Project EMBER

Evidence-Based Innovations for Student Success in Introductory Mathematics

PROJECT EMBER
ELIMINATING MATHEMATICS BARRIERS THROUGH EVIDENCE-BASED REFORMS

TPSEMath
Transforming Post-Secondary Education in Mathematics

Association of Public & Land-Grant Universities

Association for Undergraduate Education at Research Universities

every learner everywhere

Author Information

Innovation Overview(s)	Author(s)
Active Pedagogy & Course Coordination:	**Nicholas Jacome**, doctoral student, Mathematics and Science Education, San Diego State University
Math Pathways:	**Dave Kung**, Executive Director, TPSE Math; Visiting Research Professor, University of Maryland
Corequisite Supports:	**Laura M. Schueller**, Mathematics Consultant, Almy Education
Tech-Enabled Instruction:	**Riccardo Purita**, Assistant Director, Digital Transformation for Student Success, Association of Public and Land-grant Universities
Alternative Grading:	**Drew Lewis,** Director of Research, Center for Grading Reform **Sharona Krinsky,** Executive Director, Center for Grading Reform and First-Year Course Coordinator, Department of Mathematics, California State University Los Angeles
Using Data in Decision-Making:	**Marco Molinaro**, Executive Director for Educational Effectiveness, University of Maryland, College Park **Mary E. Pilgrim**, Professor, Department of Mathematics and Statistics, San Diego State University
Identity and Belonging:	**Catherine Good**, Professor, Psychology, Baruch College and The Graduate Center, City University of New York

About Our Organizations

Project EMBER is a network of 50-100 institutions that empowers teaching-focused faculty at research institutions to adapt evidence-based reforms in introductory mathematics, track progress to improve overall student success and eliminate equity gaps, all in collaboration with departmental and institutional leaders.

TPSE Math is a professional organization of mathematicians dedicated to ensuring that all high education students – regardless of their background, location, identity, or chosen program of study – develop the modern mathematical knowledge and skills they need for productive engagement in society and in the workplace. TPSE aims to identify effective practices where they exist, advocate for innovation where they do not, and work with and through partners to implement and scale effective practices, striving throughout to ensure that students and society are enriched by the power and beauty of mathematics.

The **Association of Public and Land-grant Universities (APLU)** is a research, policy, and advocacy organization dedicated to strengthening and advancing the work of public universities in the U.S., Canada, and Mexico. The association's membership consists of more than 250 public research universities, land-grant institutions, state university systems, and affiliated organizations. The association and its members collectively focus on: increasing student success and workforce readiness; promoting pathbreaking scientific research; and bolstering economic and community engagement. Drawing on the powerful collective action of its members, APLU's advocacy arm helps shape federal policy that maximizes the positive impact of public and land-grant universities.

The **Association for Undergraduate Education at Research Universities** (UERU, pronounced "You-Roo") is dedicated to excellence and access in undergraduate education. The UERU membership is comprised of 141 R1/2 research universities which collectively serve nearly 3 million undergraduate students. UERU fosters connections across academic units to help leaders meet current challenges and opportunities facing undergraduate programs. Learn more at ueru.org.

Every Learner Everywhere is a network of partner organizations with expertise in evaluating, implementing, scaling, and measuring the efficacy of education technologies, curriculum and course design strategies, teaching practices, and support services that personalize instruction for students in blended and online learning environments. Our mission is to partner with institutions to harness digital learning technology, driving innovation in higher education to improve outcomes for every learner. We build capacity in colleges and universities to improve student outcomes with digital learning through direct technical assistance, timely resources and toolkits, and ongoing analysis of institutional practices and market trends. WCET (the WICHE Cooperative for Educational Technologies) and WICHE (the Western Interstate Commission for Higher Education) serve as the intermediary organizations for the Every Learner Everywhere Network. For more information about Every Learner Everywhere and its collaborative approach to advance student success in higher education through digital learning, visit everylearnereverywhere.org.

Table of Contents

Recommended Citation:

Pilgrim, M. E., Callahan, K.M., Carney, D., Kung, D., La Rose, P.G., Lindsey, M., Rasmussen, C., Speer, N., & Tesene, M (Eds). (2026). Project EMBER Evidence-Based Innovations for Student Success in Introductory Mathematics. Every Learner Everywhere. everylearnereverywhere.org/resources/project-ember-innovations-for-student-success

Photos by **Allison Shelley/Complete College Photo Library.**

PROJECT EMBER

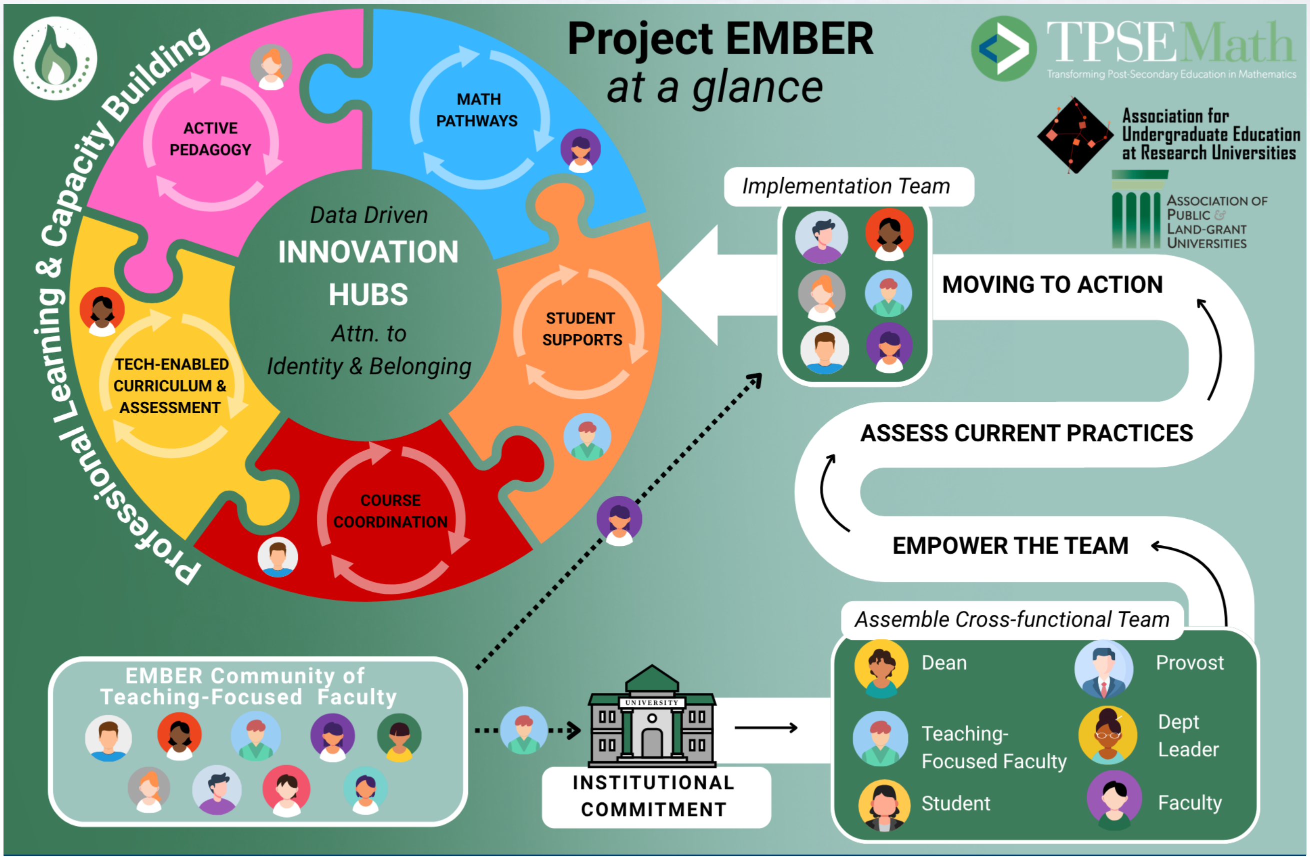
PREFACE

Welcome to Project EMBER (Eliminating Mathematics Barriers through Evidence-based Reforms) where we envision a world where:

Every higher education math student succeeds in introductory mathematics aligned with their interests and aspirations.

Introductory college mathematics is the largest academic barrier to college completion and STEM success, particularly for students from historically underserved groups. At most universities, these courses have the highest DFW rates, derailing student progress, wasting talent, and weakening the nation's STEM workforce and national security pipeline. The problem is not a lack of effective solutions. Decades of research and practice have produced proven, scalable reforms that have improved student outcomes, including redesigned pedagogy, better alignment of mathematics pathways with students' majors, and restructured developmental sequences. Yet these reforms remain unevenly adopted across institutions.

Teaching-focused faculty (TFF), especially at research universities, will be the primary leaders toward adoption, as they are responsible for teaching and coordinating most introductory mathematics courses. Project EMBER aims to support and elevate TFF while simultaneously engaging with departmental leaders and institutional leaders. At each institution, those faculty collaborate with departmental and institutional leaders to establish a cross-functional team, assess current practices, and plan for transformation. Members of the implementation team then join faculty from other institutions in communities of practice centered on particular innovations.



The Project EMBER model.

Project EMBER has developed tools to guide reformers through this process, available at the Project EMBER website:

- Project EMBER Guidebook
- Project EMBER Self-Assessment

This document, **Project EMBER Innovation Overviews**, is designed to help teams answer a key question: **Which reforms should they try to implement?** Various departments will answer that differently, depending on their unique, individual contexts. This resource provides overviews of innovations that have been shown to improve student outcomes in introductory mathematics.

For each innovation, we provide a brief description, supporting research and evidence, case studies as examples, notes on professional development, and connections with other innovations. The purpose is to guide readers as they think through enacting change in introductory mathematics at their own institution—adopting and adapting innovation(s) in their local context.

EIGHT INNOVATIONS COVERED IN THIS RESOURCE:

1. **Active Pedagogy:** Improving learning through active pedagogies

2. **Course Coordination**: Using this lever for professional learning and better and more fair outcomes

3. **Math Pathways**: Getting students into courses aligned with their interests

4. **Corequisite Supports**: Avoiding developmental courses and sequences

Curriculum and Assessment:

5. **Tech-Enabled Instruction**: Leveraging today's tools for greater student engagement and learning

6. **Alternative Grading**: Improving student outcomes by moving away from high-stakes tests

Cross-cutting Themes (central to all other innovations):

7. **Using Data in Decision-Making**

8. **Identity and Belonging**

PROJECT EMBER

ACTIVE PEDAGOGY

What Is the Challenge?

Research shows that effective teaching and deep learning require student engagement with mathematics both inside and outside the classroom. However, historically, mathematics pedagogy has relied heavily on passive lecture. Additionally, we tend to teach the way we learn, which leads to outdated teaching practices. Transforming teaching practices across a high-enrollment introductory course is a challenging and time-intensive task. Instructors—whether postdocs, graduate students, teaching-track faculty, full-time faculty, or adjuncts—may need to learn and utilize new skills. They may also need support to develop both their thinking about instruction and their adoption of active pedagogies, especially if these are different from how they have taught before or how they have experienced instruction as students. Common challenges instructors face with the use of these pedagogies include attaining student buy-in, fostering student engagement, selecting appropriate mathematical tasks, working around inflexible classroom designs, and assessing student learning outcomes.

Addressing the Challenge

We encourage folks to learn about, adapt, and adopt evidence-based instructional strategies for active learning (there are many ways to do this, including readings, workshops, and collaboration with colleagues). Try them out in your own class, reflect on their effectiveness, and iterate. Iteration is crucial for refining the skills for effectively using new teaching strategies. We further recommend that you learn about and utilize professional development strategies to support the adoption of evidence-based instructional practices, which we later discuss.

We have compiled resources to help instructors and coordinators with

1. Helping others see the merit of using evidence-based instructional practices through supported reflection after trying each technique in the classroom.
2. Supporting instructors in adopting active learning teaching strategies.
3. Supporting professional development of instructors.

