Project Outcomes Report

The goals of the Resequencing Calculus project were to develop a three-semester calculus sequence that better aligns the ordering of topics with the needs of STEM students from a variety of disciplines, to develop a text and other course materials for the sequence, to pilot the sequence at a variety of institutions, to assess its effectiveness, and to work towards gaining widespread adoption of the approach. The project team consisted of 6 faculty involved with content development, organization and administration of piloting and assessment efforts, and dissemination. This core group was assisted by an external evaluation team and an advisory board consisting of experts on the AP calculus sequence, life-science focused calculus sequences, trends in engineering education, calculus instruction at community colleges, and the application of vector calculus in the physical sciences.

The new sequence is structured so that material prerequisite for success in upper-level STEM courses is front-loaded into the first two semesters and so that the difficulty level increases gradually throughout the three-course sequence (instead of peaking in Calculus 2). This is accomplished by introducing some multivariate calculus in Calculus 2 and postponing infinite series—often considered the most daunting topic in calculus—until Calculus 3. As a consequence, Calculus 1 and 2 form a strong two-course sequence for students in the life sciences, economics, and chemistry, all of whom are likely to encounter multivariable models in later courses within their disciplines. Moreover, students successful in Calculus 2 may enter directly into not only Calculus 3, but also differential equations, linear algebra, and probability.

The team developed a complete three-semester textbook and other course materials to support the piloting effort. The 1200-page text includes approximately 700 examples, 2000 graphics, and 7000 exercises. A 1000-page student solutions manual was developed with the assistance of students at several universities, and more than 2000 online homework problems were developed in conjunction with the new text. A collection of instructional videos covering multivariate topics was developed to assist transfer students who entering into the revised sequence from a traditional one.

Pilots were conducted at 7 institutions, both private and public, with enrollments ranging from 2000 to 30,000. In all, more than 120 sections of calculus were taught using the project's course materials, impacting roughly 2500 students. Assessment of the text and the revised calculus sequence was conducted at 5 of the pilot sites through a variety of instruments—including surveys, interviews, and focus group sessions involving STEM students and instructors; a comparative analysis of performance on common final exam questions by students in traditional and early multivariate calculus courses; and comparative analyses of pass rates. Key results from the assessment efforts are that the text was rated significantly more favorable in usefulness and helpfulness compared to other texts, that the topics selected for reordering were rated as both appropriate and necessary in order for students to be able to draw on their calculus understanding in subsequent STEM courses, that the revisions in the calculus sequence supported student success, and that the revisions did not lead to a deterioration in student mastery of fundamental skills.

Word of the projects goals and progress was shared through multiple channels. Dissemination activities included

- Developing and maintaining an extensive website

- Presenting papers and serving as panelists at conferences. In all, there were 13 conference presentations.
- Exhibiting at conferences. The team developed and staffed an exhibition booth, which resulted in extensive conversation with approximately 1000 math educators at a total of 7 conferences.
- Conducting a full-day workshop for high school mathematics teachers. In addition to sharing the purpose, goals, and findings of the project with teachers, the workshop provided specific training in ways of incorporating early multivariate topics throughout the high school curriculum.
- Preparing and submitting a journal article (currently under review) describing the project, with a focus on a study performed at one of the pilot institutions demonstrating the improved pass rates for students in an early multivariate sequence compared to a control group at the same institution.

It is challenging to convince institutions—particularly large ones—to consider making large-scale modifications to their calculus sequences, even though there is surprisingly strong support among individual faculty members. Many institutions will not even consider a text unless it has undergone development by a large commercial publisher with the ability to deliver the product in a variety of formats and the resources to provide ongoing support of the product for many years. For this reason, the project team worked towards securing a commercial publishing contract and obtaining a commitment to publish the text and its ancillaries as the best way of protecting the NSF's investment in the project. This goal was accomplished in the final two years of the project. A preliminary edition of the text will be in print in 2017 followed by the first edition in 2018.