Building Readiness through Just-in-Time Review in Calculus I

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Abstract: This paper describes the next phase of a multi-year redesign of a Calculus I course in an engineering school at a major research university, following three years of studies on mastery-based grading. Earlier phases of this study showed that while mastery grading reduced test anxiety and supported less-prepared students, precalculus readiness remained the strongest predictor of Calculus performance regardless of grading structure. In addition, frequent assessments led to over-testing and left little time for students to reflect on feedback, practice, and correct mistakes before the next round. Building on these findings, this phase focuses on improving pacing, readiness, and learning flow through three key changes: (1) adding short pre-lecture videos and class-prep assignments to introduce definitions and basic ideas before class, (2) delivering just-in-time precalculus reviews immediately before related calculus topics, and (3) shifting to a bi-weekly assessment cycle, each preceded by a dedicated problem-solving session to support student preparation.

This study investigates two main questions: 1. In what ways does the integration of just-in-time precalculus reviews affect student performance in Calculus I, including both overall final exam outcomes and performance on topics that rely directly on precalculus skills, compared to previous cohorts without this structure? 2. How do students perceive the role of just-in-time reviews in supporting their understanding and confidence when learning new topics?

The paper presents the instructional design rationale and implementation details, along with findings from precalculus assessment data, final exam performance, and student surveys including open-ended reflections. These results inform future iterations of the course and contribute to broader discussions on aligning pacing, scaffolding, and review timing with mastery-based structures, to promote more holistic instructional design beyond grading reform alone.

Keywords: Calculus I, just-in-time review, precalculus readiness, mastery-based grading

Introduction

Calculus I plays a critical role as a gateway course for engineering students. At our institution, while most first-year engineering students begin in Calculus II or III, a growing proportion start in Calculus I, particularly since the COVID-19 pandemic. These students enter with widely varying levels of mathematical preparation and historically experience higher rates of D/F/W outcomes in Calculus I than their peers starting at higher calculus levels. As a result, Calculus I students often report high levels of anxiety, low confidence, and uncertainty about their ability to succeed in engineering.

To address these academic and affective challenges, we introduced a mastery-based grading approach, specifically, a standards-based grading system organized around discrete learning targets, in Calculus I beginning in Fall 2022. In earlier work, we documented the design of this grading system and examined its impact on student outcomes [1]. Results showed that mastery grading significantly reduced students' test anxiety and improved several dimensions of math

self-efficacy. However, no significant differences in overall performance on a common final exam were observed between mastery-graded and traditionally graded sections.

In a subsequent study, we expanded the implementation to additional sections and refined the grading structure [2]. We found that mastery grading provided the greatest benefit for students entering Calculus I with the lowest diagnostic scores. At the same time, analyses across both studies consistently showed that precalculus readiness remained the strongest predictor of calculus performance, regardless of grading structure. These findings suggested that while mastery grading can improve students' affective experiences and provide meaningful support for less-prepared students, grading reform alone is not sufficient to address underlying gaps in readiness.

Beyond these performance findings, a key practical challenge also emerged during implementation. Mastery-based grading is built on the idea that students should have time to learn from feedback before being assessed again. In practice, however, weekly checkpoints moved too fast for this to happen. Students did not have enough time between assessments to absorb feedback, work on their mistakes, and genuinely improve. The pace of testing undermined the purpose of the grading reform itself.

This paper describes the next phase of our multi-year Calculus I redesign, which shifts the focus from grading reform to instructional pacing, readiness, and learning flow. Building on prior findings, we introduced three design changes: (1) short pre-lecture videos and class-preparation assignments to introduce definitions and basic ideas before class, (2) just-in-time precalculus reviews delivered immediately before related calculus topics, and (3) a restructured assessment schedule with bi-weekly checkpoints and dedicated problem-solving sessions.

Although the redesign included multiple coordinated changes, the analysis focuses specifically on just-in-time precalculus review as the primary intervention, and is guided by the following research questions:

1. In what ways does the integration of just-in-time precalculus reviews affect student performance in Calculus I, including both overall final exam outcomes and performance on topics that rely directly on precalculus skills, compared to previous cohorts without this structure?

2. How do students perceive the role of just-in-time reviews materials in supporting their understanding and confidence when learning new topics?