What Is Active Pedagogy?

Active pedagogy, according to the Conference Board of the Mathematical Sciences (CBMS), refers to "classroom practices that engage students in activities, such as reading, writing, discussion, or problem-solving, that promote higher-order thinking." It emphasizes student-centered, collaborative, and, when applicable, inquiry-based methods over traditional passive lecturing.

Thus, active pedagogy is a continuum of practices that work to actively engage students in learning, and all techniques are welcome. Active learning can be unique within different schools, different courses, differently sized courses, and even different classrooms. Further, active learning will vary by instructor, their experience, and their students.

What Is the Evidence?

We now have strong evidence that active learning consistently better supports student learning outcomes and passing rates when compared to passive lectures. This evidence comes from studies that include randomized trials and large meta-analyses comparing student outcomes in active learning classrooms to more passive, lecture-driven classrooms.

The largest meta-analysis, conducted by Freeman and colleagues, included over 200 STEM courses with more than 40 being mathematics courses. Their National Academy of Sciences Proceedings paper reported a 55% higher failure rate and nearly a half a standard deviation drop in performance in passive lecture-based classes compared with active learning ones. The authors suggested that, if this were a medical trial, ethics standards would require stopping the control group (i.e., lecture classes) and universally adopting active learning. They indicated that not doing so would constitute professional malpractice. Further, a follow-up study showed that the gains were concentrated among women and racially minoritized students.

Studies specifically targeting mathematics courses showed similar results. A randomized control trial in college calculus showed active student engagement significantly improved student learning outcomes and pass rates in calculus across all student groups. Further, students' attitudes toward mathematics were higher among the students doing group work in class.

When studying inquiry-based learning (IBL)[1], a popular style of active learning in mathematics courses, researchers found increases in immediate understanding as well as long-term benefits. In particular, lower-achieving students saw improved grades and greater continued engagement in STEM courses.

Evidence for active learning is so strong that, in 2016, presidents of 15 organizations in the mathematical sciences signed onto the CBMS statement on active learning, urging the field to adopt such teaching practices. The Mathematical Association of America (MAA) is one such organization that not only has Best Practices Statements but also has an Instructional Practice Guide that supports this type of classroom instruction. More recently, the National Academies of Sciences, Engineering, and Medicine (NASEM) featured active learning prominently in its report on equitable and effective STEM teaching.

Professional Development

Shifting from traditional lecture-based teaching to active or inquiry-based learning requires more than just new strategies—it demands changes in beliefs, habits, and classroom culture. While instructors and TAs may be convinced by the research that inquiry-driven approaches improve student learning, confidence, and persistence, we now know that many STEM instructors who value active learning still face barriers to implementation, such as lack of time or confidence, class size, classroom setup, and evaluation pressures that limit its use. We also know that modeling active learning within professional development helps teachers and TAs internalize and adopt active learning strategies. Additionally, instructors can implement small modifications without having to change things dramatically, like think-pair-share and the use of clickers. Ongoing professional development and sustained support help instructors not only to learn new teaching procedures but also to reflect on the underlying concepts, challenge existing assumptions, and build supportive communities. Mathematics educators can often find free professional development resources for enhancing teaching practices through active learning strategies through various websites and organizations like the MAA. These resources include the following.

The MAA Instructional Practices Guide (IPG) is a comprehensive, research-based resource developed by the MAA to support college mathematics instructors in improving teaching and learning. The guide provides evidence-informed recommendations on course design, classroom practices, assessment, and department culture, all grounded in current scholarship on how students learn mathematics effectively. Further, the guide invites instructors to engage in inquiry about their teaching practices and lowers the barriers for entry into using active learning strategies. The guide does so by showing instructors how to make incremental changes that have an outsized impact on their teaching practices.

[1] "In the context of mathematics, IBL approaches engage students in exploring mathematical problems, proposing and testing conjectures, developing proofs or solutions, and explaining their ideas" (Kogan & Laursen, 2014, p. 184).

The College Mathematics Instructor Development Source (CoMInDS) offers a suite of resources and various professional learning opportunities through workshops (summer) and follow-up opportunities (academic year). It gives access to curricular materials such as lessons, activities, assignments, etc., and connects professional development with research-based practices in undergraduate mathematics teaching. Research has argued that effective professional development should engage instructors in inquiry about their own teaching, not just deliver techniques. Accordingly, CoMInDS gives instructors and TAs structured resources and activities that they can adapt and reflect on, thereby building conceptual understanding of teaching rather than simply adopting methods. These materials offer manageable, scaffolded activities for TAs/instructors, making change less overwhelming for educators and more likely to be sustained. This addresses issues brought up by research, which found that a key barrier to adopting active learning is a lack of preparation/experience. However, as research indicates that small changes in teaching can lead to big impact, these types of incremental improvements to teaching will address concerns related to preparedness/experience.

Video Cases for College Math Instruction features authentic video examples of real college math classrooms where instructors and students engage in collaborative inquiry-based learning embedded within lesson plans appropriate for TA workshops or courses. Instructors can see active learning strategies modeled in a real setting and reflect on them. Some theories argue that inquiry-based instruction not only promotes deeper mathematical understanding but also empowers diverse student voices. In line with those theories, the video cases allow instructors to examine and analyze participation patterns, teaching choices, and real classroom interactions through a student success lens. Design-based research shows that effective active learning is student-centered, so by analyzing the videos and reflecting on teacher moves and inquiry-based practices, instructors can be most effective in using active learning strategies.

The First Day video case is a powerful professional development tool that allows instructors and TAs to see how to begin active learning and inquiry-based teaching from the very first class meeting. Rather than simply describing effective teaching practices, the case models them in action, which is consistent with researchers who have found that faculty development should mirror the teaching we want instructors to enact.

Interested in joining a community of educators committed to improving teaching practices?

- EMBER Network for Teaching-Focused Faculty (on Zulip)
- MAA Connect

Connections to other innovations

- **Course Coordination**: Active learning in larger or multi-section courses is more sustainable and student-centered within coordinated courses. Shared materials, common tasks, and aligned expectations help instructors implement active learning consistently across sections. Instructors' training on active pedagogy is improved when they have the support of other instructors learning to implement active pedagogy in the same course.
- **Identity and Belonging**: Active learning can promote student voice, collaboration, and participation, which directly supports belonging. In the Identity and Belonging innovation, we advocate for teaching that empowers all student voices, showing how active pedagogy can strengthen students' identity as capable mathematics learners.
- **Alternative Grading**: Active learning emphasizes meaningful engagement and higher-order thinking, which aligns with assessment systems that evaluate conceptual understanding rather than one-shot performance. Approaches like standards-based grading or exam recovery fit naturally with active-learning environments because both prioritize learning as an ongoing process rather than a single event.

CASE STUDY: UNIVERSITY OF MICHIGAN

UNIVERSITY OF MICHIGAN

The University of Michigan embeds active learning in all sections of Calculus I, II, and the course required before calculus. Educators teach these courses in sections that are capped at 24 students and meet three times a week. Each beginning instructor (post-doc or graduate student) participates in a week of pre-semester training on using interactive teaching methods before teaching in one of these courses. Each class session should include extensive group work, and the course coordinator should include materials that have been tested. New graduate students first teach their section of the course in a large team-learning room with three or four other sections, including graduate students and an experienced faculty member.

After a semester in this supportive environment, instructors teach independently. Instructors are observed teaching independently at least once in their first semester, and in subsequent semesters as needed. Each observation specifically focuses on their facilitation of group work in the classroom and is a formative exercise with a follow-up discussion with the instructor. The institution provides ongoing additional support to promote the effective management of an active learning classroom as needed or desired by the instructor.

References

Abell, M. L., Braddy, L., Ensley, D., Ludwig, L., & Soto, H. (2018). *MAA instructional practices guide* (Vol. 89). Mathematical Association of America. https://maa.org/wp-content/uploads/2024/06/InstructPracGuide_web.pdf

Akin, V., Braley, E., & Bookman, J. (2023). Modeling active learning in professional development for teaching. *The Journal of Faculty Development*, *37*(3), 28–39.

Apkarian, N., Henderson, C., Stains, M., Raker, J., Johnson, E., & Dancy, M. (2021). What really impacts the use of active learning in undergraduate STEM education? Results from a national survey of chemistry, mathematics, and physics instructors. *PLOS ONE*, *16*(2), e0247544. https://doi.org/10.1371/journal.pone.0247544

Conference Board of the Mathematical Sciences. (2016, July 15). Active learning in post-secondary mathematics education. *Active Learning in Post-Secondary Mathematics Education*. https://cbmsweb.org/2016/07/active-learning-in-post-secondary-mathematics-education/

Duran, P. A., Castillo, A. J., Watson, C., Fuller, E., Potvin, G., & Kramer, L. H. (2024). Student attitudes and achievement in active learning calculus. *International Journal of Mathematical Education in Science and Technology*, *55*(3), 759–780. https://doi.org/10.1080/0020739X.2022.2150902

Ecke, V., & von Renesse, C. (2022). Using inquiry in professional development for faculty in mathematics. *PRIMUS*, *32*(9), 975–997. https://doi.org/10.1080/10511970.2021.1962459

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Kogan, M., & Laursen, S. L. (2014). Assessing long-term effects of inquiry-based learning: A case study from college mathematics. *Innovative Higher Education*, *39*(3), 183–199. https://doi.org/10.1007/s10755-013-9269-9

Kramer, L., Fuller, E., Watson, C., Castillo, A., Oliva, P. D., & Potvin, G. (2023). Establishing a new standard of care for calculus using trials with randomized student allocation. *Science*, *381*(6661), 995–998. https://doi.org/10.1126/science.ade9803

National Academies of Sciences, Engineering & Medicine. (2025). *Transforming undergraduate STEM education: Supporting equitable and effective teaching* (A. Holmes, K. Brenner, & J. Gao, Eds.). National Academies Press. https://doi.org/10.17226/28268

Rasmussen, C., & Johnson, E. (2023). When small changes lead to big impact: Hysteresis in mathematics teaching. *Notices of the American Mathematical Society*, *70*(10). https://www.ams.org/journals/notices/202310/rnoti-p1684.pdf

Stone-Johnstone, A., Kurianski, K., Soto, R., & Marzocchi, A. (2025). Mathematics equity through teaching actively: Centering equity in our active learning pursuits. *PRIMUS*, *35*(4–5), 479–492. https://doi.org/10.1080/10511970.2024.2354813

Tang, G., El Turkey, H., Cilli-Turner, E., Savic, M., Karakok, G., & Plaxco, D. (2017). Inquiry as an entry point to equity in the classroom. *International Journal of Mathematical Education in Science and Technology*, *48*(sup1), S4–S15. https://doi.org/10.1080/0020739X.2017.1352045

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

PROJECT EMBER

COURSE COORDINATION

What Is the Challenge?

When students in different sections of the same course have wildly different experiences, the fallout is predictable—and avoidable. Students notice the inconsistencies immediately, and issues arise when students in the same course are learning different material, being assessed in different ways, and/or facing different outcomes simply because of the section in which they happen to be enrolled. In uncoordinated multi-section introductory courses such as Precalculus, Calculus, or Introductory Statistics, departments routinely see the same systemic problems resurface. Instructors often vary in course pacing, content coverage, grading practices, and exam difficulty across sections. Even small or perceived differences can grow into perceived unfairness in what is expected of students. Additionally, instructors often enter coordinated courses with varied pedagogical preparation and levels of teaching experience, including new graduate teaching assistants and adjunct instructors. These differences can cause uneven instructional quality and can decrease the consistent use of research-based teaching practices across sections in uncoordinated settings.

When courses lack coordination, instructors may also end up teaching in isolation, which can lead to minimal communication, resulting in little opportunity to talk through student thinking, share materials, or coordinate expectations. This independence can result in dramatic differences in difficulty and conceptual emphasis from one section to another. And when departments try to improve teaching—especially by adopting active learning—those efforts often depend on a single motivated instructor. Without professional learning opportunities and without structural support, that progress rarely lasts.

