"They Will Need It for Calculus"

Structure and Content for the STEM-Prep Pathway

Dana Center
Mathematics
PATHWAYS

August 2014

These are exciting and liberating times for developmental mathematics instructors and their students.

The Dana Center Mathematics Pathways (DCMP) solution to the ubiquitous high failure rates in developmental mathematics is a comprehensive, long-term, systemic approach to improving student success and completion built around three mathematics pathways:

- Statistics
- Quantitative Reasoning
- STEM-Prep

with a supporting student success course.[1]

In 2011–2012, the DCMP developed course materials for the Statistics and Quantitative Reasoning pathways, providing mathematics faculty and their institutions with curricular materials, a network of colleagues, and the institutional agency to teach the mathematics that matters to non-STEM majors.

The DCMP leaders from the Charles A. Dana Center, the Texas Association of Community Colleges, and several Texas DCMP course "codevelopment" colleges in Texas have turned their attention to creating materials for the STEM-Prep pathway, including college-level transferable mathematics course content that will move students from developmental mathematics through college-level precalculus with learning outcomes specific to STEM preparation.

How do you clear a pathway to calculus?

The DCMP leaders were keenly aware that the STEM-Prep pathway would differ from the other pathways in two distinct ways. First, while the Statistics and Quantitative Reasoning pathways involved content and pedagogy that could be taught by a few committed members of a mathematics department, the algebraic-intensive pathway is sacred ground for nearly all mathematics faculty. Second, courses in the STEM-Prep pathway must prepare students to succeed in Calculus 1, the very definition of a high-stakes course.

The path that DCMP is creating for developmental mathematics students through algebra and precalculus must quickly advance them to a highly rigorous level of mathematics and prepare them to succeed in any one of dozens of different versions of calculus offered across the country.

These drivers motivated DCMP leaders to approach the development of STEM-Prep course materials with no fixed ideas about what the materials should entail. To ensure a scalable,

[1] A description—and course materials—for *Frameworks for Mathematics and Collegiate Learning* is available here: https://dcmathpathways.org/resources/nmp-frameworks-mathematics-and-collegiate-learning-course-overview-and-learning-outcomes

quality course design, the DCMP sought input from a broad range of researchers and practitioners.

Two teams—content and structure—convened to plan STEM-Prep course materials

To plan course materials for the STEM-prep pathway, the DCMP staff intentionally invited prominent mathematics educators and designers to join a design team for content or for structure. Each team includes representatives from two-year and baccalaureate-granting institutions of higher education, and each was asked to provide initial input during the design phase and to act as a working group to support the authors during the development phase.

The *content design team* consists of 5 nationally renowned leaders in mathematics education research with particular emphasis on student learning in calculus. The *structure design team* consists of a larger group of faculty members and institutional leaders invited from across the country. This team's 14 members represent several Texas colleges and universities, the Mathematical Association of America, and the American Mathematical Association of Two-Year Colleges (AMATYC).

In January 2014, these two teams kicked off their independent (and hence initially—and intentionally—divergent) work collecting data and responding to questions to inform the course design. Over the winter and early spring of 2014, STEM-Prep pathway coordinator Frank Savina led the process of converging this information and the teams toward a workable set of suggestions and recommendations.

In May 2014, both the content team and the structure team met at the Dana Center for a day and a half of active conversation, healthy debate, and tough decision-making.

What is the proposed STEM-Prep course content?

The content design team's charge from January to June was to create a set of student learning outcomes, identify the basic content to be taught, and provide suggestions of research-based approaches for teaching the content, a detailed course outline, and ideas for sequencing the course materials. The team began working on key questions through a series of divergent and convergent activities.

First, team members responded individually to a core question—*What are the overarching mathematical concepts that students will need to be successful in Calculus?*—through emails to Savina, who then synthesized these responses into one document for discussion by the team in a conference call.

When the team arrived in Austin in May, they brought with them their draft responses to these three framing questions, consisting of student learning outcomes and suggested main topics for the course.

From these materials, the team launched into two days of intense discussion and revision.