Background and Related work

Alternative Grading Approaches

In recent years, alternative grading systems, including mastery-based testing, standards-based grading, specifications grading, and ungrading, have gained attention in undergraduate mathematics education. These approaches emphasize students' demonstration of proficiency in specific learning outcomes rather than accumulation of points through partial credit [5, 6]. Prior studies have documented several benefits of mastery grading, including reduced test anxiety,

improved student confidence, and greater focus on learning rather than grades [7]. However, results on overall performance are mixed [8], and implementation challenges related to pacing, assessment load, and instructor workload are common. Our earlier work aligns with these findings. While mastery grading improved students' affective experiences and supported less-prepared students, it did not eliminate performance gaps tied to precalculus readiness, suggesting the need to better align instructional design with the goals of mastery-based systems.

Precalculus Readiness and Calculus Success

A large body of research indicates that students' performance in Calculus I depends heavily on their precalculus preparation [3]. Placement scores and diagnostic assessments have repeatedly been found to predict course performance more reliably than instructional variables such as teaching approach or grading structure. At the same time, prior work has suggested that traditional precalculus courses can act as a barrier when prerequisite content is taught in isolation and disconnected from calculus applications, and that integrating precalculus ideas into calculus instruction may better support learning and transfer [4].

Just-in-Time Review and Instructional Timing

Just-in-time learning approaches emphasize providing review or instruction precisely when learners are most ready to apply it. In contrast to broad, front-loaded review, just-in-time review aims to reduce cognitive overload and increase relevance by aligning prerequisite support with upcoming tasks. In mathematics and STEM education, this approach has been shown to support student learning and engagement, particularly on topics that students traditionally find difficult [9]. This perspective aligns with cognitive load theory, which suggests that reducing extraneous load and sequencing instruction carefully can improve learning outcomes [10].

Pre-Class Preparation and Learning Flow

Pre-class preparation, including videos, readings and low-stakes preparatory assignments, has been widely used in flipped and active-learning classrooms. These tools allow students to encounter definitions, notation, and basic ideas before class, freeing class time for problem-solving, discussion, and sense-making. Research suggests that when students complete meaningful pre-class work, they come to class better prepared, participate more productively in activities, and demonstrate stronger learning gains [11].

The course redesign described in the next section draws directly on each of these areas.

Instructional Design and Implementation

This study was conducted in a first-year Calculus I course at a large public research university, primarily serving engineering majors. In prior years, enrollment was typically around 150 students. However, starting in Fall 2025, the School of Engineering reinstated Calculus I as a required course for students without qualifying AP or transfer credit — a change that significantly expanded the course population. As a result, enrollment in Fall 2025 reached 230 students, including both students encountering calculus for the first time and those with prior exposure through dual-enrollment or other courses that did not transfer. This more diverse population increased the need for instructional structures that support readiness while keeping all students meaningfully engaged.

In prior iterations of the course, instruction was organized around a standards-based grading structure with weekly checkpoint assessments and an initial 2-week block of precalculus review at the start of the semester before transitioning to calculus topics. Over time, this approach revealed two related challenges: First, the front-loaded review did not serve students equally: those who needed additional support often struggled to connect precalculus material to later calculus applications, while students with stronger backgrounds found the extended pre-calc review repetitive and disengaging. Second, weekly checkpoints accelerated the assessment cycle, leaving limited time for reflection, practice, and revision, and contributing to a sense of constant testing. These observations motivated a redesign comprising four coordinated changes, each addressing a specific challenge identified in prior iterations:

Pre-class Videos and Assignments: To help students arrive in class better prepared and reduce time spent on basic exposition, pre-class preparation was redesigned to shift initial exposure to new ideas outside of class. Short pre-lecture videos were developed to introduce essential definitions, notation, and basic intuition, as well as to provide brief refreshers on prerequisite skills when needed. These videos were paired with low-stakes, completion-based class-prep assignments, allowing class time to be used more intentionally for problem-solving, discussion, and application rather than first exposure to content.