What Are Some Common Elements of Course Coordination?

Course coordination can vary, but generally it is a practical, department-level strategy and a structured, collaborative system for managing multi-section courses so that students receive consistent and welcoming experiences. Course coordination transforms a patchwork of independent sections into a unified course and curriculum by establishing shared structures, robust communication, and clear leadership. Coordinated courses commonly develop shared syllabi, pacing guides, assessments, and grading rubrics to stabilize student experience across sections. Research shows that shared assessments and grading practices can reduce variation across sections, while shared course structures such as syllabi and pacing guides help align expectations and learning goals[2] across sections.

Course coordination typically involves a designated coordinator or leadership team[2] who organizes shared structures and communication routines. Coordinators play a central role in organizing materials and assessment structures. Coordination is more effective when it includes regular instructor meetings and collaborative exam development. Coordination models emphasize aligned expectations and instructional coherence across sections. Shared decision-making and communication are key features of effective coordination. Regular meetings create space for instructors to troubleshoot student challenges,[2] reflect on instruction, and function as a community of practice that supports instructor learning. This means coordination makes instructional work more manageable by structuring logistics and shared materials. Additionally, it helps support instructors in adopting active-learning and inquiry-oriented methods. Collective exam creation, LMS setup, and grading can increase efficiency and reduce instructor workload. By stabilizing leadership, strengthening communication, and aligning instruction across sections, coordination supports department-level improvement and equitable student experiences.

Research has found two primary orientations to course coordination:

1. **Materials Management**: Focuses on organizing and managing the structural components of a course—such as syllabi, pacing guides, assessments, and instructional resources—to ensure consistent delivery across sections.

2. **Humanistic Growth**: Focuses on supporting the people involved in the course—helping instructors develop their teaching, building community among instructors, and responding to differences in instructor experience and needs.

Professional development is a central component of effective course coordination because coordination creates ongoing, embedded opportunities for instructors to learn from one another and improve their teaching. Coordinated courses build professional learning into the routine work of the instructional team through regular meetings, collaborative assessment design, and shared reflection on student thinking. Research shows that these structures help instructors adopt research-based pedagogies, calibrate expectations, and develop more coherent approaches to teaching across sections. Coordinators who intentionally support instructor growth—by treating instructors as learners and fostering communities of practice—help create meaningful, job-embedded professional development for instructors. These efforts can help new instructors quickly get up to speed and strengthen the overall instructional capacity of a department.

[2] See chapter 9, pp. 107-115: Calculus coordination at PhD-granting universities: More than just using the same syllabus, textbook, and final exam.

What Is the Evidence?

There is strong evidence that coordination is effective at reducing inconsistency and perceived unfairness in multi-section courses. Coordination can also reduce students' perceptions of unfairness across sections. This research also shows that coordinated courses with shared syllabi, collaboratively written exams, and common scoring rubrics saw reduced variations in student experiences. Consequently, students were more likely to perceive the course as fair and well organized, while sections with less collaboration were not. In addition, well-coordinated courses had a statistically significant higher rate of A's and a lower rate of withdrawals than non-coordinated courses. We acknowledge that many factors contribute to these results, and we, as a research community, are only beginning to understand the potential impact of course coordination.

Researchers have also found that, before coordination, grade distributions in a multi-section introductory statistics course varied significantly by instructor—and the statistical relationship between the instructor and grade distribution disappeared after implementing coordination. Students in the coordinated course reported clearer expectations and identical requirements across sections, which supported cross-section study groups and created a more predictable experience.

There is also evidence that coordination can strengthen teaching, particularly when institutions build in ongoing professional development into the coordination model. Coordination that supports active learning has also been linked to improved student learning outcomes. In a large Calculus for Life Sciences program, students in coordinated active-learning sections consistently outperformed those in traditional lecture sections on identical exam items, and students reported gains in understanding, metacognition, and work habits. More coordination in STEM courses—especially when collaborative decision-making is involved—is associated with greater use of research-based pedagogy and stronger instructor knowledge-sharing networks.

Getting Started and Improving Your Strategies

Establishing a Clear Coordinator Role: Course coordination is demanding work, and should be compensated in a way that reflects that reality. Identify a course coordinator or a small leadership team with protected time and authority to guide the course. Effective coordinators organize regular meetings and lead collaborative assessment creation to support alignment across sections. They also act as facilitators who cultivate a sense of community among instructors and support shared instructional growth. Coordinators who view instructors as learners are especially effective because they balance logistical management with real instructional support.

Collaboratively Develop Shared Learning Goals and Essential Course Structures: Start where student experience is most directly shaped. Collaboratively develop shared learning outcomes, common syllabi, and pacing guides. Prioritize structures that reduce inconsistencies and confusion across sections. Even shared exams or unified grading rubrics can significantly reduce disparities.

Create Regular, Collaborative Instructor Meetings: Consistency and improvement do not happen by accident; they are built through regular collaboration. One of the strongest factors supporting consistency and instructional improvement is meeting regularly. If possible, hold weekly or bi-weekly meetings to discuss pacing, upcoming assessments, student challenges, and/or instructional routines so coordination actually influences what happens in classrooms.

Develop and Use Shared Assessments: Shared assessments are one of the most concrete ways to make coordination real for students (and establish consistency) and instructors. Collaborative assessment design can also prompt productive, faculty-driven conversations about student thinking and course goals. Sharing quizzes, midterms, finals, and rubrics will help align expectations for students and support fair grading.

Build Coordination That Supports Active Learning: Coordinators can create shared active-learning materials, help instructors learn new teaching strategies, and design assessments that fit active learning approaches.

Maintain and Adapt the Coordination Over Time: To keep coordination effective, it must be stable and responsive. The coordinator role should be consistent and reliable; frequent turnover leads to inconsistent vision and uneven coordination. Coordination must be maintained by revisiting materials, updating assessments, and using student and instructor feedback to refine the course. Coordination is most effective when it allows the curricula to evolve in response to student needs.

Connections to other innovations

- **Active Pedagogy**: Course coordination scales research-based pedagogies by shifting active learning from an isolated effort to a departmental standard. By aligning materials, collaboration, and assessments, coordinators embed these plans into an institution's fabric.
- **Data Use**: By generating comparable data across sections, coordinated courses enable departments to identify inequities and monitor instructional variation. This fosters a continuous improvement model in which feedback and materials are regularly refined to enhance teaching.
- **Alternative Grading**: Coordination facilitates alternative assessment by aligning exams, rubrics, and grading practices. This consistency makes implementing alternative grading more feasible across multiple sections.

CASE STUDY: CALIFORNIA STATE UNIVERSITY, EAST BAY

California State University East Bay is an example of how course coordination can support student success, consistency, and instructional improvement in multi-section mathematics courses. As part of the SEMINAL project,[3] the mathematics department focused on its Precalculus through Calculus II sequence, which serves a large and diverse student population. With many students entering directly into college-level mathematics, the department prioritized creating structures to support student success and reduce inconsistencies across sections. Faculty collaboratively curated course content around core ideas and conceptual understanding and then developed shared activities and guided notes aligned with common learning goals.

A central coordination tool was a dynamic calendar that functioned as a shared pacing guide and resource hub. It included recommended timelines, suggested group tasks, and links to ready-to-use materials. Using this system, instructors maintained aligned expectations while still exercising professional judgment in their classrooms. Regular meetings through a Mathematics Community of Practice complemented these shared materials. Instructors met to discuss pacing, reflect on student learning, and share teaching strategies. New instructors were oriented to the materials and invited into the community, reducing isolation and supporting onboarding. Over time, the department saw broader use of active learning, greater communication across sections, and stronger alignment in course expectations. The East Bay experience shows that institutions can implement coordination in a flexible, faculty-driven way that promotes instructional improvement and student success.

[3] Student Engagement in Mathematics through an Institutional Network for Active Learning: https://www.aplu.org/our-work/2-fostering-research-innovation/seminal/

References

Adeyemi, A., Grant, C., & Sebastian, K. (2023). Course coordination: A necessary requirement for consistency. *PRIMUS*, *33*(4), 378–401. https://doi.org/10.1080/10511970.2022.2073414

Apkarian, N., & Rasmussen, C. (2021). Instructional leadership structures across five university departments. *Higher Education*, *81*(4), 865–887. https://doi.org/10.1007/s10734-020-00583-6

Bressoud, D., & Rasmussen, C. (2015). Seven characteristics of successful calculus programs. *Notices of the AMS*, *62*(2), 144–146. https://www.aplu.org/wp-content/uploads/AMS20notices.pdf

Bressoud, D., Mesa, V., & Rasmussen, C. (2015). Insights and recommendations from the MAA national study of college calculus, 2015. https://maa.org/wp-content/uploads/2025/01/insights.pdf

Couch, B. A., Prevost, L. B., Stains, M., Whitt, B., Marcy, A. E., Apkarian, N., Dancy, M. H., Henderson, C., Johnson, E., Raker, J. R., Yik, B. J., Earl, B., Shadle, S. E., Skvoretz, J., & Ziker, J. P. (2023). Examining whether and how instructional coordination occurs within introductory undergraduate STEM courses. *Frontiers in Education, Volume 8-2023*. https://doi.org/10.3389/feduc.2023.1156781

Fuchs, S., & Sahmbi, G. (2025). Investigating the impact of active learning in large coordinated calculus courses. *International Journal of Research in Undergraduate Mathematics Education*, *11*(2), 217–240. https://doi.org/10.1007/s40753-024-00234-6

Martinez, A. E., Gehrtz, J., Rasmussen, C., LaTona-Tequida, T., & Vroom, K. (2022). Course coordinator orientations toward their work and opportunities for professional development. *Innovative Higher Education*, *47*(2), 327–346. https://doi.org/10.1007/s10755-021-09579-1

Oliver, J., Olkin, J., & Sisneros-Thiry, S. (2025). Leveraging a community of practice model to accelerate change. *PRIMUS*, *35*(4–5), 460–478. https://doi.org/10.1080/10511970.2024.2354811

Rasmussen, C., & Ellis, J. (2015). Calculus coordination at PhD-granting universities: More than just using the same syllabus, textbook, and final exam. In D. Bressoud, V. Mesa, & C. Rasmussen (Eds), *Insights and recommendations from the MAA national study of college calculus* (pp. 107-115). The Mathematical Association of America. https://maa.org/wp-content/uploads/2025/01/insights.pdf

Smith, W. M., Voigt, M., Ström, A., Webb, D. C., & Martin, W. G. (2021). *Transformational change efforts: Student engagement in mathematics through an institutional network for active learning* (Vol. 138). American Mathematical Soc. https://doi.org/10.1090/mbk/138

Strong, S., & Moskal, B. M. (2006). Caveats of course coordination. Proceedings. Frontiers in Education. *36th Annual Conference*, 4–8. https://doi.org/10.1109/FIE.2006.322604

Williams, M., Apkarian, N., Uhing, K., Martinez, A. E., Rasmussen, C., & Smith, W. M. (2022). In the driver's seat: Course coordinators as change agents for active learning in university precalculus to calculus 2. *International Journal of Research in Undergraduate Mathematics Education*, *8*(1), 121–148. https://doi.org/10.1007/s40753-021-00153-w

PROJECT EMBER

MATH PATHWAYS

What Is the Challenge?

Too many students face introductory mathematics requirements that are misaligned with their academic goals. Historically, mathematics requirements funneled most students through a calculus pathway, enrolling them in college algebra, precalculus, or calculus, regardless of their field of study. Students not pursuing STEM, economics, or business degrees struggled through algebra-heavy courses with little connection to their majors, creating unnecessary barriers to graduation. Low success rates in the courses in this sequence, particularly among historically underserved groups, compounded the problem by creating bottlenecks for degree progression. At the same time, the modern world increasingly demands statistical literacy and quantitative reasoning skills that are not centered by traditional calculus-track courses. As a result, for many students, these required mathematics courses become a huge obstacle to their academic success.