The team went through three iterations of the process, using these framing questions:

Anchoring questions for discussion included:

- "Did we miss anything?"
- "Was there anything on the list that shouldn't be there?"
- "If the team had to prioritize because time was not available in the course, what would go?"

1. What are the overarching mathematical concepts that students will need to be successful in Calculus?
2. What are the student learning outcomes that could be derived from these overarching concepts?
3. What are the more detailed content items or topics underneath these overarching concepts?

During the morning of the first day, Stuart Boersma, lead author for STEM-Prep and at this time also acting as lead facilitator for the discussion, took advantage of the assembled expertise in education research and literature to elicit specific approaches to content that could be passed on to the course authors later in the year.

In Boersma's "back-mapping" exercise, the discussion began with the question:

> **"What are the skills and knowledge needed for students to pass over some of the most significant barriers in calculus?"**
>
> or, put another way:
>
> **"What big ideas are students getting bogged down with in calculus?"**

The resulting list of what Boersma calls "boggy areas" was not short and would likely be of no surprise to many experienced mathematics instructors.

Some boggy areas include:

- rate of change
- the building blocks of the limit
- the integral as an accumulator
- exponential growth
- the difference between exponential functions and power functions
- logarithms as inverse processes of exponentials, and, more generally, inverses and reversing processes
- fluency with notation
- understanding why we use function notation
- increasing and decreasing with negative quantities
- the derivative as a function and a process
- fluency in going back and forth with graphs of derivatives, etc.

With these topics in hand the group then addressed the question

> **"What can you do at the precalculus level to prepare students to succeed through these difficult areas in calculus?"**

After this process, Boersma felt he would be able to direct the authors to write a thoughtful set of lessons based on best practices.

In the afternoon, the team brainstormed a collection of *motivating examples*, that is, rich scenarios that students would encounter several times during the course.

For example, consider the classic focus on position, velocity, and acceleration in calculus. In a STEM-Prep course, students could investigate motion graphs from day one and revisit these graphs in different contexts many different times over the course. Once students are in calculus, they can pay attention to the calculus with a foundation of velocity as the slope of position or change in position as the accumulation of movement over time.

The second day was focused on getting feedback and making final revisions. It began with a convening of both the content team and the structure team. In this larger meeting, the structure and content teams each presented their ideas for feedback from the other team. The content team found the exercise valuable, and its members were motivated to clarify their thinking and reduce the ambiguity in their documents. The structure team ended up using some of the information generated by the content team (specifically, the learning outcomes) to guide some decisions. The content team reviewed the structure team's decisions and in response, they made a few minor additions but for the most part used the input to clarify the chosen topics and reduce ambiguity in their descriptions.

What is the proposed STEM-Prep course structure?

The structure design team began its work in January 2014 with a conference call to discuss the team's initial assignment. Over the course of the next few months, each of the 14 members would research and describe promising programs across the country where colleges were restructuring their developmental algebraic-intensive sequences.

For the structure team, the goal of the May meeting was to create a recommended structure for the STEM-Prep course materials that would include recommendations for classroom norms and instructional modes as well as the necessary supporting materials for faculty.

The structure team also created a template so that team members could report findings consistently; the findings were then assembled into a notebook that was used as the basis for the initial discussion at the May meeting in Austin.

Because of the structure team's size, DCMP employed the expertise of Dana Center staffer Jodie Flint, the Dana Center's manager of organizational learning, to help Frank Savina organize and facilitate the meeting. Dr. Flint's expertise proved invaluable in moving the team to consensus over the short day-and-a-half meeting.

Over the course of the first day, Flint and Savina led several activities that were intentionally composed to give the team time to arrive at individual conclusions, share those thoughts in small groups, and then synthesize their ideas as a team.

The first morning began with a review of the notebook of promising programs and a sorting out of similarities and differences among the practices as well as some potential issues with select practices. The meeting facilitators then cross-walked the collected practices against some course design tenets.

