CURRICULAR CHANGE IN INSTITUTIONAL CONTEXT: A PROFILE OF THE SUMMIT-P INSTITUTIONS

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ABSTRACT

There is a national call to improve the mathematics curricula in the first two undergraduate years to improve student success and engagement. But curricular change happens in an institutional context: Who are the students, and what do they need to succeed? What is the climate for change? Does the department regularly revise its courses and curriculum? Is it common for different departments to collaborate on curricular change? What supports or obstacles does the department, college, or university have for changing the curriculum? Who are the institutional stakeholders, and what practices build their buy-in? In the SUMMIT-P project, nine different institutions ranging from small private colleges to mid-sized state universities to large public universities and a community college worked on changing the undergraduate mathematics curricula in the first two years. This paper examines the context at each institution in the project. We hope that other institutions looking to follow in our collaboration with the partner disciplines on revising the introductory mathematics curriculum at their institution will find a familiar context in one (or more) of these institutions. We include a list of questions that programs can use to examine their own institutional context.

KEYWORDS

curriculum, interdisciplinary, mathematics, partner disciplines, SUMMIT-P

In the National Consortium for Synergistic Undergraduate Mathematics via Multi-Institutional Interdisciplinary Teaching Partnerships (SUMMIT-P) collaborative research project, teams of mathematics and partner-discipline faculty members from nine colleges and universities are revising introductory mathematics courses to better meet the needs of students in the partner disciplines. The project builds on the findings of the Curriculum Foundations (CF) project, which was a collaborative effort of mathematics and partner-discipline faculty members to determine the important mathematics concepts students need to understand in order to be successful in courses in Science, Technology, Engineering, and Mathematics (STEM) disciplines. The findings from the CF project appeared in two seminal publications (Ganter & Barker, 2004; Ganter & Haver, 2011).

In this paper we describe each of the participating institutions and the project that each institution's collaborative team is working on. Then we share some of the lessons we are learning about how curricular change is, for better or for worse, influenced by the local institutional context. We end with a list of questions for faculty members to consider when planning a new curriculum revision project. We invite faculty members at other colleges and universities interested starting similar work to peruse the list of projects presented below for a familiar or useful context and to reach out to the team leader for guidance or support.

The Nine Colleges and Universities

Augsburg University is a private university in Minneapolis with around 2,000 undergraduates. The institution is known for experiential and active learning and for programs for students with disabilities or who are in recovery. Augsburg University is a popular transfer destination for students from local community colleges. The leadership of the Augsburg University SUMMIT-P team includes five faculty members: a chemist, an economist, and three mathematicians.

The Augsburg University SUMMIT-P team is revising their three-semester calculus sequence to align with the CF recommendations. Specifically, they are working to focus instruction on students' conceptual understanding and to strengthen students' ability to transfer knowledge to new contexts. The team is revising existing lab activities and creating new weekly lab investigations for Calculus I & II. These investigations allow students to explore applications of mathematics content. Through the lab experiences, they recognize different concepts and apply their mathematical knowledge and skills in STEM-related in contexts.

They are increasing active and collaborative learning in Calculus I & II by creating a three-part structure for the three weekly class sessions. Each class session now includes group work on an exploratory activity, a brief lecture, and exercises worked by pairs of students on the classroom white boards. Both the daily exploratory activities and the weekly labs are inquiry-based. The materials developed throughout this project are suitable for use as supplementary activities for calculus courses at other institutions.

The team is also re-examining and re-ordering the content of the three-course sequence, including: bringing some differential equations and multivariable calculus into Calculus I; creating a pathway from Calculus I directly into Calculus III; moving the study of limits, continuity, and formal definition of the derivative and integral from Calculus I to Calculus II; and increasing the depth and breadth of vector calculus concepts in Calculus III.

Ferris State University is a public university in Michigan serving 13,000 undergraduates. This institution is a popular transfer destination for students from local community colleges. The leadership of the Ferris State University SUMMIT-P team includes three faculty members: a social worker, a nurse, and a mathematician.