Addressing the Challenge

To remove this obstacle, Math Pathways provides alternate sequences of courses that are better tailored to student needs within different degree or career tracks. These sequences most often focus on statistics and data analysis, quantitative reasoning, and calculus. Implementing Math Pathways requires coordinated action: building consensus among faculty about mathematical content needs, transforming advising systems to guide students appropriately, updating placement policies, rethinking prerequisites, and, often, incorporating corequisite support. Most fundamentally, it requires shifting institutional culture so that mathematics courses become pathways to success rather than gatekeepers to degrees.

We have resources to help instructors and coordinators with

- Understanding the evidence supporting Math Pathways and making the case to stakeholders.
- Aligning academic programs with appropriate introductory mathematics courses.
- Transforming advising practices to embed Math Pathways information into student guidance.
- Providing support for faculty to teach diverse introductory mathematics courses, including statistics and quantitative reasoning, and adjusting teaching assignments as needed.
- Coordinating with K-12 partners to ensure that dual credit offerings align with Math Pathways.

What Is Math Pathways?

Math Pathways is a student success strategy that guides students into introductory mathematics courses based on their academic goals. Rather than sending all students to a calculus-preparation sequence, it provides multiple pathways—typically statistics, quantitative reasoning, and calculus—each aligned with different academic fields. At its core, Math Pathways groups academic programs into "meta-majors" based on shared mathematical needs. For example, arts and humanities might align with quantitative reasoning, social sciences and allied health with statistics, business with business calculus and statistics, and STEM with calculus. This ensures that students satisfy their graduation requirements while learning mathematics content that is relevant to their aspirations.

Math Pathways, as a strategy, requires consideration of many parts of an institution. More than offering different courses, Math Pathways demands fundamental changes in institutional thinking. A comprehensive implementation strategy incorporates establishing meta-majors, removing unnecessary prerequisites, implementing Corequisite Support for students who need it, embedding guidance into advising, ensuring effective placement policies, and partnering with K-12 schools for dual credit alignment. When combined with other innovations, Math Pathways transforms mathematics from a barrier to a catalyst for student success.

What Is the Evidence?

The evidence supporting Math Pathways is robust. In a study of over 20,000 community college students, Schudde and Kiesler found that students completed higher college-level math and earned more credits compared with traditional algebra-heavy pathways. A CAPR[4]/ECS[5] analysis of StatWay and QuantWay also showed dramatic results. While traditional models saw only 21% of students passing a college credit-bearing course in one semester (29% in two), StatWay/

[4] Center for the Analysis of Postsecondary Readiness (CAPR): https://ccrc.tc.columbia.edu/research-project/center-analysis-postsecondary-readiness.html

[5] Education Commission of the States: https://www.ecs.org/

QuantWay students achieved 63% success in one semester. Prior to implementing Math Pathways, some institutions saw 50% of their students failing remedial courses, but—after implementing Math Pathways—75% of the students at these same institutions succeeded in college-level courses.

Math Pathways is included in the What Works Clearinghouse, which maintains rigorous standards. Beyond completion rates, Math Pathways makes the mathematics world a more fair place—benefits are substantial for all students but differentially positive for minoritized students.

Math Pathways is rarely implemented in isolation. The cases covered in the studies above typically included Active Learning, Corequisite Support Courses, and other innovations. Sizeable gains in student success outcomes likely resulted from a complex mix of different innovations—of which Math Pathways is one important part.

Professional Development

Successfully implementing Math Pathways requires professional development across multiple stakeholder groups. Mathematics faculty may need support for teaching statistics and quantitative reasoning, ideally combining content knowledge with active learning pedagogies. Academic advisors may need support to shift from established practices—understanding not just which course students should take, but why. This is especially important for dual credit advisors and high school counselors who guide significant numbers of students. Faculty across all disciplines benefit from understanding how Math Pathways affects their students so that they can reinforce relevant mathematical concepts in their own courses.

CASE STUDY: CALIFORNIA STATE UNIVERSITY, LOS ANGELES

CAL STATE LA

Students at California State University, Los Angeles (Cal State LA) receive customized guidance based on their intended major. After selecting their major, the university provides students with appropriate pathway options. The high-level structure distinguishes between non-STEM majors (who are guided toward Quantitative Reasoning or Statistics, with corequisite support if needed) and STEM majors (who are placed in calculus or in precalculus with corequisite support if needed). Students needing substantial additional support can access a summer "Early Start" program. Cal State LA has nearly eliminated college algebra, placing students directly into courses appropriate for their goals with appropriate support structures.

Resources to Get Started

Implementation Guides: Several organizations offer implementation guidance, including Complete College America's Formula for Success guide, CCRC's implementation resources, and materials from the Dana Center. Together, these resources provide research-backed strategies for institutions implementing this proven approach to improve student success.

Connections to Other Innovations

- **Corequisite Support**: Math Pathways works best when combined with corequisite models in which students can enroll directly in college-level courses with concurrent support rather than taking prerequisite sequences. This removes delays while providing necessary scaffolding, helping students complete college-level mathematics faster and at higher rates.
- **Active Learning**: Evidence-based active learning amplifies Math Pathways benefits. When students engage with relevant content through collaborative problem-solving, they develop a deeper understanding and motivation. Math Pathways ensures content relevance; active learning ensures effective pedagogy.
- **Identity and Belonging**: When students take mathematics aligned with their goals, they're more likely to see themselves as capable learners. Math Pathways supports identity development by showing the relevance of mathematics to their chosen field, particularly benefiting historically underserved students.

References

Ganga, E., & Mazzariello, A. (2018). Math pathways: Expanding options for success in college math. *Education Commission of the States*. https://postsecondaryreadiness.org/wp-content/uploads/2018/10/math-pathways-expanding-options-success.pdf

Schudde, L., & Keisler, K. (2019). The relationship between accelerated dev-ed coursework and early college milestones: Examining college momentum in a reformed mathematics pathway. *AERA Open*, *5*(1), 2332858419829435. https://doi.org/10.1177/2332858419829435

Complete College America. (2025). Formula for success: How to support every student through math pathways. https://completecollege.org/wp-content/uploads/2025/08/CCA-Formula-for-Success-Jan2025.pdf

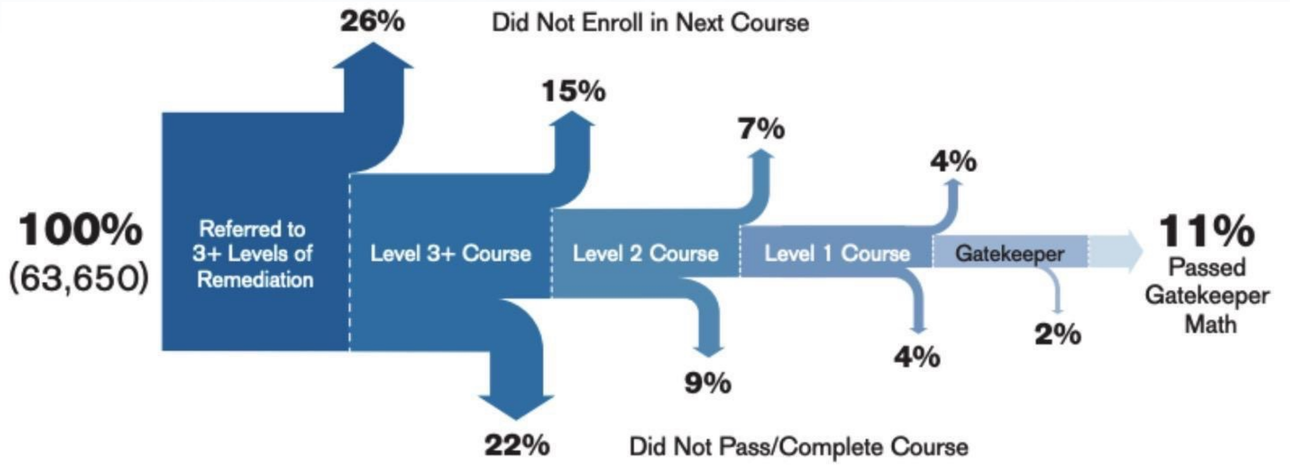
PROJECT EMBER

COREQUISITE SUPPORTS

What Is the Challenge?

For much of the past century, colleges placed students directly into their gateway math course, the first college-level math course that counted toward their degree, under a de facto “right to fail” model. As access expanded and institutions saw that many students, especially those from under-resourced backgrounds, were being left behind, they introduced placement policies and prerequisite sequences to address preparation gaps. Today, COVID-related disruptions, uneven high school math experiences, and increased reliance on technology have further widened variation in students’ readiness for college-level math, prompting institutions to look toward corequisite models in which students enroll in extra credits taken simultaneously with their gateway math courses as a more effective response.

Student Progression Through the Developmental Math Sequence



Early analyses of developmental sequences often suggested that students who successfully completed preparatory courses performed as well as, or sometimes better than, students who were placed directly into gateway courses. However, this framing focused narrowly on outcomes in that first course. Even students who succeed in prerequisite courses learn material that they might not need for many months. When accounting for throughput, the proportion of the entire cohort of students attempting any level of mathematics course who successfully complete the college-level goal course, these sequences often functioned less as on-ramps and more as barriers. In practice, structures designed to help students were frequently the very mechanisms that prevented them from being successful. The figure on the next page highlights how, in one large study, due to the multiplicative effects of attrition, just 11 percent of students placed three levels below ultimately finished their gateway math course.

At the same time, abandoning developmental education entirely has never been the answer. Faculty have widely recognized the need to fill gaps in students' backgrounds, provide additional practice, and explicitly support metacognitive skills. However, when these supports were offered primarily through tutoring centers, optional workshops, or extra office hours, many students, especially those balancing work, family, and commuting, could not access them. The supports existed, but they were too far removed from the classroom to effectively help students.

Corequisite courses attempt to resolve this tension. Rather than delaying students' progress, corequisite courses embed intentionally designed support directly into students' schedules alongside their gateway math course. These supports are delivered through just-in-time instruction and targeted practice that bridges students from where they are to where they need to be within their gateway courses. Importantly, these supports—when offered as credit-bearing courses—create a sustainable funding structure for institutions to provide meaningful, scalable academic support without relying solely on external or optional services.

We have resources to help instructors and coordinators with

Casemaking: Colleges and universities have been designing and implementing corequisite support courses for well over a decade. A robust body of literature offers evidence of corequisites increasing student success. Additionally, a number of pieces, such as Complete College America's Formula for Success, offer a macro perspective.

Planning: With institutions nationally implementing and then iterating corequisite offerings, there is a growing understanding of how to offer corequisites and maximize their impact. Consider, for example, the toolkit developed by the Dana Center at the University of Texas with support from Strong Start to Finish.

Implementation: As the popularity of this remediation model has grown, there has been an explosion of materials from publishers [Open Educational Resources (OER) and for-profit] for corequisite courses in multiple math pathways, including math for liberal arts, introductory statistics, college algebra, precalculus, and calculus, smoothing the way for course-level adoption.

What Are Corequisites?

First, it might be helpful to consider what corequisites are not. Corequisites are not a series of two half-semester courses (first half developmental, second half accelerated gateway course); neither are they a study hall—extra time for students to work on homework or work independently in a computer lab on foundational skills.

Corequisite courses are courses that are offered alongside or extra credits attached to gateway math courses. The extra time with students is intentionally planned using backward design by first defining what students will need to be successful in the gateway course and then creating targeted instruction and activities to support the mastery of those prerequisite competencies and to bridge to the gateway course content. By leveraging the benefits of just-in-time learning, instructors can maximize the impact of developmental instruction. By bringing the extra support directly into students' schedules, they are not relying on students to navigate external structures and identify the help they need. Moreover, students can see right away how they will apply prerequisite skills in service of their gateway course.

A common concern is that a few extra hours a week will not be enough time to replicate all of the high school or college prerequisite content that students with stronger backgrounds may have engaged with. Luckily, this is not necessary. By using the backward design process, students are only addressing the prerequisite skills, knowledge, and habits required for success in the gateway course.