Just-in-time Precalculus review: Given the wide variation in students' precalculus backgrounds, precalculus review was restructured to occur only when it was directly relevant to upcoming calculus topics, rather than as a front-loaded block at the start of the semester. This took two forms. During the first six weeks, dedicated class periods were used to deliver structured precalculus mini-lessons and guided practice immediately before the calculus topics that depended on those skills. After the sixth week, precalculus skills were revisited briefly and informally within class as they came up naturally within calculus topics, without dedicated review sessions.

Redesigned Precalculus Assessment: In prior iterations, precalculus skills were assessed through separate learning targets — individual standards tied to specific topics that students had to demonstrate mastery on one at a time. While this fit the mastery grading structure, it made it harder to get a clear picture of students' overall precalculus readiness. In this phase, we replaced the individual targets with a single 30-question precalculus assessment covering four skill areas: algebra, functions, trigonometry, and exponential, logarithmic, and inverse trigonometric functions. The assessment was offered three times in class and counted for 10% of the course grade. The first attempt was taken during the first week of the semester, before any precalculus review had been delivered, allowing us to use these scores as a baseline estimate of students' incoming precalculus knowledge. The second attempt came mid-semester after targeted in-class review, and the third was near the end of the semester after additional practice. To help students study between attempts, each question was labeled by skill category. After each attempt, students could use Gradescope to see which questions they missed, identify the skill areas to work on, and review those topics using aligned practice packets.

Restructured Assessment Schedule: The course uses a standards-based grading system built around approximately 20 learning targets. In earlier versions of the course, these targets were assessed through weekly checkpoints. Over time, this pace proved too fast. Students had little

time between checkpoints to get feedback, practice, and improve. To address this, we shifted to bi-weekly checkpoints, freeing up class time for structured problem-solving sessions before each assessment. The goal was to give students more breathing room to absorb material, learn from feedback, and feel genuinely prepared before being assessed again.

Data and Methods

This study uses a mixed-methods approach drawing on both performance data and student survey responses. Quantitative data include precalculus assessment outcomes and performance on selected Calculus I final exam items that rely on precalculus skills. The analysis compares two cohorts: Fall 2024 (without just-in-time pre-calc review) and Fall 2025 (with just-in-time pre-calc review), with enrollments of 166 and 224 students, respectively. In Fall 2024, precalculus skills were assessed through four separate learning targets with up to three attempts for mastery. In Fall 2025, these same skills were assessed using a single precalculus assessment consisting of 30 multiple-choice questions, with up to three attempts to achieve an 80% threshold. Performance on precalculus skills and aligned calculus exam items were compared across cohorts to examine differences associated with the just-in-time approach. Qualitative data were collected through post-course student surveys administered to the Fall 2025 cohort, with 170 student responses. The survey included Likert-scale items and open-ended questions focused on students' experiences with the just-in-time precalculus review.

Results

Research Question 1: Effects of Just-in-Time Precalculus Review on Student Performance

Precalculus Performance

Student precalculus readiness was examined using both prior cohort mastery data from Fall 2024 and performance on the redesigned pre-calculus assessment in the fall 2025 cohort.

In Fall 2024, precalculus skills were assessed through four separate learning targets, with students allowed up to three attempts to demonstrate mastery by the end of the semester. By the end of the semester, mastery rates for general function-related targets and trigonometric functions were both approximately 86%. In contrast, mastery of the target covering exponential, logarithmic, and inverse trigonometric functions was substantially lower, with only 49% of students achieving mastery.

In Fall 2025, these same precalculus skills were assessed using a single combined precalculus assessment rather than separate learning targets. In response to challenges observed in prior cohorts, the assessment also included basic algebra skills—such as factoring, working with rational expressions, and rearranging equations—which were not previously addressed as explicit targets but had consistently emerged as a major barrier to student success. The assessment consisted of 30 multiple-choice questions and allowed up to three attempts. Questions were distributed across four skill categories: algebra (8 questions, 27%), functions (6 questions, 20%), trigonometry (6 questions, 20%), and exponential, logarithmic, and inverse trigonometric functions (10 questions, 33%).

As shown in Table 1, students in the Fall 2025 cohort showed substantial gains in precalculus performance over the semester. On the first attempt, both the mean and median scores were approximately 14 out of 30 (47.5%), reflecting limited initial readiness. By the end of the semester, performance increased to a mean of 20.8 (69.4%) and a median of approximately 22 out of 30 (73.3%). This improvement within the cohort suggests meaningful growth in precalculus knowledge over time, consistent with repeated exposure and reinforcement provided through the just-in-time review structure.