In an earlier course design project, faculty members teaching mathematics and business collaboratively developed a course, Quantitative Reasoning for Business. This new project is focused on revising and scaling the course to reach more students under a new name, Quantitative Reasoning for Professionals. The revised course now serves students majoring in business, social work, and nursing. The updated course expands the use of inquiry-based pedagogy in applied contexts to develop students' problem-solving skills. It incorporates CF recommendations to prioritize depth over breadth of knowledge, emphasizes problem solving, uses active learning pedagogy, and incorporates the appropriate technology. Project faculty members are creating additional instructional materials to focus on the mathematical concepts used in health science and social work professions. These new materials also supplement the existing inquiry-based "explorations" designed for business contexts. Health science and social work faculty members are identifying the mathematical concepts needed for contexts associated with their disciplines, reviewing exploration-based activities written by mathematics faculty members, and assessing the impact of the curriculum materials on the students in their programs. The materials that have been developed for this project are suitable for use as a textbook for a quantitative reasoning pathway course at other institutions.

Located in New York City, **LaGuardia Community College** (LAGCC) is a public, Hispanic-serving institution with over 50,000 students. A large percentage of the students are first-generation college students or are from low-income families. One of LAGCC's central goals is to improve students' quantitative reasoning and digital literacy. The leadership of the LAGCC team includes faculty members who teach mathematics and economics.

The project team is revising College Algebra to include interesting, authentic applications from business and the social sciences, to increase the emphasis on students' conceptual understanding through hands-on explorations using applets and to improve students' ability to transfer mathematical knowledge to other contexts. They are incorporating real-world problems from economics, business, and the social sciences in the course, including carefully incorporating the notation and vocabulary used in these disciplines.

The LAGCC team is also creating open-source, interactive web applets that demonstrate different quantitative relationships graphically. Students use the applets to explore concepts and to collaborate on questions about the mathematical relationships and properties that they encounter. These applets help students to deepen their conceptual understanding before they do computations and follow other procedures. The applets are suitable for use at other institutions.

Lee University is a private, four-year liberal arts college in east Tennessee serving 4,000 undergraduates. The leadership of the Lee University SUMMIT-P team consists of faculty members who teach mathematics, biology, chemistry, education, psychology, and sociology. The team from Lee University originally planned to work on three courses for SUMMIT-P, but their work expanded to five courses.

Before the project, Lee students in a wide range of majors took College Algebra. Project faculty recognized that future STEM majors, pre-service teachers, and other students would be better served by a trio of courses, each focused on the needs of the partner disciplines. They created Algebra for Calculus for students intending to major in a STEM field, revamped the existing College Algebra course to address content necessary for pre-service teachers, and added Introduction to Statistics as the course of choice for students majoring in disciplines outside of STEM and education. All three courses have been informed and enhanced by the conversations with the partner discipline faculty members participating in the project and the CF recommendations. In discussions with education faculty about College Algebra, the project team recognized some changes were also needed to Concepts of Mathematics I & II, the mathematics content courses that pre-service elementary school teachers take after College Algebra. This example of a "pathways" structure could be useful to other institutions. For a discussion of pathways models and their connection to student success see Charles A. Dana Center (2019).

In addition, the Lee University team is implementing CF recommendations for the social sciences by developing a "student exchange" program. They have recruited and prepared a team of advanced social science and mathematics majors to provide peer support for students enrolled in the Introduction to Statistics course. Faculty-supervised seminars and mentoring sessions are part of the support efforts for students participating in the exchange. This type of exchange model could be adopted by other institutions.

Norfolk State University is a public, historically black university (HBCU) in Virginia serving 5,500 undergraduates. The Norfolk State University SUMMIT-P team includes faculty members from the mathematics and engineering departments.

Project faculty partnered to redesign Calculus I & II and Differential Equations, which are courses that, due to high drop, fail, or withdraw (DFW) rates, had previously been identified as roadblocks for science and engineering majors. The engineering department teaches a course called Engineering Problem Solving that introduces engineering applications requiring the use of algebra and trigonometry concepts to strengthen students' readiness for calculus. Through this project, faculty members incorporated application-based activities into Differential Equations and Calculus I & II in a manner similar to what is used in Engineering Problem Solving. The team developed problems for key applied topics and created video lectures for procedural skills for the students to watch before class. These changes to the course also freed up class time for the study of other concepts. The activities that have been developed are suitable for use as supplementary materials in similar courses at other institutions.