What is the Evidence?

As colleges and universities of all types join the growing number of institutions engaging with corequisites as a strategy to support student success, new evidence—from formal research papers to informal sharing—is appearing in literature and at both national and regional conferences.

The MAA Subcommittee on Curriculum Renewal Across the First Two Years (CRAFTY) encouraged institutions to move from prerequisites to corequisites based on evidence collected from large state efforts. They sponsored a session devoted to corequisite instruction at the 2023 Mathfest, where the University of Alaska Fairbanks, University of Nebraska-Lincoln, University of Louisiana at Lafayette, Temple University, and others shared the use cases and results of their experiences with corequisites.

Early indicators suggest that using corequisites in calculus increases student success even at open enrollment institutions, when students are enrolled in calculus with corequisite support. Additional evidence is needed to strengthen confidence in these early outcomes.

A study of Texas students found that corequisite remediation is a cost-effective alternative to traditional developmental education, improving course progression and potentially strengthening persistence and completion through higher initial placement and concurrent academic support.

A randomized controlled study of students needing introductory statistics concludes not only that students in the corequisite model are more successful than students in a traditional algebra prerequisite model in completing their gateway course but also that they are more successful in other courses and have higher eventual graduation rates.

Statewide work in Tennessee has demonstrated that corequisites can be effective for students across placement levels and across multiple math pathways. Results from Georgia similarly show higher throughput in corequisite models than in traditional prerequisite sequences, though they also indicate that not all corequisite designs yield the same level of benefit.

Professional Development

Many statewide and system groups offer professional development for their higher education institutions, like Illinois Developmental Education Equity in Action (IDEEA), the Board of Regents in Louisiana, and Developmental Education and Corequisite Capacity Building (DECCB) in Texas. Many of these state groups publish resources on their websites, which might be useful even if no such initiative is available in your own state.

Additionally, much of the classroom-level work of creating successful corequisites is a formalization of the scaffolding and practice that instructors already use to support students. For example, in a traditional calculus course, it would be common to spend time revisiting trigonometry or other precalculus topics. Corequisites allow students time for the extra support beyond the brief review offered in a traditional course. Thus, a group of faculty within a department, through a community of practice, will often create their own professional development spaces.

CASE STUDY: OKLAHOMA STATE UNIVERSITY

Oklahoma State University (OSU) was an early adopter of corequisite mathematics courses. Before implementing corequisites, students who were not prepared for college-level courses, such as college algebra, were directed to a local community college to complete remedial coursework, yet many of these students did not ultimately complete their gateway math requirement. In response, OSU developed corequisite models for both college algebra and the Math Modeling pathway. These courses proved highly successful, with particularly strong outcomes for first-generation students.

The gateway courses met on a Monday, Wednesday, Friday schedule, and the corequisite support was offered on Tuesdays and Thursdays at the same time of day as the parent course. In the initial years, the corequisite support carried no additional cost to students and was funded externally. In the current model, students are placed, based on OSU's placement policy, either into a standalone three-day-per-week section or into a five-day-per-week section with embedded corequisite support, with a course fee applied to the supported sections.

Colleges and universities have used many different models to meet the needs of their students within their unique contexts. The Dana Center Toolkit reveals how the University of Wisconsin-Milwaukee (UWM) almost completely replaced its developmental courses with corequisite supports and the importance of course design, including the embedding of social-emotional supports, on its success.

Hawkes Learning, which describes the work at Seminole State College, and consultant groups like Almy Education, which spotlights their work with Manchester University, offer both a glimpse of institutional progress as well as the types of resources available to guide and support institutions in moving to scale with both logistical and classroom-level considerations.

Resources to Get Started

Sometimes, state requirements will drive the implementation of corequisite courses, but many of these state policies were themselves motivated by pilot programs at institutions within the state, like the University of New Orleans, which informed the Louisiana Board of Regents policy.

To connect with peers who have already implemented corequisites as well as those just beginning to explore them for various use cases, consider joining conversations with EMBER Community for Teaching-Focused Faculty (on Zulip) or MAA Connect.

Departments may find it helpful to examine curricula developed specifically for corequisite courses, such as the OER [Carnegie Math Pathways], to draw on concrete models that inform the design of just-in-time support within their own offerings.

To contract for comprehensive support, consider engaging with state partners, nonprofit organizations, or a for-profit organization that specializes in corequisite design and implementation, like [Almy Education].

Connections to other innovations

- **Math Pathways**: Corequisite math courses provide just-in-time support for concepts in gateway courses, giving underprepared students additional opportunities to engage with essential material. Clarity about the appropriate gateway courses for each program of study allows institutions to build corequisite supports that are targeted rather than generic add-ons.
- **Active Learning**: Active learning engages students in reasoning, problem-solving, and explaining their thinking rather than passively reviewing skills. In corequisite courses, these interactive approaches help students make explicit connections between the underlying prerequisite skills they are developing and the demands of the gateway course. By creating structured opportunities for practice, feedback, and sense-making, active pedagogy strengthens the bridge between support and college-level expectations.

References

Austin, M., Martorell, P., Miller, T., & Daugherty, L. (2024). The benefits of math corequisite support for academic outcomes for students in Texas. EdWorkingPaper No. 24-903. *Annenberg Institute for School Reform at Brown University*. https://edworkingpapers.com/sites/default/files/ai24-903.pdf

California Community Colleges, & The RP Group. (2024). *Preparatory pathways and STEM calculus completion: Implications of the AB 1705 Standards*. https://www.rpgroup.org/resources/updated-preparatory-pathways-and-stem-calculus-completion-implications-of-the-ab-1705-standards

Complete College America. (2017). *Corequisite support case study: Oklahoma State University*. https://completecollege.org/news/corequisite-support-case-study-oklahoma-state-university/

Complete College America. (2021). *Corequisite works: Student success models at the University System of Georgia*. https://completecollege.org/wp-content/uploads/2025/08/CCA_Corequisite-Works.pdf

Jaggars, S. S., & Stacey, G. W. (2014). What we know about developmental education outcomes. Research overview. *Community College Research Center, Teachers College, Columbia University*. https://files.eric.ed.gov/fulltext/ED565668.pdf

Kozak, K., & Savina, F. (2020). *The case for change in developmental mathematics education: Transitioning from prerequisites to corequisites*. Mathematical Association of America. https://maa.org/wp-content/uploads/2024/09/CRAFTY_2020_Corequisite.pdf

Logue, A. W., Douglas, D., & Watanabe-Rose, M. (2019). Corequisite mathematics remediation: Results over time and in different contexts. *Educational Evaluation and Policy Analysis* (Vol. 41, Issue 3, pp. 294–315). https://journals.sagepub.com/doi/abs/10.3102/0162373719848777

Ran, F. X., & Lin, Y. (2022). The effects of corequisite remediation: Evidence from a statewide reform in Tennessee. *Educational Evaluation and Policy Analysis*, *44*(3), 458–484. https://doi.org/10.3102/01623737211070836

PROJECT EMBER

TECH-ENABLED INSTRUCTION

What Is the Challenge?

Many students enter introductory mathematics courses underprepared and with widely varying levels of prior knowledge. Traditional, one-size-fits-all instructional models do not address these differences, and without targeted support and practice, many students struggle to reach the level of proficiency required to meaningfully engage in higher-order problem-solving during class. Learning technology, such as adaptive courseware, offers a potential avenue to address this challenge by providing students with personalized guidance and engagement with course content and adjusting to the learners' unique skills and learning needs in real time. These tools also provide faculty with meaningful data about student learning so they can diagnose readiness and offer differentiated instructional paths based on student need. By helping students build their conceptual understanding and procedural fluency outside of class, adaptive courseware can help prepare students to participate more actively inside of class, allowing faculty to focus on deeper learning activities rather than remediation.

We have resources to help instructors and coordinators with

- Applying best practices for implementing adaptive courseware in mathematics courses, including course design, faculty workflow integration, and effective use of student learning data to inform instruction.
- Supporting math faculty in meaningfully integrating technology into teaching and learning, emphasizing alignment with evidence-based pedagogy and instructional goals rather than technology adoption for its own sake.
- Leveraging university leadership and faculty support units that provide faculty with the resources to effectively integrate technology and implement department-level reform efforts.

What Is Adaptive Courseware?

Adaptive courseware is a digital instruction tool that creates personalized learning pathways for students to move through the course material based on their demonstrated knowledge and unique learning needs. The technology has been in development for decades and relies heavily on learning science, intelligent tutoring systems, artificial intelligence, and user-centered design. Courseware provides immediate feedback for students to build learner autonomy and learner agency. For faculty, it provides real-time data on students' progress and interaction with the course. An institution can integrate adaptive courseware products with its learning management system (LMS) so students can access their assignments within the course shell and their grades can be automatically updated in the LMS without requiring manual data transfer.

What's the Evidence?

A multi-year, independent study conducted by Digital Promise examined an adaptive courseware platform developed by Lumen Learning on student success in introductory statistics courses. The national study analyzed institutional research data from 79 course sections and controlled for key student characteristics, including race, Pell eligibility, and prior GPA. Preliminary findings indicate that students using Lumen One were twice as likely to pass their course with a grade of C or better compared to students in non-Lumen sections. On average, students in Lumen One courses earned course grades that were 0.25 points higher on a 4.0 scale. In addition, results from a nationally normed assessment showed comparable learning gains across all student backgrounds, suggesting that the adaptive courseware supported improved learning outcomes.

The study also highlighted the role of adaptive courseware in supporting instructional change. The Lumen One platform supports approaches such as active learning, activating prior knowledge, and fostering a sense of belonging, all practices associated with improved engagement and mastery. The findings suggest that adaptive courseware, when intentionally designed and implemented, can promote higher pass rates, strengthen learning outcomes, and narrow longstanding gaps in student success.

Researchers documented similar findings in an analysis of 12 public institutions (2- and 4-year) participating in a grant initiative that prioritized both the use of adaptive courseware and the adoption of evidence-based teaching (EBT) practices across disciplinary contexts (and including mathematics). With findings reported across multiple publications, participating faculty reported an increase in their use of EBTs over time, including personalized teaching methods that led to improved student success rates. Differences in students' academic achievement across racial groups also narrowed.

Professional Development

Effective technological integration in a classroom requires instructors to align their use of the technology with their pedagogical and content knowledge. Educational technology like adaptive courseware provides real-time student performance data from formative assessments that allow instructors, with adequate knowledge of how to monitor, analyze, and use the data, to modify their course instruction and activities to meet student needs. It can be overwhelming to understand all the features in courseware. Institutions should support instructors in regular professional development on how to use courseware for data-informed teaching through technological vendors or their teaching and learning centers. This includes reviewing dashboards, interpreting performance indicators, and connecting data to instructional decisions before and during implementation.

When integrating adaptive courseware, faculty benefit from professional development that supports course structure, alignment, and backwards design. Training should guide instructors to map course objectives, assessments, and in-class activities to courseware content so that students experience a coherent learning path across modalities. This includes reviewing courseware from the student perspective to anticipate alternative conceptions, differences in terminology, or instructional framing.

Faculty need targeted support to move from accessing courseware data to using it to inform their instructional practices. Professional development should focus on how to read common reports and use those insights to adjust pacing, reteach concepts, group students for peer learning, or provide targeted outreach. An emphasis should be placed on using data as a formative, student-centered tool.

The effective use of adaptive courseware depends on strong student onboarding, and faculty often require some level of professional development to properly prepare students. Training could include explaining the value and purpose of courseware in class and through one's syllabus, how to run in-class or video demonstrations, and how to regularly reference courseware data during instruction. Professional development on this topic should also emphasize transparency around how student data are used to support learning, which can increase student trust and engagement.