Table 1. Growth in Precalculus Assessment Performance (Fall 2025)

	Mean (%)	Median (%)
Beginning of Course	47.5	46.7
End of Course	69.4	73.3

Note: Values represent mean and median percentages of correctly answered questions out of 30 questions. Beginning-of-course values reflect the first attempt; end-of-course values reflect the highest score achieved by the end of semester.

To better understand where growth occurred, Table 2 presents performance by skill category. Clear improvement was observed across all categories over the semester. Gains were largest in algebra and exponential/logarithmic/inverse trigonometric skills, where beginning-of-course performance was lowest. Despite this improvement, these areas—particularly exponential, logarithmic, and inverse trigonometric topics—remained the weakest by the end of the course.

Table 2. Growth in Precalculus Assessment Performance by Skill Category (Fall 2025)

Skill Category	Beginning of Course Mean (%)	End of Course Mean (%)	Beginning of Course Median (%)	End of Course Median (%)
Algebra	39	62	38	63
Functions	63	76	67	83
Trigonometry	59	71	67	83
Exp / Log / Inverse Trig	38	64	40	60

Note: Values represent mean and median percentages of correctly answered questions within each skill category. Beginning-of-course values reflect the first attempt; end-of-course values reflect the highest score achieved.

Because the assessment format differed between Fall 2024 and Fall 2025, direct comparisons across cohorts are limited. However, the results from Fall 2025 suggest improved overall proficiency in areas that previously showed low mastery, especially exponential and logarithmic functions. Across cohorts, students consistently struggled most with exponential, logarithmic, and basic algebraic skills.

Calculus Performance on Prerequisite-Dependent Topics

To examine whether changes in precalculus support translated into downstream calculus performance, we compared final exam outcomes between Fall 2025 (with just-in-time precalculus review) and Fall 2024 (without just-in-time review) using a common final exam.

Overall performance was higher in Fall 2025 than in Fall 2024 (Fall 2025: n=224, mean=83.6; Fall 2024: n=166, mean=77.9). A two-sample Welch's t-test confirmed that this difference was statistically significant ($p = 0.0026$). Importantly, students' incoming readiness was assessed using the same department precalculus diagnostic administered in person under proctored conditions at the beginning of the semester in both cohorts. Scores were similar across the two cohorts (mean score of 60.9 in Fall 2025 vs. 64.5 in Fall 2024), with no significant difference ($p=0.167$), suggesting that final exam improvement was not driven by differences in initial preparation.

To examine precalculus-related performance, we identified a subset of questions on the common final exam administered in Fall 2024 and Fall 2025 (23 points total out of 150 points) that depended primarily on algebraic manipulation, functions, trigonometry, and exponential expressions. Across these items, student performance in Fall 2025 was largely comparable to that in Fall 2024, with no statistically significant differences observed at the individual item level.

As shown in Table 3, in Fall 2024 students earned a mean score of 17.8 and a median score of 19.5 out of 23 on these precalculus-dependent items. In Fall 2025, the mean score was 18.1, with a median of 19 out of 23. Overall, performance on precalculus-dependent items was comparable across the two cohorts.

Table 3: Final Exam Performance by Cohort

	Fall 2024	Fall 2025
Overall final exam mean (%)	77.9	83.6
Precalculus-dependent items (mean, out of 23)	17.8	18.1
Precalculus-dependent items (median, out of 23)	19.5	19

