Foreword

COVID-19 has changed education forever. A sudden jolt required all classrooms to hastily dive into the virtual world. Institutions in SEMINAL—Student Engagement in Mathematics through an Institutional Network for Active Learning—shifted to adapting what we have learned about institutionalizing active learning and inclusive practices to this new virtual education space. Although students and faculty will not return to the same classrooms they left, these lessons from SEMINAL will enhance engagement of all students in their own learning to heighten their success.

SEMINAL addresses a critical challenge facing STEM education. Far too many students, 25-30%, receive grades of D, F, or Withdraw (DFW) from Precalculus and Calculus courses. These are the lowest rates of any college entry-level classes; when combined, Precalculus and Calculus courses are among the three top-attended entry-level courses at universities. The good news is that more students succeed at a few institutions than most others. SEMINAL seeks to create a system in which large numbers of faculty and institutional leaders learn and adapt—as their own—what is known by some faculty, in some classrooms, at some institutions.

It is a national problem that almost a million students annually do not pass Precalculus or Calculus. Of particular concern, students from underrepresented groups, as a whole, have lower success than their majority peers. If they cannot succeed in these entry courses, they lose the opportunity to pursue a major in STEM fields. Not only does this deny these students the personal opportunities for exciting and well-paying careers, it also robs the nation of a more diverse STEM workforce. Left untended, the personal and national toll will only increase—as in the aggregate, present underrepresented groups will become the majority of the U.S. population in less than two decades.

Transforming STEM education to help all students achieve their potential is often simplified as “how to scale” promising practices. But it’s more than simple replication of a practice that worked elsewhere. How do we create a resilient education system of reliable, consistent adaption of proven practices for sustained student success across different classrooms in a variety of institutional contexts?

In *Calculus Reform: What Is Different This Time?* David Bressoud describes how the calculus reform movement of some 35 years ago was all about reforming course content. He notes a certain naiveté about that effort, with its assumption that simply rewriting the texts would automatically lead to widespread institutional adoption of more effective teaching. Today we realize that to convey that content, we need to both engage students in active learning and their institutions in adapting effective practices.
These are the lessons in this foundational volume. Faculty and institutional leaders in diverse institutions have learned how to enhance student success in mainstream Precalculus through Calculus 2 courses for their circumstances and context. This book tells the stories and analyzes the development and implementation of practices that worked and how they were adapted by a purposeful variety of six institutions. The study includes not only how faculty practice active learning, but also how departments enact programs and structure to use active learning precepts to enhance student success and, overall, how institutions provide the context for these efforts.

This volume is the first phase. SEMINAL’s second phase brings another nine institutions into a network to study how faculty from varied institutions adopt these changes for their classes, sharing their progress and experiences. In a third phase, SEMINAL has invited about an additional 12 non-networked institutions to compare progress with the existing SEMINAL community. The broader intention will be to build a larger movement from these two dozen institutions to promote national systemic change.

Returning to Bressoud’s question: What is different this time? SEMINAL is not simply a research project attempting to understand local change. The project makes explicit diversity, equity, and inclusive practices to meet the needs of all students. It strives to understand and enact change across all key stakeholders across an entire system. SEMINAL is: energized by creative and smart young faculty, instructors, and graduate students; guided by the wisdom of senior faculty and departmental leaders; learning from peers undertaking parallel work in other institutions; supported by departmental and college administrators; proving what is possible to institutional leaders while challenging them to provide appropriate resources; aligning with efforts of national disciplinary societies—MAA and AMS; and communicating the promise and needs to institutional leaders through a national university association—the Association of Public and Land-grant Universities.

Mathematics faculty, instructors, departmental and institutional leaders: SEMINAL invites you to glean the lessons of this first volume, compare with your own successes and integrate them into contemporary and post-COVID instruction to transform entry-level calculus. We hope you will connect with SEMINAL partners to build a system in which all STEM courses, and all university instruction, further student success, to help students achieve their potential and help them begin on the path to a rewarding and satisfying career.