CASE STUDY: FLORIDA INTERNATIONAL UNIVERSITY

Florida International University (FIU), a large public Hispanic-Serving Institution, participated in the Adaptive Courseware for Early Success (ACES) Initiative, from 2019 through 2021, to increase student completion rates in its Calculus for Engineers course. FIU built a cross-functional team that included mathematics and engineering faculty, instructional leaders, and technical experts. Rather than adopting a commercial product, the team developed a customized adaptive learning solution using the open-source assessment platform IMathAS. The zero-cost platform aligned with FIU's priority to reduce student expenses while allowing faculty full control over content, sequencing, and feedback.

FIU embedded adaptive prerequisite modules into the course structure, requiring students to demonstrate mastery of foundational algebra concepts before advancing to weekly assignments. When students answered questions incorrectly, the system delivered additional practice and resources, which provided immediate feedback and targeted review. The adaptive courseware also provided instructors with real-time data on student progress, allowing them to adjust instruction and provide "just-in-time" support during class.

FIU compared outcomes from sections of Calculus for Engineers taught with and without adaptive courseware during the implementation period. Students taking the on-campus course with adaptive courseware had a pass rate of 87% in spring of 2020 and 77% in summer of 2021 compared to students taking the online course, who had a pass rate of 71% in spring of 2020 and 72% in summer of 2020. Students in courses using adaptive courseware also reported greater satisfaction with their learning experiences than those in non-adaptive courses. These efforts took place during the COVID-19 pandemic, which likely affected the results. The instructional delivery may have also impacted the results, as the adaptive courses were taught on campus and remotely, while the non-adaptive course was taught only remotely.

Resources to Get Started

- Understanding Adaptive Courseware
- Adaptive Courseware Implementation Guide–Focus on Faculty
- Adaptive Courseware: New Models to Support Student Learning
- A Guide for Implementing Adaptive Courseware–An Institutional Approach
- Improving Critical Courses Using Digital Learning & Evidence-based Pedagogy
- Digital Learning Instructional Strategy Guides - Achieving the Dream

Connections to other innovations

- **Using Data in Decision-Making**: Adaptive courseware provides faculty with real-time data about student engagement, learning, and progression. This data can and should be used by faculty to diagnose student learning needs and implement instructional practices that meet students where they most need support.
- **Active Pedagogy**: Since adaptive courseware provides students with a structured environment to practice and engage in low-stakes assessment prior to class, faculty can use class time to engage in higher-order thinking and applications of student knowledge, such as active learning.
- **Course Coordination**: Adaptive courseware provides a shared instructional backbone such as common content, assessments, student and course level data, and professional development tools, which lend themselves to supporting course coordination within faculty teams and academic departments.

References

Achieving the Dream. (2022). Adaptive courseware: New models to support student learning. https://achievingthedream.org/wp-content/uploads/2022/05/atd_ele_adaptive_courseware_new_models_to_support_student_learning.pdf

Achieving the Dream. (2022). Digital learning instructional strategy guides. *A joint publication between Achieving the Dream and Every Learner Everywhere*. https://achievingthedream.org/digital-learning-instructional-strategy/

Adams, S. (2022) Digital learning instructional strategy guide: Onboarding students to digital courseware. *Every Learner Everywhere and Achieving the Dream*. https://achievingthedream.org/wp-content/uploads/2022/09/Onboarding-Students-to-Digital-Courseware_2022September.pdf

Buchan, T. (2022). Digital learning instructional strategy guide: Data-informed instruction with courseware. *Every Learner Everywhere and Achieving the Dream*. https://achievingthedream.org/wp-content/uploads/2022/09/Data-Informed-Instruction-with-Courseware_2022September.pdf

Digital Promise. (2022). Supporting student success at the course level: Lessons from change efforts during a Pandemic. *Digital Promise Global*. https://www.everylearnereverywhere.org/resources/supporting-student-success-at-the-course-level/

Hampton, M. (2022). Digital learning instructional strategy guide: Course structure and alignment. *Every Learner Everywhere and Achieving the Dream*. https://achievingthedream.org/wp-content/uploads/2022/09/Course-Structure-and-Alignment_2022September.pdf

Holiday, T., O'Sullivan, P., & Adams, S. (2020). Adaptive Courseware Implementation Guide, 2nd ed. *Every Learner Everywhere*. https://www.everylearnereverywhere.org/wp-content/uploads/Adaptive-Courseware-Implementation-Guide-updated-links-by-CF-3-updated-links-included.pdf

Lumen Learning. (2025). Preliminary research finds students using Lumen One twice as likely to pass. *Lumen Learning*. https://lumenlearning.com/preliminary-research-finds-students-using-lumen-one-twice-as-likely-to-pass/

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054. https://rediie.cl/wp-content/uploads/Mishra-Koehler.pdf

Neisler, J. and B. Means. 2021. Teaching practices of faculty adopting adaptive courseware. *Digital Promise Global*. https://www.everylearnereverywhere.org/wp-content/uploads/Teaching-Practices-of-Faculty-Adopting-Adaptive-Courseware.pdf

Purita, R., & Tesene, M. (2023). Florida International University: Adaptive courseware for early success case study. A collaborative publication between the Association of Public and Land-grant Universities and Every Learner Everywhere. *Every Learner Everywhere*. https://www.everylearnereverywhere.org/wp-content/uploads/Final_Florida_International_University1-1.pdf

Tyton Partners. (2019) Understanding adaptive courseware: Time for Class Toolkit. *Tyton Partners and Every Learner Everywhere*. https://www.everylearnereverywhere.org/wp-content/uploads/TYTON_9_UnderstandingAdaptiveCourseware_5.6.19.pdf

Vignare, K., Cole, E. L., Greenwood, J., Buchan, T., Tesene, M., DeGruyter, J., Carter, D., Luke, R., O'Sullivan, P., Berg, K., Johnson, D., & Kruse., S. (2018). A guide for implementing adaptive courseware: From planning through scaling. *A collaborative publication between the Association of Public and Land-grant Universities and Every Learner Everywhere*. https://www.aplu.org/wp-content/uploads/a-guide-for-implementing-adaptive-courseware-from-planning-through-scaling.pdf

Vignare, K., Lorenzo, G., Tesene, M., and Reed, N. (2020). Improving critical courses using digital learning & evidence-based pedagogy. *Joint publication of Association of Public and Land-grant Universities and Every Learner Everywhere*. https://www.everylearnereverywhere.org/resources/improving-critical-courses-using-digital-learning-evidence-based-pedagogy/

PROJECT EMBER

ALTERNATIVE GRADING

What Is the Challenge?

Grades are an embedded part of our educational systems. However, traditional grading practices, when instructors assign grades via a weighted average of various categories of assignments, typically undermine, rather than support, student learning. Students are often led, quite rationally, to focus their attention on accumulating points rather than mastering content. In recent years, a collection of practices under the umbrella of alternative grading has been gaining popularity with instructors across disciplines, with mathematics in particular being a discipline adopting these practices the fastest. Currently, most implementations of alternative grading occur in single classrooms. Common challenges include obtaining buy-in from students as well as colleagues and administrators, an initial time investment in converting a course, and generating additional assessment questions for students.

We have resources to help instructors and coordinators with

1. Convincing colleagues and administrators of the benefits of alternative grading.
2. Choosing an alternative grading system that works for you and your students.
3. Finding resources and professional development to support instructors in adopting alternative grading.

What Is Alternative Grading?

Alternative grading is not a well-defined term. It refers to a loose collection of grading practices that seek to shift away from assigning points and percentages toward providing rich feedback to students. In alternative grading systems, students are typically given many chances to demonstrate their learning, with past attempts not being held against them. Three such systems are most commonly used in mathematics courses:

- **Standards-Based Grading** involves articulating a clear list of learning objectives (standards) to students and basing grades based on how many of these objectives students master by the end of the term—without penalizing students for when they demonstrate this learning.
- **Specifications Grading** involves basing student grades on completion of various bundles of assignments. A clear list of specifications of what constitutes acceptable work will accompany these assignments, and students can revise their work until it meets these specifications.
- **Collaborative Grading** involves course grades being assigned collaboratively by instructors and students.

Many instructors will create hybridizations of these systems, blending aspects of one system with another to suit their pedagogical goals or situational constraints. For example, some departments may require certain courses to use a common final exam, and they will base a specific percentage of the course grade on this exam; systems such as standards-based testing (often called mastery-based testing in literature) have been developed to bring as much of a standards-based philosophy as possible in line with these requirements. Another way of blending some alternative grading practices into a more traditional system is the use of gateway exams, in which students must demonstrate proficiency on certain skills (typically being given many attempts to do so, if needed) before moving on to more advanced topics.

What's the Evidence?

Evidence on the efficacy of alternative grading continues to emerge, but a number of Scholarship of Teaching and Learning studies have already found positive benefits for students. The most consistent finding across studies is that students report feeling less stress and anxiety in alternatively graded courses. In particular, alternative grading systems have been shown to significantly reduce students' test anxiety.

Many instructors are motivated to adopt alternative grading strategies to promote a growth mindset in their students (this is reflected in the use of the phrase "Grading for Growth" both as a title of a popular book on alternative grading as well as a synonym for alternative grading). However, studies to date have not provided sufficient evidence that students develop more of a growth mindset in alternatively graded courses. Instead, research has found that alternative grading helps students develop more productive achievement goal orientations and enhance their mathematics identity, which have both been linked to improved academic outcomes. Students also report that the grades in alternatively graded courses more closely reflect their learning.

Professional Development

Instructors wishing to adopt alternative grading practices often seek out support beyond their department or institution. Fortunately, there is an increasing number of opportunities for them to obtain this support, both in mathematical and interdisciplinary spaces. MAA's annual Mathfest has a number of sessions, including contributed paper sessions, workshops, and minicourses centered on alternative grading. Professional development sessions on alternative grading are also sometimes offered at the Joint Mathematics Meetings. The Center for Grading Reform hosts the annual Grading Conference, an interdisciplinary virtual conference each June devoted to alternative grading practices, as well as other professional development opportunities such as workshops and learning communities.

The practitioner-focused journal PRIMUS has a number of articles dedicated to alternative grading practices in math courses, including a special issue on the topic, as well as a curated collection of articles on assessment. A growing number of books, such as Grading for Growth and Specifications Grading, are available, as well as blogs focused on the topic such as the Grading for Growth blog. These and other professional development resources, such as a repository of syllabi from alternatively graded courses, are collected by the Center for Grading Reform.

CASE STUDY 1: CALIFORNIA STATE UNIVERSITY, LOS ANGELES

CAL STATE LA

At California State University, Los Angeles, a coordinated Quantitative Reasoning with Statistics course has used a standards-based grading system since 2018. The course was designed as a general education course with a specific focus on enabling students to become "critical consumers of data." The standards-based grading system evolved over time, but by the fall of 2019 the course had settled down into a system with 15 total learning outcomes encompassing statistics content, mathematical practices, critical thinking, and metacognition about learning. To demonstrate proficiency on a content or mathematical practices learning outcome, a student has to demonstrate a sufficient level of competence on checkpoint assessments, usually taking the form of quizzes, exams, or presentations. These assessments are evaluated on a proficiency scale with three levels—success, need to retake, and not enough evidence to measure.

Two successes are needed to "complete" a learning outcome and for it to count toward the final grade. One learning outcome, the metacognition about learning outcome, is measured by accumulating enough preparation, participation, and practice activities to meet a given threshold. In addition to doing activities such as watching videos before class, participating in discussions and classroom activities, and doing practice problems, students also complete a variety of reflection activities, such as exam corrections and reflections, which enable them to learn about their own learning processes and how to learn from their mistakes.

To get a specific grade, students need to meet the following thresholds.

Desired Course Grade	A	A-	B+	B	B-	C+	C	C-	NC
# of standards required to be proficient	14 or 15	13	12	11	10	9	8	7	6 or fewer

Since fall of 2018, over 8,000 students have enrolled in this program. Overall, 59.82% of all non-college-ready students and 74.65% of college-ready students who took this course between the fall of 2020 and the fall of 2025 passed, a significant[6] improvement to the pass rates of the course. Simultaneously, there was a dramatic rise in the number of students taking the course, increasing the diversity of their preparation levels. We have also seen the erasure[7] of opportunity gaps based on gender, Pell eligibility, and first-generation status while closing the gap based on race.