Oregon State University is a public, land-grant institution serving 23,000 undergraduates. The leadership of the Oregon State University SUMMIT-P team includes faculty members who teach mathematics, biology, and chemistry courses, as well as graduate and undergraduate serving as curriculum development assistants.

The team is creating activities for Differential Calculus based on CF guidelines for biology and chemistry. Differential Calculus is a 10-week, first trimester calculus course, as compared to the 15-week, first semester Calculus I courses which also includes concepts from integral calculus. These activities help students develop connections between mathematics concepts and the content covered in General Chemistry and Principles of Biology. These activities are being implemented in recitation sections of Differential Calculus that are taught by graduate teaching assistants. Course coordination includes a shared calendar and weekly activities that are used across all sections. In addition to connecting mathematics concepts to partner discipline content, the activities also include questions with a conceptual focus to encourage students to participate in pair or small group conversations. The activities developed through this project are suitable for use in first semester calculus courses at other institutions.

The team is also designing and offering professional development sessions for Differential Calculus instructors and teaching assistants. The purpose is to increase the consistency in the content that is covered and the pedagogy that is used across all course sections, with the goal of improving students' abilities to transfer knowledge across the different disciplinary contexts.

Saint Louis University is a private university in Missouri serving 8,000 undergraduates. The Saint Louis University SUMMIT-P team consists of faculty who teach mathematics and business courses.

Through prior collaborative efforts, mathematics and business faculty wrote a textbook for Survey of Calculus that featured computing with spreadsheets (i.e., Microsoft Excel) in the course. While the course helped students to understand the important connections between mathematics and business concepts, students continued to have difficulty transferring their knowledge between courses in the two disciplines.

The current SUMMIT-P project at Saint Louis University extends that work to College Algebra. The team also developed curriculum units for two upper division finance courses, Fixed Income Securities and Markets and Derivative Securities and Markets. To help students see that the algebra and finance courses were connected, examples from the finance courses were incorporated into College Algebra with nearly identical notation and terminology. For example, in College Algebra a constant revenue stream is used as an example of exponential growth, and in the finance courses, a constant revenue stream is the focus of a curricular unit. The materials developed for this project are suitable for use as a textbook for a business calculus course or as supplemental materials for coordinated business and mathematics courses at other institutions.

San Diego State University (SDSU) is a public, Hispanic-serving, research university serving over 30,000 undergraduates, with over half of the student population being from underrepresented groups. SDSU is committed to increasing student retention in STEM courses and has conducted research on the factors leading to high failure rates in bottleneck courses such as Precalculus. The leadership of the SDSU SUMMIT-P team includes biology, physics, and mathematics education faculty members.

In this project, the SUMMIT-P team is revising the content and pedagogy for Precalculus based on CF recommendations to emphasize conceptual understanding while also maintaining a focus on procedural fluency and increasing the number of mathematical applications from other sciences. The team is also revamping recitation sections of the course to incorporate active learning strategies. They are also working to improve the training provided for Precalculus teaching assistants. The materials developed through this project can be used as supplementary activities for Precalculus at other institutions.

Virginia Commonwealth University (VCU) is a large, urban research university serving 22,000 undergraduates. Each year, approximately 7,000 students take a lower-division mathematics course ranging from College Algebra through Differential Equations. Almost 80% of these students are STEM majors. Helping students develop procedural fluency, conceptual understanding, and reasoning skills in mathematics is critical to students' future success in STEM, and so these lower-division mathematics courses are a priority for STEM partners, including mathematics. The leadership of the VCU team includes engineering and mathematics faculty members.

Through an earlier collaboration based on CF recommendations, VCU substantially reformed College Algebra to a modeling-oriented course that includes a variety of applications from the partner disciplines. In the SUMMIT-P project, faculty members are working to better align other lower-level mathematics courses with engineering and the sciences. The team decided to start with Differential Equations. Changes to the course include incorporating collaborative learning experiences for students, increasing the use of technology in the classroom, and presenting examples from engineering fields. The materials that have been developed for this project include engineering examples that can be used as supplementary activities in Differential Equations courses at other institutions.

A Few Lessons Learned

In this section, we mention a few ways in which the institutional context had an impact on the development and implementation of the SUMMIT-P projects. We hope these examples might illustrate some less-obvious considerations for institutions considering similar curricular work.