Howard Gobstein
Executive Vice President
Association of Public and Land-grant Universities
September 2020
How to Use This Book

This book is divided into four main parts. Part I provides an overview of SEMINAL. This includes a chapter giving an overarching view of the SEMINAL project and is meant to provide readers with an understanding of the motivations and theory that drive this work, followed by a chapter on the research design of SEMINAL. Part II contains case studies of the six institutions we selected for the first phase of SEMINAL. In Part III we present cross-case analyses of these institutions, focusing on change levers we identified as critical in their efforts to successfully establish active learning as the norm for instruction in the Precalculus through Calculus sequence. Part IV synthesizes what we have learned about change, providing a list of recommendations for change agents operating at various levels of the system. What follows is a recommendation for how to use each section of this book, as well as a more thorough description of what each chapter entails.

Part I: Overview of SEMINAL

In Chapter 1 we describe our motivation for the SEMINAL project, as well as the recent research and calls for educational innovation that have informed this work, before providing summaries of the six selected sites and an introduction to six factors we found to be potentially relevant in affecting change at the departmental level. Chapter 1 provides a bird’s-eye view of the project, and as such we recommend that all readers begin here. In Chapter 2 we detail our research methods, including our site selection, data collection, and data analysis procedures. Readers who are primarily interested in the results and recommendations from this book may skip Chapter 2 without disrupting the flow of the book.

Part II: Six Case Studies

Part II contains six chapters, Chapters 3 through 8, each of which presents individual case study reports of one of six sites that have successfully established active learning as the norm for instruction in the Precalculus through Calculus sequence for at least three years. The case study reports provide a narrative of how and why each institution accomplished this transformation. Each of Chapters 3 through 8 are self-contained in that they each present the change story of one institution. Institutional summaries can be found at the end of Chapter 1. Readers may find these summaries useful in prioritizing which chapters to read first. We suggest starting with institutions that are similar to the reader’s institutional context.

Part III: Levers for Change

Part III contains Chapters 9 through 16, which present cross-case analyses organized by the following topics: active learning, leadership, coordination, professional
development, student engagement, resources, equity and culture, and sustainability. Chapter 9 focuses on active learning, which is central to the SEMINAL project. All of the institutions involved in SEMINAL are working to support the use of active learning in their Precalculus through Calculus courses. As such, this chapter is critical to this volume. It provides both an overview of SEMINAL’s vision for active learning, as well as an analysis of the ways in which active learning strategies are being used at the six Phase 1 SEMINAL sites, and what challenges the sites are facing in their implementation of active learning. The rest of the chapters in this section focus on levers which we identified as influential in supporting the institutionalization of active learning at these six sites. Since change efforts work best when the whole system is considered, we recommend that change agents read each of these chapters in their entirety; however, the reader may want to prioritize certain chapters based on their local priorities and needs.

Part IV: Summarizing What We’ve Learned

Part IV is Chapter 17, which is a summary of recommendations to readers looking to enact similar reforms, including department chairs, instructors, and campus administrators. In this part of the book we also include a sneak peak into what to expect from future work of the SEMINAL study. We recommend that the reader use this last chapter as a reference guide, as it provides a manageable list of recommendations associated with each one of the critical change levers we identify earlier in the book.
Common Terms, Definitions, and Abbreviations

0.1. List of Abbreviations

- DFW: Drop, Fail, and Withdraw. These represent the rates of students who drop, fail, or withdraw from mathematics courses.
- IBL: Inquiry-Based Learning. Inquiry-based learning is a type of active learning.
- MCOP: Mathematics Classroom Observation Protocol for Practices. This was the classroom observation instrument used during the project.
- NSF: National Science Foundation.
- SEMINAL: Student Engagement in Mathematics through an Institutional Network for Active Learning.
- X-PIPS: X-Postsecondary Instructional Practice Survey. This represents the suite of surveys (instructors, students, teaching assistants) that were administered in this project.

