on the CSPCC Survey. This resulted in our considering the extent to which research indicates that a particular variable is a powerful factor in learning calculus or in student persistence in calculus. Other criteria we took into account include: (1) How amenable is this factor to actual change or manipulation? (i.e. can the instructor or department do anything about it?); (2) How hard is it to answer the question? (respondent burden); and (3) How confident are we that students will give us a truthful answer? (expected reliability).

Our literature review (see bibliography) guided our choice of variables to include in our surveys. These variables have been articulated in the form of a taxonomy. The student post-survey variables characterize both the dependent and independent variables that we hypothesize (based on our review of the literature) are critical for student success and continued mathematics study.

**Taxonomy Keyed to Student Post-Survey**

What follows is a curtailed taxonomy that shows only the major dimensions. As noted below, most dimensions has several subcategories. The full taxonomy will be presented with the full report and related to the literature.

**Potential Dependent Variables**
A. Course grade and intention to take Calc II (with 4 subcategories)
B. Impact of Calc I course on student (with 4 subcategories)
C. Student self-perception of knowledge/skills in calculus

**Potential Independent Variables**
A. Student Beliefs and Affect (with 5 subcategories)
B. Perceived Behaviors and Values of the Calculus Instructor (with 4 subcategories)
C. The Role of Homework and Exams (with 4 subcategories)
D. The Role and Behavior of the Student in Learning (with 6 subcategories)
E. Supports for Students (with 2 subcategories)
F. Readiness for Calculus (Pre-survey) (with 3 subcategories)
G. Readiness for Calculus (Post-survey)

**Format and Design of Survey**

While the variables embedded in the CSPCC Survey questions relate to factors identified from the literature, the format and design of the questions are consistent with recommended practice in survey design (Colton & Covert, 2007; Fowler, 1995; Saris & Gallhofer, 2007). Depending on the information sought by each question, a specific question format was selected as deemed most appropriate (Likert, contrasting alternative, categorical, matrix configuration). Professional advice was also sought from Dr. Jillian Kinzie, Associate Director, Indiana University Center for Postsecondary Research and NSSE Institute, whose area of expertise is survey design. In addition,
we have been in periodic communication with Co-PIs Phil Sadler and Gerhard Sonnet regarding survey formatting and data processing plans. They have also reviewed drafts of the survey taxonomies and instruments, and have offered suggestions for survey question refinement.

Survey Development

The project team developed the following five surveys: i) course coordinator, ii) instructor pre-survey, iii) instructor post-survey, iv) student pre-survey and v) instructor post-survey. The development process for each instrument involved cycles of: i) constructing items for each taxonomy item for each survey; ii) conducting clinical interviews with a talk-aloud protocol with subjects for each of the respective surveys (i.e., course coordinators, instructors and students); refining the item questions and answer choices based on analysis of clinical interview data.

Each survey included multiple question types, including likert, contrasting alternative, and categorical. The question format for each taxonomy variable was considered with the format choice relying on which format would provide the most valid and reliable data relative to that variable. As one example, the contrasting alternative format is more reliable in instances where likert scales are ambiguous because different survey respondents construct different images of what it means to select a value in the scale. They are also more valid in instances where the goal is to gain information about the relative degree to which students agree with two common alternatives to a particular statement. In the case of the contrasting alternative format a brief description is provided for each end of the survey scale so that the respondent is clear on what it means to select that answer choice. As one example, we devised a contrasting alternative item that provides two alternatives about what a score on a mathematics exam is measuring because these two choices were revealed during interviews to be the most common uses of exams.

Example contrasting alternative item type that appears on both the student pre- and post-survey.

30. My score on my mathematics exam is a measure of how well
(a) I understand the covered material.
(b) I can do things the way the teacher wants.

The conference presentation and report will provide additional exemplars of survey items for each of the four surveys and some time will be allotted for participants to react to the taxonomy and sample items.

Significance

The potential significance of this five-year study is very strong and members of the RUME community will be interested in the progress and outcomes of this national project. Through the policies and publications of the Mathematical Association of America, the results of this project will effect calculus instruction and curricular development across the nation by providing knowledge of approaches to teaching calculus that are more successful, with particular attention paid to the differential effects of racial/ethnic and gender variables. This report represents the first in a series of reports at the RUME conference detailing the progress and results of this important work.
Bibliography


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