Each team started by considering the student population for the courses that were being redesigned and the reasons students were enrolling in the courses. Rather than designing a mathematics course linked to one major (e.g. College Algebra for Biology), most institutions revised a mathematics course to address students from a range of related majors. For example, Lee University's College Algebra for STEM serves students from the STEM disciplines; VCU and Norfolk State University's focus on calculus applications from engineering in Calculus I & II and Differential Equations serves students from all of the available majors in engineering and physics; Ferris State University's Quantitative Reasoning for Professionals serves students majoring in business, nursing, and social work. Such collections of academic majors that have related course content or career goals, and often overlapping sets of introductory courses, are commonly known as "meta-majors." Focusing curricular reform on meta-majors appears to have a positive impact on college completion rates (Waugh, 2016). Waugh explains:

> Sometimes also referred to as 'career clusters' or 'communities of interest,' meta-majors [as an approach to curriculum reform] refers to the creation of broad program streams such as allied health or business as a key component of guided pathways reforms. (p. 2)

A critical step for each institution was building support for the project among mathematics faculty members beyond the project. The type of support varied considerably between different institutions. For example, at Augsburg University, one of the smallest institutions in the collaboration, there are only five tenured mathematicians in the department. Three of these faculty members are directly supported by the project. It became clear early on that the team needed to find ways to include the other two tenured mathematicians in the work. The institution supported the project by providing internal support funding for each of them to participate in the curriculum reform process for one summer. In addition, teaching schedules were revised so that all tenured faculty members in mathematics were able to teach a section of the course that was being redesigned.

In contrast, teams from larger departments often had only one mathematician who was being supported by project funding. In these cases, rather than working towards consensus across the entire mathematics faculty, the teams identified a smaller, critical group of faculty members who would directly interact with the courses being revised. The instructors that were chosen to participate depended on the type of work being done. The team at VCU worked closely with all mathematics faculty members who were teaching the courses under revision. The Oregon State University project brought together mathematics course coordinators and instructors. At SDSU, the collaborative efforts involved the Math and Stats Learning Center coordinator and teaching assistants for mathematics courses.

Registration issues can throw a project off-track. For example, after mathematics and business faculty members at Saint Louis University developed sections of College Algebra specifically designed for business majors, they found out that the registration system would not separately identify the special sections. As a result, both business and non-business majors registered for the section that was intended to focus on business applications. While this problem was resolved for future terms, it resulted in a delay of the full implementation of the course.

A defining feature of the SUMMIT-P project is the close collaboration between mathematics and partner discipline faculty members. Sometimes even the course under consideration can change based on those conversations. At Oregon State University, an early outcome of this collaboration was that the faculty members changed which mathematics course would be the focus of their project. Originally, they planned to work on College Algebra. In conversations with chemistry and biology faculty, the derivative as a rate of change emerged as a pivotal concept. Based on this information, the team switched to work on Differential Calculus where derivative rate of change could be addressed at multiple points using problems from biology and chemistry.

Similarly, when project faculty at Augsburg University were working on finding chemistry examples for Calculus II, they quickly realized that multivariable calculus and vector calculus concepts in Calculus III were much more commonly used in Physical Chemistry I & II. As a result, they created a pathway from Calculus I to Calculus III for chemistry majors.

Mathematics faculty member's level of knowledge of disciplines beyond mathematics and prior experience working in interdisciplinary contexts contributed to their ability to work in collaboration with faculty in the partner disciplines. This finding aligns with the research; for example, Bouman-Gearheart et al., (2014) found that "[s]uccessful collaborations recognize the value of others' expertise and that those involved in postsecondary improvement activities are at different points in their appreciation of interdisciplinary knowledge and work" (p. 42).

At Saint Louis University, the lead professor had participated in an earlier project to develop a business-rich curriculum for Survey of Calculus. This expertise helped to jump-start the new partnership through the SUMMIT-P project work on College Algebra. VCU selected Differential Equations as the first course to revise in part because the faculty members teaching that course were more familiar with modeling and applications in science and engineering contexts than faculty members teaching other lower-level mathematics courses. Increasing the focus on modeling in Differential Equations was a natural fit for their project.