In the afternoon, the structure team was split into three groups and spent an hour answering the broad question **"What course would you design?"**

The first group created a chart dividing the course into three self-reinforcing modes:

- in-class learning—focusing on engagement and collaboration
- online resources—supporting self-paced learning
- independent learning (with a safety net).

This group also identified the types of learning that would occur in each mode. For example, in-class time was seen as the best time for a focus on conceptual understanding, for discussion, for collaboration, and as a safe environment for students to engage in productive struggle.

The second group organized their thinking around the amount of time that a student would be engaged in the course. recommendations:

- students meet face-to-face at least three times a week
- a typical lesson be split evenly between lecture and guided practice
- there be frequent homework with video resource support
- students engage in projects that facilitate explicit connections between past and future material

Each group's response was unique, and yet in the end, there was broad agreement across the recommendations.

The third group responded by splitting their attention between the support needs of students and faculty and "a day in the life" of a STEM Prep pathway student. Recommendations:

- ongoing faculty development
- peer mentoring and/or supplemental instruction for students
- the need to integrate time for collaborative learning and time for students to work individually with instructor supervision.

On its surface, the last recommendation supports the idea of immediate and accurate feedback for the student—yet a secondary and intentional outcome was for the instructor to experience first-hand the specific needs of his or her students.

This group was the first to bring up the need for a flexible approach in course design in order to promote wide-scale adoption of the course.

These three recommendations were synthesized into the larger recommendation that the STEM Prep course materials be structured into three self-reinforcing modes:

- in-class collaboration
- an instant-feedback environment
- resources for at-home independent learning (with delayed feedback)

The morning of the second day was a lively and beneficial meeting of the structure and content teams.

The structure team presented first. For the most part, the feedback from the content team involved requests for clarification or emphasis on key features. There was absolute concord that the proposed STEM Prep course would be a stronger and richer course than the traditional curriculum.

The pivotal question coming out of the discussion was

"What would be the mechanisms for creating faculty buy-in?"

or:

"How do you convince faculty that this course will help students be more successful?"

The content team proposed to leverage results of research studies to motivate faculty to implement the core structures of the STEM-Prep course. Publications suggested included:

- Marilyn P. Carlson and Chris Rasmussen (Eds.). (2008). *Making the Connection: Research and Teaching in Undergraduate Mathematics Education*. MAA Notes Volume 73. Washington, DC: Mathematical Association of America.
- National Research Council. (2000). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. Washington, DC: The National Academies Press.

The combined content and structure teams spent the afternoon reflecting on the past day and a half and providing feedback to Savina on what they liked and what they were concerned about with respect to the draft content—and what changes they would make. While there were still many open questions, the team adjourned having provided a clear direction for DCMP STEM-Prep course development.

To receive updates on events and releases of materials through the monthly Dana Center Higher Ed In Brief, email us at dcmathpathways@austin.utexas.edu.

About this resource

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About the development of this document

The work on STEM Prep began in earnest in January 2014. This resource is one of several that will document the development of the STEM-Prep pathway—a college-level transferable mathematics course moving students from developmental mathematics through college level precalculus with learning outcomes specific to STEM preparation.

This August 2014 first release of this resource constitutes our initial description of how members of the mathematics education community collaborated to develop recommended structure and content for the STEM-Prep pathway.

As the STEM-Prep development process continues, we plan to issue revisions and additional documents to reflect on—and clarify—the approaches and strategies the DCMP is employing to support students in learning rigorous mathematics content and progressing to and through a program of study that leads to a certificate or degree.

About the Dana Center

The Dana Center develops and scales mathematics and science education innovations to support educators, administrators, and policy makers in creating seamless transitions throughout the K–14 system for all students, especially those who have historically been underserved.

We focus in particular on strategies for improving student engagement, motivation, persistence, and achievement.

The Center was founded in 1991 at The University of Texas at Austin. Our staff members have expertise in leadership, literacy, research, program evaluation, mathematics and science education, policy and systemic reform, and services to high-need populations.

For more information:

- about the Dana Center Mathematics Pathway, see **www.dcmathpathways.org**
- about the Texas Association of Community Colleges, see **www.tacc.org**