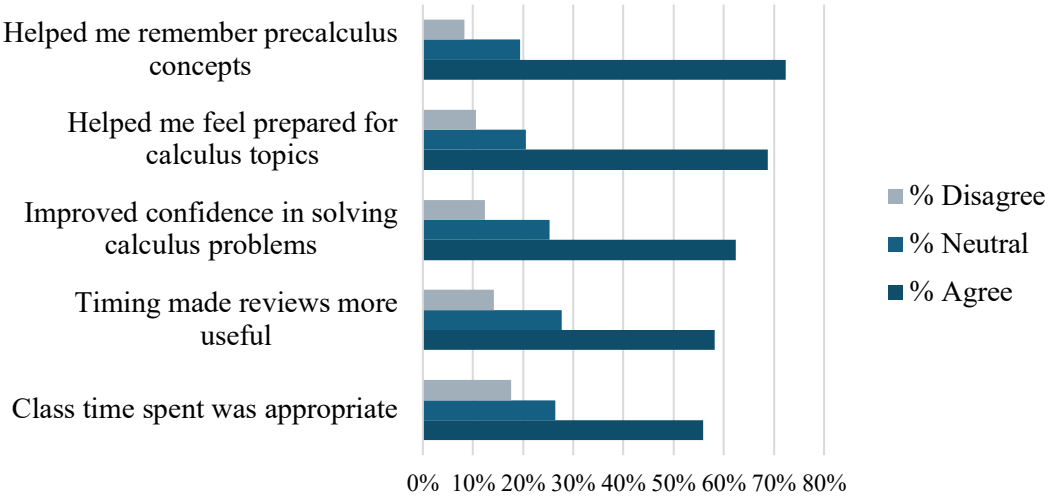
The overall final exam improvement in Fall 2025 does not appear to be explained by gains in precalculus skill. Instead, the gains may reflect a combination of factors: just-in-time review may have improved students' fluency and confidence in applying precalculus skills within calculus contexts, while other design changes, including the shift to bi-weekly checkpoints, dedicated problem-solving sessions, and pre-class videos and assignments, may have supported broader improvements in calculus-specific skills.

Research Question 2: Student Perceptions of Just-In-Time Precalculus Review

Perceived Usefulness and Preparedness

Student perceptions of the just-in-time precalculus reviews were generally positive. Likert-scale responses were summarized descriptively by examining the distribution of responses, grouped into Agree (Agree/Strongly Agree), Neutral, and Disagree (Disagree/Strongly Disagree), as shown in Figure 1. Across all survey items, a clear majority of students expressed agreement with statements related to preparedness, usefulness, and confidence. Most students agreed that the reviews supported precalculus recall (72%) and preparedness for calculus topics (69%). In addition, 62% reported increased confidence in solving calculus problems. A majority also viewed the timing of the reviews as useful (58%) and felt that the amount of class time devoted to review was appropriate (56%). Overall, responses suggest that just-in-time reviews supported both preparedness and confidence when learning new material.

Figure 1. Student Perceptions of Just-in-Time Precalculus Reviews



Note: n = *170 student responses.*

Student Reflections on Effective Elements

To better understand which elements of the just-in-time precalculus review most supported student learning, students were asked the open-ended question: "When reflecting on the just-in-time precalculus review this semester, what aspects most helped your learning?" Open-ended responses were analyzed using thematic analysis, a process of reading responses, generating codes, and grouping them into recurring themes. The frequency of each theme is summarized in Table 4.

Table 4: Student-Identified Supports That Most Helped Learning in the Just-in-Time Precalculus Review

Theme	**Description**	**Count**
Practice Materials	Worksheets, review packets, WebAssign practice problems	82
Dedicated Class Time	Lectures or review days focused on precalculus topics	43
Supportive Learning Environment	Instructor or TA support, office hours, peer or group learning	10
Skill-Specific Benefit	Review of specific topics (e.g., trigonometry, algebra, exponentials/logs) was especially helpful.	9
Timing and Relevance	Review occurring immediately before related calculus topics	8
Background and Assessment	Prior precalculus background; value of multiple attempts and feedback	5
Not Helpful/Unclear What JIT Means	Confusion about the meaning of the term "just-in-time" or limited perceived benefit	12

Note: n = *142 student responses. Individual responses could be coded into multiple themes.*

Students also frequently pointed to dedicated class time for review as beneficial, particularly when review days were explicitly built into the course structure. One student shared that

"Actually dedicating in-person days really helped my learning. Having time in class to go over precalculus material and ask questions made it much easier to understand and apply when we moved on to calculus." Another student noted: "I liked that this was taught through the course and incorporated with the calculus material. It didn't feel squished in, and having class time dedicated to review made it easier to keep up."