0.2. SEMINAL Terminology

- Academic advisor: Non-academic administrator, which includes student support services and other academic advisors.
- Academic dean: Includes deans of colleges and associate/assistant deans.
- Active learning classroom: Classroom spaces designed to support student collaboration, usually featuring movable tables and chairs and extensive board space.
- Adjunct: Includes people hired to teach mathematics courses, not on a tenure-track line; can be full or part time. Includes lecturers, instructors, adjuncts, etc.
- Assistant chair: Vice chair, associate chair, etc.; a person who is not the department chair or head but assists in department administration in an official capacity.
- Campus administrator: Refers to university administrator at a high level, such as provost, assistant provost, chancellor, vice chancellor, etc.; does not include deans or department chairs/heads.
- Client discipline: Physical science and engineering departments whose students are required to take at least Calculus 1 and often Calculus 2; does not include business or biology majors when there are special sections of Calculus for them (e.g., Calculus for Life Sciences).
- Coordinator: Faculty member or other staff who has responsibility for coordinating one or more Precalculus through Calculus courses, such as setting the syllabus, selecting the text, setting the homework, and writing
the assessments. Coordinators may observe and monitor what is being taught and usually lead regular course meetings of instructors. Sometimes called conveners.

- **Department administrator**: Can refer to anyone in the department with a formal leadership role, such as chair/head or assistant chair.
- **Department chair**: The chair, head, or director of the math department.
- **Faculty**: Tenured or tenure-track faculty, as well as others with “permanent” status such as professors of practice.
- **Graduate student instructor**: Graduate student with teaching responsibilities, also called graduate teaching assistant.
- **Instructors**: Anyone who is teaching Precalculus through Calculus courses as an instructor of record, regardless of role (e.g., faculty, postdoc, adjunct, graduate student instructor).
- **Lead Coordinator**: Faculty member or other staff who oversees the Precalculus through Calculus 2 coordination (multiple courses). May also have responsibilities of coordinators.
- **Lead graduate student instructor**: A graduate student instructor who assists the course coordinator.
- **Mainstream Precalculus through Calculus**: The calculus sequence for physical science and engineering students; does not include courses that are only for specific subsets of students such as Calculus for Biology or Business Calculus.
- **Precalculus through Calculus committee**: A faculty committee that oversees one or more Precalculus through Calculus courses, focused on the reforms. They may review local data, oversee coordinators, determine curricular changes, review assessments, etc.
- **Postdocs**: Postdoctoral position with teaching responsibilities; not in a tenure-track.
- **Professors of Practice**: Includes teaching professors and clinical professors; these are faculty members (not tenure-track), for whom most of their appointment is devoted to the teaching/instructional mission of the department. Contracts tend to be multi-year.
- **Professional development**: Includes trainings, workshops, and other activities designed to help instructors improve their instructional practices. Can include one-on-one mentoring, weekly meetings, etc.
- **Recitation**: Also called labs, discussion sections, breakouts. These are small (around 15-30 students) sections associated with large lecture classes, often led by a graduate student instructor or undergraduate learning assistant, that meet 1-3 times per week, separate from the large lectures. These are regular sessions that all students in the large lecture are expected to attend.
- **Supplemental instruction**: Small sections associated with a Precalculus through Calculus course (can be large or small lecture), designed for “at-risk” students (often through placement test identification or other student characteristic such as a first-generation college student). These sessions are designed to address gaps in student knowledge, and otherwise help support students in being successful in the primary Precalculus
through Calculus course with which the supplemental instruction is associated. Supplemental instruction is often optional (or, once students opt in, all sessions are required).

- **Teaching and learning center**: A center where faculty go as a resource; such centers may provide professional development for faculty and other instructors.
- **Tutoring center**: Where students go to get help with mathematics; the Director of the Tutoring Center is in charge of this place.
- **Undergraduate learning assistant**: An undergraduate who assists with Precalculus through Calculus instruction (not as an instructor of record). May also be called learning assistant, instructional learning assistant, instructional student assistant, undergraduate student assistant, or supplemental instructor on particular campuses. Undergraduate learning assistants may be alone in a classroom with students (e.g., running a lab or breakout section) or may be in a classroom with a lead instructor. Does not include undergrad whose only role is in a tutoring capacity. Undergraduate learning assistants are paid, have regular hours, and have responsibilities within classroom instruction environments.
Executive Summary of Transformational Change Efforts: Student Engagement in Mathematics through an Institutional Network for Active Learning

The purpose of this handbook is to help launch institutional transformations in mathematics departments to improve student success; the intended audience is faculty and department chairs in collegiate mathematics departments. To achieve this goal, we report findings from the Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) study. SEMINAL’s overarching purpose is to help change agents, those looking to (or currently attempting to) enact change within mathematics departments and beyond, who are trying to reform the instruction of their lower-division mathematics courses in order to promote high achievement for all students.