Early in the project, each team held "fishbowl" format listening sessions to hear partner discipline faculty members discuss the mathematics their majors needed to know. Follow-up discussions often began by trying to translate the skills and concepts identified by the partner disciplines into mathematical skills and concepts. For example, partner disciplines might refer to "variation" or "dependence," which mathematics faculty members would call "functions" or "covariation." Both instructors and students have trouble navigating across the linguistic differences between disciplines. In creating curricular materials, faculty members paid attention to need for a glossary to help with the translation between mathematics and the other disciplines.

This ability to speak across disciplines echoes broader research findings showing that teams can benefit from having members who “bridge the knowledge and experience gaps of those struggling with content or practices, often in informal ways during everyday situations that do not necessarily have this bridging as an explicit focus” (Vasquez et al., 1994, p. 41). The authors dubbed these collaborators “brokers,” who they defined as individuals who provide “recourse to multiple sources of linguistic and cultural knowledge in order to create meaning, negotiate a task, or solve a problem” (Vasquez et al., p. 96).

For example, in a previous project at Ferris State University, the lead mathematics faculty member had worked closely with members of the business faculty to design a course. He was able to leverage that expertise when working with members of the social work and nursing faculty to transform the mathematics courses for business majors into Quantitative Reasoning for Professionals, which serves students majoring in business, social work, nursing, and other pre-professional majors.

At Augsburg University, applied mathematicians with expertise in biology, chemistry, and physics are participating in the project, and another mathematics faculty member had studied economics in college. While not experts in these partner disciplines, the additional knowledge base has been very helpful when engaging in in-depth conversations with the partner discipline faculty members.

Questions to Ask

Here are some questions the institutions considered, or in some cases wish they had considered, early in the project planning process. The reader who is interested in embarking on a similar curricular journey should ask themselves questions like these.

1. What are the goals of the interdisciplinary collaboration at your institution?
    a. What issues or problems are you trying to address through the work?
    b. How does the work align with departmental, college, or institution-level initiatives?
    c. How will you disseminate the work within your institution? Are there campus leaders who should be engaged early in the project?
    d. How will you determine the impact of the project? How will you get feedback during the initial phases? How will you know if it was successful?
2. What course or courses are the focus of your project?
    a. What is the scale of your project—completely revising a course or course sequence (large scale), or adding some activities labs to an existing course (small scale), or something in between?
    b. Does the project have a curricular focus, pedagogical focus, or both? If the focus is on the curriculum, what level of support do you need from the department in which the course is being offered? If the focus is on pedagogy, will professional development opportunities be needed for instructors or teaching assistants?
    c. What partner disciplines are most interested in or affected by the course?
3. Who are the possible team members (including yourself)?
    a. What key interests and expertise should be represented in the project?
    b. How many members of your department should be on the team?

   c. How will members of the partner disciplines faculty contribute to the project? What will members of the partner disciplines faculty gain from the project?
   d. What are individuals' interests and commitment levels?
   e. How does the work support what individuals are currently doing or align with work they want to be doing?
   f. Will the work be valued in decisions about an individual's tenure, promotion, or re-appointment?
   g. Realistically, are individuals already too busy to commit to another project?
4. How and when will the work be accomplished?
   a. What resources will you need to complete the project? How much time does each team member need to do the work?
   b. How often will the team meet? Will there be intensive working times (e.g. summer or travel to workshops)?
   c. Where will you travel to gather information for the project (e.g. workshops or site visits to similar institutions)? Where will you present your findings (e.g. conferences)?
   d. What is the project timeline? How soon will you be able to implement some or all of the changes?
   e. Have you considered any obstacles to the work? How will obstacles be addressed should they arise?
5. How might you build a collaborative network that extends beyond your institution? Could you, for example, join a SUMMIT-P project?
   a. Which SUMMIT-P projects have similar aspects to your intended project?
   b. Have you reached out to a SUMMIT-P team as a possible collaborator?
   c. Can you use some of the methods from the SUMMIT-P project to start or accelerate your work?

An Invitation

A key purpose of this paper is to describe the SUMMIT-P institutions and provide examples of how each institutional context has influenced the work with the hope that faculty members at other colleges and universities interested in starting a similar project might recognize a familiar context. Such faculty members are welcome to contact the SUMMIT-P project team leader for possible support which might take the form of video conversations, in-person meetings at mathematics conferences, or potential on-site visits.

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