[6] Improvement to the pass rates compared to the course before redesign (historical data 2016–2017), which included a transition in placement practices due to the removal of non-college-level courses in the California State University system. Thus, simultaneously, more students with higher levels of gaps in mathematical skills and knowledge were enrolled in the course, and the pass rates were higher as measured by a two-sample Fisher test at the 95% confidence level.

[7] Pass rates for equity groups were analyzed using a two-sample Easy Fisher Exact Test for both large and small samples. Gaps were not largely significant at the 95% confidence level, and most gaps were not largely significant at the 99% confidence level.

CASE STUDY 2: UNIVERSITY OF MICHIGAN

The University of Michigan has implemented repeatable mastery assessments in its Introductory Program courses over the past six years. Although these courses still use a weighted-average grading scheme, in Calculus I and the course before calculus ("Precalculus"), 35% of students' final course averages comes from four or five repeatable mastery assessments that cover different parts of the course material. The material assessed by these mastery assignments spans a significant part of the primary conceptual and procedural material in the course, with an emphasis on the parts that are most easily assessed with an online math testing system. Students generally have a week or two to complete each assessment, may practice the test as often as they like, and are limited to two (proctored) attempts per day for possible credit. Credit requires a nearly perfect score on the assessment, and full credit is granted only for a perfect score.

The university has coupled this implementation with greater transparency in the grading schemes for the courses and increased attention to evidence-based instruction and instructor preparation. Preliminary evaluation of the changes in the course before calculus is quite promising: for example, between 2018 and 2024, the DWF rate in the course dropped from 19% to 12%, and the rate for students from groups underrepresented in STEM dropped from 27% to 16%. Because this change occurred from before to after the global pandemic, this makes the changes all the more notable.

Interested in joining a community of alternative grading practitioners?

- Alternative Grading Slack Community
- Ungrading Discord

Connections to other innovations

- **Active Pedagogy**: Instructors adopting student-centered, active pedagogies often begin questioning how to make their assessments align with this pedagogy, focused on learning over performance, and they move to adopt some degree of alternative grading approaches.
- **Using Data in Decision-Making**: Alternative grading systems such as standards-based grading naturally produce granular data on student understanding of granular learning objectives, allowing instructors to adapt their instruction (both in real time during a course and at a more structural level for longer term change). Alternative grading approaches that align grades to student learning rather than behavior often produce more meaningful data that can filter upward into broader assessment at the program or department level.
- **Course Coordination**: Presently alternative grading is mostly implemented in uncoordinated settings, but its use in coordinated courses is an emergent trend. Systematic use in a coordinated environment often leads to more consistent grading across instructors and can support coordinated implementations of active pedagogy.

References

Lewis, D. (2022). Impacts of standards-based grading on students' mindset and test anxiety. *Journal of the Scholarship of Teaching and Learning*, *22*(2), 67–77. https://files.eric.ed.gov/fulltext/EJ1347380.pdf

Swanson, R., Bingham, A., Sanders, M., & Moulton, C. (2025). Mastery-based testing in linear algebra: An entry point to alternative grading. *Teaching and Learning Inquiry*, *13*, 1–20. https://doi.org/10.20343/teachlearninqu.13.10

Villalobos, C., Garza, G., Setayesh, S., Fernandez, L., Balogh, A., Serbin, K. S., & Huber, T. J. (2025). Our never-ending pathway to innovate Calculus 1: Course coordination and active learning to specifications grading and growth mindset. *PRIMUS*, *35*(4–5), 406–422. https://doi.org/10.1080/10511970.2024.2352874

PROJECT EMBER

USING DATA IN DECISION-MAKING

What Is the Challenge?

Using data from a diverse set of sources is vital in planning for course improvement. While data is vital for educational change, relying solely on surface-level metrics (e.g., average grade or DFW rates) limits meaningful analysis. Nuanced insights—such as instructional beliefs and student experience—are harder to obtain but essential for understanding why students struggle. Ultimately, data inform people, but people make decisions.

Getting Started with Data

There are numerous productive ways to get started working with data. There is no single "best" way to begin working with data, and it is important to think about the different ways you can focus your efforts and the types of data you want to incorporate. Though you are most likely focused on the classroom and/or department, the approaches presented here can easily translate to the college and institution. Let's start by exploring the various focal points to use for our analyses.

Student Outcome Focus

At the course level, DFW rates are commonly collected and can be useful, but they provide a limited picture of what might be going on with the students. More useful DFW data allows disaggregation by demographic and other such variables (e.g., transfer, course repeaters, semester taken), but these data are often inaccessible to most and lead to small sample sizes, which makes conclusions difficult. Further, small numbers can identify specific students and/or lead to misconceptions about who is good at math (or not). This can cause inaccurate generalizations about a population of students. Student outcome data can be interpreted at the level of a whole department, course sequence/group, or individual instructor teaching instances. **Be Aware**: Differences in student outcomes can be attributed to the students themselves (their background, behavior, etc.), but differences could also be a result of how the course is being taught and/or structured. Often you will find that the structure of a course and/or disciplinary beliefs on assessment and curving (and more!) may have a very large impact that is often missed.

Course Structure Focus

The structure of a course can significantly impact student outcomes and faculty success with teaching. These data questions are often overlooked:

- What is covered in a course and to what depth?
- How is the course taught in terms of pedagogical practices?
- How are students assessed?
- What is the structure (course components, number of students enrolled, recitations/discussion section expectations and instruction, assessment approach/structure, content coherence between different instances of the same course)?

Small variations in structures across different sections of the same course can result in a significant difference in DFW rates and overall student success.

Individual Classroom Focus

Looking at fine-grained instructional data includes asking:

- What content is being covered?
- What is valued in terms of course grades?
- What are the instructor's beliefs about teaching?
- What is the point allocation by topic?
- What student supports exist? How are assessments used, etc.?

Looking at individual faculty classrooms will blend student outcome data and course structure information. However, for a couple of reasons, this is rarely done: (1) It can be time consuming to obtain these data, and (2) there is a perceived threat of judgment. It is best of the individual conducts these analyses and then brings them into facilitated discussions with peers to dig into the data and discuss ways of improvement. Department culture can be critical in promoting or discouraging such peer conversations.

Think of Quantitative Data and Qualitative Data

Data discussed above tend to have a strong quantitative dimension and are often considered "concrete" due to the numerical nature. In reality, culture and beliefs can easily alter what at first appears impartial. Further, this type of data lacks the student perspective. Collecting feedback from students through exit tickets, check-in surveys, focus groups, and other similar approaches can bring in qualitative data that can be productive for conversations among faculty and provide a stronger sense of the student experience.

We have resources to help instructors and coordinators with

1. The 2024 Critical Issues in Mathematics Education booklet chapter on Effective Uses of Data[8] can help you think about how to leverage data for change.
2. The National Academies Report on Equitable and Effective Teaching has various segments of direct utility, including multiple forms of data overview (p. 84-87), getting to know students (p. 124-125), course and program learning outcomes (p. 145-149), Evaluation of Teaching (p. 163-165), and how to Analyze Institutional Data (p. 239-259).
3. Chapter 12[9] of *Adoption of Data Analytics in Higher Education Learning and Teaching* takes a deep dive into the cycle of progress for enacting change and engaging in continuous improvement.

What does it mean to use data to support and guide decision-making?

Here we provide some examples of using data in undergraduate mathematics. We present some examples that illustrate:

1. Making comparisons between courses at peer institutions.
2. Identifying trends from data examined longitudinally.
3. Using AI to analyze data at the course level (e.g., course materials).

---

[8] Carney, D., LaRose, G., Pilgrim, M., Rasmussen, C., Speer, N., & Villalobos, C. (in press). *Critical Issues in Mathematics Education Series, Volume 17: Bringing innovation to scale: Teaching-focused faculty as agents of change*. Simons Laufer Mathematical Sciences Institute. https://library.slmath.org/cime/

[9] Rehrey, G. et al. (2020). Supporting faculty adoption of learning analytics within the complex world of higher education. In: Ifenthaler, D., Gibson, D. (eds.) *Adoption of Data Analytics in Higher Education Learning and Teaching. Advances in Analytics for Learning and Teaching*. Springer, Cham. https://doi.org/10.1007/978-3-030-47392-1_12

We see data as a tool to analyze courses and course structures rather than people. Data provides us with information to spark conversations and create opportunities for faculty to collaboratively build courses that support student learning.

Data Comparisons: Comparing course data between faculty instructors is easy to do; however, it is relatively rare for these comparisons to happen at an individual institution and/or between institutions. While internal data comparison can feel threatening to faculty, anonymous cross-institutional comparisons are often more palatable. These are best managed by a neutral third party, such as the Association of Public Land-Grant Universities (APLU). In their Big10 DFW study, the APLU aggregated and anonymized data from multiple institutions. This allowed for a safe, intersectional analysis of course outcomes and scale, fostering productive peer dialogue without exposing individual departments.

Data Comparison Case Study: Peer comparison to promote improvement: A Big10 mathematics department faced DFW rates exceeding 30% in introductory math courses. While initially attributed to COVID-19, longitudinal data and peer comparisons revealed that the issue was systemic rather than pandemic-related, as the majority of other peer institutions had substantially lower DFW rates. This evidence dispelled internal myths, shifting the focus from external to internal instructional improvement.

Local Outcome Understanding: When looking at local data on course outcomes, it is critical to examine the data longitudinally to understand trends. Ideally that data is at the individual student level and can be disaggregated by a campus entity. Typically such an entity is not part of the department but can support the instructional mission of the university, thus maintaining student and faculty privacy while allowing student characteristics to be brought into the conversation. Knowing the background of students taking a course, their path through courses, intended major, and other variables can focus the conversation away from deficit narratives of students and faculty. Rather, conversations can shift to productively thinking about and testing ways to improve outcomes. Additionally, tools like UC Davis' *Ribbon* or other Sankey diagramming tools can help the math department visualize where students enter and exit the major and correlate that information with courses taken and outcomes.

Local Context Case Study: **Impact of first exam retake:** Students taking introductory math courses are often new to the campus and the expectations of college-level courses. First exams do not always go well for these students. As a solution, an instructor offered an unannounced exam retake capped at a score of 70%. This intervention dropped the DFW rate by 6 percentage points, allowing 7 additional students to pass the course.

Local Context Case Study: **Impact of partial credit on exams:** How a math problem is graded can substantially impact overall student outcomes. Teaching Assistants (TAs) grading different sections of the same course were given different grading instructions. One TA used a standard 0–10 scale, while another awarded only 0, 5, or 10 points. This difference caused a 15 percentage point gap in exam averages, highlighting the critical need for consistent grading criteria across course sections.

Using AI-generated analysis data allows for individual course material improvement and, probably more importantly, for more objective and neutral conversations between colleagues compared to colleagues or administrators conducting these analyses. Generative AI tools can act like objective mirrors that are neutral and non-judgmental, helping support data-based discussions. Therefore, we use generative AI in our first example.

Using AI to understand the course level: When provided with structured prompts and course materials, generative AI enables faculty to analyze and improve their exams and course materials (e.g., syllabi). Through the use of AI tools, faculty can:

- Learn, in greater detail, what topics their students are struggling with on their exams
- Gain a deeper sense of the similarities and differences between different exams that they and/or their faculty peers give
- Determine the range and depth of topics covered in a course through an analysis of all course assessments.

These are just samples of ever-expanding opportunities that generative AI is unlocking.

Course Level Case Study: Course testing consistency over time: Off-sequence mathematics courses often enroll retaking or hesitant students. However, AI analysis revealed that off-sequence exams were more difficult than on-sequence versions, covering more topics with greater depth. This misalignment contributed to a 15 percentage point increase in the off-sequence DFW rate. While no one suggests that the off-sequence offering should be easier, making it more difficult is not productive. The AI analysis provided an objective start to the conversation.