Why This Handbook?

- SEMINAL specifically studies the change mechanisms that allow postsecondary institutions to incorporate and sustain active learning in Precalculus through Calculus 2 learning environments.
- Out of the approximately 2.5 million students enrolled in collegiate mathematics courses each year, over 90% are enrolled in Precalculus through Calculus 2 courses [3].
- 44% of mathematics departments think active learning mathematics strategies are important for Precalculus to Calculus 2 courses, but only 15% state that they are very successful at implementing such strategies [4].
- Therefore, insights into the following research question will help with institutional transformations: What conditions, strategies, interventions, and actions at the departmental and classroom levels contribute to the initiation, implementation, and institutional sustainability of active learning in the Precalculus through Calculus 2 courses across varied institutions?

What is Active Learning? Laursen and Rasmussen [3] reviewed different types of inquiry-oriented and inquiry-based mathematics instruction, and synthesize multiple traditions to identify four pillars for inquiry-based mathematics education:

- Students’ deep engagement in mathematical thinking;
- Peer-to-peer interaction;
- Instructors’ interest in and use of student thinking;
- Instructors’ attention to equitable and inclusive practices.
This definition includes behaviors for both instructors and students, and includes an explicit focus on equity. A key goal in utilizing active learning strategies is to improve student outcomes; without an explicit attention to issues of equity and inclusion, inquiry-based mathematics education strategies may perpetuate current inequities in mathematics outcomes.

**What is Necessary to Enact and Sustain Institutional Change?** Undergraduate institutions are, by design, resistant to change. Change is hard to implement, and sustain, from the organization of majors, to course syllabi, to expected classroom practices. Keys to initiate, implement and sustain change include:

- Systemic approaches;
- Understanding institutional change;
- A focus on improved student engagement and equitable student outcomes;
- Active learning;
- Effective leadership
- Departmental and institutional cultures that encourage educational improvements;
- Course coordination;
- Professional development;
- Instructor communities of practice;
- Resources to improve teaching and learning;
- Use of local data.

SEMINAL builds on the *Characteristics of Successful Programs in College Calculus* project [1, 2, 4, 5] that identified eight key features of successful Calculus 1 programs in the United States. SEMINAL’s retrospective study (Chapters 1-2) of six mathematics departments (Chapters 3-8) that were able to successfully sustain improvements to their Precalculus through Calculus 2 courses affirmed the eight characteristics of successful calculus programs [1, 2, 4, 5]. Each institution took a somewhat different route in achieving this goal, providing a range of examples for those seeking to make similar changes. Despite the different routes, common themes emerged across the six cases, suggesting key levers in promoting those changes. The SEMINAL team undertook an analysis cutting across the institutions, focusing on common aspects of the change experience (Chapters 9-16), which led to the identification of the following key change levers (Chapter 17). Most of these levers are mentioned throughout the chapters; the chapters highlighted in the table indicate where the lever is discussed in depth.
### Change Levers and Key Considerations