How has data been used in other efforts in the field?

Research and professional organizations have advocated for the use of data. For example, the Departmental Action Team Project has data-informed decision-making as a core principle, the MAA's Instructional Practice Guide advocates for making improvements to courses (including structures and teaching practices), and the National Academies identifies the use of diverse forms of data as evidence to inform improvements for "equitable and effective teaching."

Professional Development

Data analysis offers a unique opportunity for faculty to engage in collaborative inquiry and gain a deeper understanding of the student experience. Professional development in the use of data for course/program improvement needs two important pieces: (1) faculty willing to come together to meaningfully collaborate and engage with data and (2) a data expert guide to support this effort. We encourage faculty to form a data-informed learning community dedicated to professional growth and data-driven reflection. With the guidance of a data expert (from the department, college, institutional research office, teaching center, educational effectiveness group and/or student success office, etc.), faculty can uncover the stories data reveal, pinpoint critical challenges, and align goals to ask better questions about supporting student success.

PROJECT EMBER

IDENTITY AND BELONGING

What Is the Challenge?

Despite decades of reform, too many students are being pushed out of STEM. Women, underrepresented minority students, and first-generation students leave mathematically intensive fields at disproportionate rates, and high failure rates in gateway courses like calculus close doors to STEM careers before students even get started. Because mathematics is a required stepping stone to other STEM disciplines, these patterns have real consequences for workforce diversity and scientific innovation.

The problem isn't just about whether the students know the material. Even well-prepared students often do not see themselves as "math people" and don't feel like they belong in the math community. Research shows that a strong sense of belonging is a better predictor of students staying in math than grades and prior performance, with especially strong effects for women and historically marginalized students.

When students encounter difficulty, some of them interpret struggle as a sign that they just aren't cut out for math, rather than as a normal part of learning. Past efforts to address this have focused on student-level motivation or remediating skills gaps. But these approaches have had limited success and often fail to scale. What's been missing is attention to the cultural messages that students receive about who math is for and what math is actually about.

Disciplinary Views of Mathematics: What students experience as "doing math" in classrooms often looks very different from how mathematicians actually work. These contrasting orientations are termed "static" and "active" views of mathematics. A static framing treats mathematics as fixed and rule-governed, with clear steps leading to a single correct answer. An active framing presents mathematics as evolving inquiry where sense-making, experimentation, and multiple approaches are central.

These framings send powerful, culture-shaping cues to students. When mathematics is framed as static—rigid, procedural, and all about getting the correct answer—students who struggle tend to interpret difficulty as a sign that they aren't math people and draw narrow conclusions about belonging. When math is framed as active—exploratory, creative, grounded in making sense of ideas—students will more likely see struggle as a normal part of math, build a stronger mathematical identity, and keep going. A single instructor simply communicating through email that the very nature of math is an active inquiry can boost students' sense of belonging, strengthen their identity as mathematicians, reduce math anxiety, and help close gender gaps in motivation.

Yet most instructors don't realize they are sending framed messages at all. In fact, even within pedagogical approaches that focus on inquiry-based learning, subtle messages about rule-bound approaches or the importance of following prescribed steps may creep in, especially in introductory-level courses. One reason for this is that inquiry-based learning is a pedagogical approach, whereas a focus on the nature of math itself is about framing the discipline. The view instructors communicate is about the culture they build, not just the methods they use. So what can instructors do?

Addressing the Challenge

Faculty need concrete, evidence-based strategies for building classroom cultures that communicate mathematics as active exploration, not just procedures to execute correctly. This means sending consistent messages that ground belonging in effort and engagement—not innate talent or flawless performance—so that all students, especially women and underrepresented groups, can see themselves as legitimate mathematical thinkers. To make this work, faculty benefit from:

- Understanding active vs. static views of mathematics as culture-shaping cues, and how they differ from (but complement) mindset theory.
- Learning specific practices for communicating the active view through course language, feedback, and the structure of class interactions.
- Distinguishing belonging and identity as separate but interconnected constructs that shape whether students persist in the field.
- Addressing impostor syndrome and math anxiety through changes in classroom culture rather than one-on-one interventions.
- Using short, targeted activities—growth mindset exercises, utility value writing, values affirmation, effort-based belonging—that reinforce your broader messaging.
- Connecting these practices to other structural innovations: inquiry-based learning, alternative grading, corequisites, math pathways, and course coordination.

What Is Faculty as Culture Architects?

Faculty as Culture Architects is about intentionally weaving an active view of math into everything you do as an instructor—your language, your assignments, your assessments and feedback, and your course policies. The goal is consistency: students should encounter the same message everywhere, from the syllabus to lectures, homework assignments, and even the purpose of office hours. When these messages are coherent and pervasive, they shape not just how students understand math but also how they see themselves in it. This approach operates through three interconnected areas:

1. Language and Framing: Keeping the Active View Front and Center

This isn't a one-time message, and it isn't just about pedagogy. It needs to show up throughout the course. Key shifts include rewriting syllabi and welcome emails to frame mathematics as exploratory inquiry, responding to student struggle with consistent scripts that normalize difficulty ("Good—that means you're doing mathematics"), and using exam return language that connects challenge to the active nature of mathematical work. Students notice when what you say doesn't match what you actually grade (and, thus, value)—alignment across all touchpoints is essential.

2. Assessment and Feedback Design: Structurally Embedding the Active View

Students believe what you assess. If grades only credit correct final answers, students get the message that math is about final answers and performance, not exploration and learning. Instead, try creating assessment structures that reward reasoning, exploration, and growth—not only correct final answers. This means awarding credit for showing multiple approaches, building in revision opportunities as belonging cues ("belonging is based on sustained engagement, not flawless first attempts"), and replacing comfort-oriented feedback with strategy-focused feedback. Comfort-based responses ("not everyone is good at math") signal inadequacy; strategy-focused feedback holds students to high standards while reinforcing that struggle represents engagement, not failure.

3. Student-Facing Interventions: Complementing Faculty Messaging

Brief, evidence-based activities for students can reinforce faculty messaging. But they should not be used as standalone solutions. Instead, they are force multipliers. These include:

- Learning about neuroplasticity
- Utility value writing (connecting course content to personal goals; improves performance especially for low-expectancy students)
- Values affirmation before high-stakes exams (reduced racial achievement gap by 40% over two years)
- Effort-based belonging exercises using peer testimonials (produced GPA gains three years later).

These interventions fail when faculty messaging contradicts them.

What Is the Evidence?

1. Views of Math Are Culture-Shaping Cues

In our own research, we have tested what happens when a single instructor conveys either a static or active view of math.[10] Students who received the active-view email felt more like math people, reported a stronger sense of belonging, had less math anxiety, and showed a narrowing of the gender gap in motivation. We also found that instructors who endorse active views report stronger growth mindsets and more adaptive instructional practices (like valuing mistake-making and embracing learning over performance).

2. Faculty Mindsets Shape Achievement Gaps

In a study of over 150 college STEM courses, Canning et al. found that racial achievement gaps were nearly twice as large in courses taught by fixed-mindset (rather than growth-mindset) faculty. What's more, students accurately picked up on their instructor's beliefs, even when nothing was said explicitly. This extends beyond individual instructors: the more a discipline endorses a culture of talent, the fewer women and Black students go on to doctoral programs.

3. Belonging Predicts Persistence—Especially When Grounded in Effort

Good, Rattan, and Dweck found that, when students perceived a culture of talent in their calculus classes, they felt less like they belonged–and that lower sense of belonging predicted intentions to leave math, even after accounting for grades and prior performance. Critically, when belonging is grounded in effort and engagement (not achievement or talent), women are more protected from stereotype threat on learning. Effort-based belonging is not only more inclusive—it is more resilient.

Professional Development

Successfully implementing Faculty as Culture Architects requires ongoing professional development, not one-time workshops. Faculty need opportunities to:

- Examine their own views of mathematics through self-assessment and syllabus audits, identifying static-view language ("apply formulas," "master procedures") vs. active-view language ("explore approaches," "develop reasoning").
- Practice translating research into action through language workshops, role-playing strategy-oriented feedback, and case analysis of student scenarios.
- Build communities of practice through faculty learning communities, peer observation with an active-view lens, and department-level coordination to ensure students receive consistent signals across sections.

[10] Manuscript under review.

CASE STUDY: CALIFORNIA POLYTECHNIC STATE UNIVERSITY

Faculty as Culture Architects synthesizes decades of social psychology research while elevating disciplinary views of math as a critical cultural foundation. No case studies of this integrated approach yet exist in the literature. However, Math Teachers Circles offers a compelling example of transformation when middle school teachers experience math as mathematicians do. A parallel effort with science teachers is underway through the Constellations program at California Polytechnic State University.

Connections to Other Innovations

Faculty as Culture Architects is most powerful when combined with structural innovations across EMBER strands:

- **Active Pedagogy**: The active view explains why active learning and IBL work—students encounter the active view structurally embedded in the environment, shifting culture-shaping cues from static to inclusive.
- **Alternative Grading**: Standards-based and specifications grading structurally embed the growth mindset, making belonging contingent on demonstrated learning and engagement rather than flawless first attempts.
- **Corequisites**: Direct enrollment in college-level courses with concurrent support communicates that students belong—and that struggle is expected and supported, not a disqualifier.
- **Math Pathways**: Alignment with students' academic goals strengthens identity development by making mathematics feel relevant to their futures.
- **Course Coordination**: Multi-section coordination scales growth-mindset and belonging messages beyond individual instructors, embedding active-view language and effort-based belonging cues as departmental culture.

References

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology*, *38*(2), 113–125. https://doi.org/10.1006/jesp.2001.1491

Canning, E. A., Muenks, K., Green, D. J., & Murphy, M. C. (2019). STEM faculty who believe ability is fixed have larger racial achievement gaps and inspire less student motivation in their classes. *Science Advances*, *5*(2), https://doi.org/10.1126/sciadv.aau4734

Cohen, G. L., Garcia, J., Apfel, N., & Master, A. (2006). Reducing the racial achievement gap: A social-psychological intervention. *Science*, *313*(5791), 1307–1310. https://www.science.org/doi/10.1126/science.1128317

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, *102*(4), 700–714. https://doi.org/10.1037/a0026659

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, *347*(6219), 262–265. https://www.science.org/doi/10.1126/science.1261375

Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok—not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology*, *48*(3), 731–737. https://doi.org/10.1006/jesp.2001.1491

Walton, G. M., & Cohen, G. L. (2011). A brief social-belonging intervention improves academic and health outcomes of minority students. *Science*, *331*(6023), 1447–1451. https://doi.org/10.1126/science.1198364

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist*, *47*(4), 302–314. https://doi.org/10.1080/00461520.2012.722805

PROJECT EMBER

CLOSING THOUGHTS

Enacting and sustaining change within large research universities is challenging and often slow. Knowing what change and how to enact that change requires engagement from key university partners, such as teaching-focused faculty, students, department chairs, upper administration, and faculty and student support staff, and a shared vision of the effort (See Project EMBER's Guidebook for how to get started). Positive transformation is achievable through evidence-based innovation(s) that leverage data and support student identity and belonging. Rather than settling for quick, surface-level fixes, institutions must use data to engage in transparent and collaborative discussions to diagnose underlying root causes to ensure change is lasting and meaningful. Success hinges on building from where a department is, securing leadership support and empowering faculty, and leveraging innovations tailored to the unique local environment while actively centering identity and belonging.

Project EMBER is striving to build a national network of institutions who are committed to enacting positive change in introductory mathematics education. The latest activities related to this work can be found on the EMBER website. If you want to get involved in this type of change work and join a community of teaching focused faculty, we welcome new partners.

Every Learner Everywhere partners with colleges and universities to leverage technology in pursuit of student-centered, faculty-powered, and institution-driven improvement in teaching and learning.

3035 Center Green Drive
Suite 200
Boulder, CO 80301
303-541-0208

every learner everywhere

Subscribe to our Monthly Newsletter