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<tr>
<th>Systemic approach</th>
<th>Chapters</th>
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<td>The current situation was not caused by a single event or person. Effective changes look broadly to “see the system” and address root causes, not just symptoms. Corollary: You need a big enough team to represent different system components (student recruitment, placement, advising, teaching &amp; learning center, campus data, facilities, scheduling, finance, academic affairs, deans, department chairs, instructors, tutoring centers, etc.).</td>
<td>1, 3-8</td>
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<th>Understanding institutional change</th>
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<td>Institutional change as a topic has research indicating best practices: Moving from initiating change on a small scale, scaling it up to additional courses, and working to institutionalize the changes so that they are sustained. However, there is not a singular “correct” path to effective transformation, nor is there a singular “best” team of people to work collaboratively on change efforts. Corollary: Successful transformation efforts involve multiple stakeholders working through the change process toward a common vision of improved student outcomes in mathematics.</td>
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<th>A focus on improved student engagement and equitable student outcomes</th>
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<td>The national status quo leads to inequitable student outcomes by most subgroups (gender, ethnicity, socioeconomic status, first generation). Keeping a focus on improving equitable student outcomes, and making sure decisions are made that prioritize the needs of students are crucial. Corollary: Putting students into groups and using active learning strategies does not automatically increase equity; instructors need to explicitly address developing norms for interaction that encourage mathematical reasoning and communication for all students.</td>
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<th>Active learning</th>
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<td>Following the active learning definition above, students need to be actively engaged in making sense of mathematics and communicating mathematical thinking and reasoning. Corollary: Active learning takes more time than simply telling students information via lectures. Departments may address this through a combination of adding more minutes to courses using active learning, and trimming the learning objectives for the targeted courses.</td>
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<th>Effective leadership</th>
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<td>Leaders who are willing to push for changes that will improve student success are needed at all levels, from campus administrators to department chairs and faculty committees. Motivated change agents are needed to keep the change efforts as a long-term priority. Corollary: Effective teams have a transition plan to bring new leaders on board both within and without the department.</td>
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<th>Departmental and institutional cultures that encourage educational improvements</th>
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<td>Change occurs more quickly when individuals who need to make changes have sufficient incentive. Annual evaluations (and merit raises) that reward attempts to improve instruction are important. Corollary: It is not enough that effective teaching is, valued on paper: actions, resources and policies of administrators need to align with the importance of instructional innovations.</td>
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## EXECUTIVE SUMMARY

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<th>Course coordination</th>
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<td>More consistent courses across sections and semesters can help reduce inequitable outcomes and improve in-house professional development opportunities. Coordination also provides institutional memory through changes in instructors assigned to teach specific courses. Corollary: Coordination of learning objectives across courses can help reduce redundancy, leaving more time to focus on key learning objectives within individual courses.</td>
<td>3-7, 11</td>
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<th>Professional development</th>
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<tr>
<td>Instructors cannot just stop lecturing and inherently know how to actively engage students while maintaining rigorous mathematical expectations. The entire instructional workforce (from tenured/tenure-track faculty to adjuncts, graduate student instructors, and undergraduate student assistants) needs to learn how to engage students actively. Corollary: Effective professional development includes both initial workshops and sustained semester-long support.</td>
<td>13</td>
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<th>Instructor communities of practice</th>
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<td>When the norm is for instructors to discuss teaching and learning with each other (akin to research groups), then instructors can learn from each other and better implement and sustain improved educational practices. Corollary: Departments need explicit plans for integrating new instructors into an existing community of practice.</td>
<td>3-8, 13, 15</td>
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<th>Resources to improve teaching and learning</th>
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<td>Improved student outcomes are not free. Although it takes time and money to effectively improve student outcomes, effective transformation does not necessarily need a huge amount of monetary resources. Corollary: Instructional innovation is a personnel-intensive activity; undergraduate learning assistants can be a low-cost resource to support active learning.</td>
<td>3-8, 14</td>
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<th>Use of local data</th>
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<td>Departments need access to relevant local data (and often to collect their own data) in order to make informed decisions, and to measure the impact of change efforts. Local data include far more than final grades in mathematics courses, potentially including: Course-taking trajectories, majors, enrollment numbers, grades in subsequent mathematics courses, item-level homework and test performance, attendance, use of student supports (tutoring centers, office hours), attitudes toward mathematics. These data should be disaggregated by targeted subgroups (e.g., by gender, first-generation, Pell-eligible). Corollary: Changes take time to show up in data, particularly longitudinal data like course-taking trajectories, STEM majors, and graduation rates. It is common to see an “implementation dip” the first time instructors attempt new teaching strategies.</td>
<td>2-8, 16</td>
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### References