Several students highlighted the timing of the reviews, noting that revisiting precalculus topics immediately before related calculus content made the material easier to understand and apply. As one student explained, "The targeted refreshers and quick practice problems right before we used the concepts in class helped me the most. They made the review focused, timely, and easier to apply." Another similarly noted, "The timing was helpful. Reviewing key precalculus topics right before using them in calculus made the material easier to understand and apply. It helped connect what we had learned before with what we were doing in class."

Additional themes included the role of a supportive learning environment and the benefits of targeted review of specific precalculus skills, particularly trigonometry and algebra. A small number of students were confused by the term "just-in-time," indicating that the approach should be described more explicitly to students in the future.

Student Suggestions for Improvement

Students also responded to an open-ended question asking for suggestions to improve the just-in-time precalculus review. Responses were analyzed using thematic analysis, with theme frequencies summarized in Table 5.

Table 5: Student-Identified Areas for Improving the Just-in-Time Precalculus Review

Theme	**Description**	**Count**
Practice Intensity	Requests for more frequent, more challenging, or exam-aligned practice problems and worksheets	30
Additional Resources and Support	Requests for videos, lecture recordings, extra office hours, or a separate pre-calc course	25
More Time and Earlier Review	Requests for additional class time, earlier introduction of review, or longer review window	24
Assessment Guide and Transparency	Requests for practice exams, clearer exam scope, and feedback on missed questions	20
Assessment and Grading Concerns	Concerns about grading weight, time pressure, all-or-nothing scoring, or requests for partial credit	12

Note: n = *95 student responses. Individual responses could be coded into multiple themes.*

The most common suggestion was centered on practice intensity. Many students asked for more practice problems, more worked examples, and practice that better matched the difficulty and style of the precalculus checkpoints. One student explained, "Adding a few more worked examples and practice problems would help, especially for topics that felt rushed," while another noted, "Make the review questions much harder since they were nowhere near the difficulty of the real test questions." These comments suggest that students valued repeated exposure and alignment between review materials and assessments.

Students also frequently requested additional resources and support, such as instructional videos, lecture recordings, office hours, or optional review sessions. Several students emphasized the value of having multiple formats available, especially when reviewing independently. As one student shared, “Having videos to help work through some problems would be really helpful,” while another suggested “more lectures and office hours for it.” A few students suggested expanding support beyond the semester, with one proposing, *“*Perhaps like pre-calculus courses during the Summer and J-term time.*”*

Many responses focused on timing and pacing. Students often felt that the review was helpful but wanted it to start earlier, occur more consistently, or span a longer portion of the semester. One student explained: “It would be a lot more effective if we had spent more time reviewing, rather than just spending 3–4 classes to cover all of precalculus material.” Others noted that spacing review out over time would help prevent forgetting.

In addition, many students highlighted the need for greater assessment guidance and transparency. Common suggestions included providing practice exams, clearer information about exam scope, and access to feedback on missed questions. As one student explained, “I would find it really helpful to be able to review my past pre-calculus checkpoints so I can see what I got wrong and focus my studying.”

Finally, a smaller but notable group of responses raised concerns about assessment structure and grading, often in connection with differences in students’ precalculus backgrounds. Students noted that not everyone enters calculus with the same level of preparation—some had not taken precalculus recently, or at all—and felt that the structure and weight of the precalculus checkpoints did not always account for this variability. Several students expressed frustration with time pressure and all-or-nothing scoring, particularly given the difficulty of the questions. As one student summarized, “It was sort of strict having to pass 24/30 to get a 100, especially since the questions are much harder than a normal pre-calc course*,”* while another noted that “it was difficult to study for both calculus and precalculus at the same time, especially with the pre-calc checkpoint being worth 10% of the grade.”

Discussion

Students in the Fall 2025 cohort showed clear growth in precalculus knowledge over the semester. In Fall 2024, less than half of the students could master the target covering exponential, logarithmic, and inverse trigonometric functions. Although the assessment format changed in Fall 2025, making direct comparisons difficult, students showed their largest gains in these specific areas in these same topics. The within-cohort gains in precalculus performance combined with higher overall final exam performance indicate that just-in-time review supported readiness without hindering progress on core calculus content. Performance on precalculus-dependent final exam items remained comparable across cohorts, suggesting that the just-in-time approach maintained, rather than disrupted, prerequisite skill application in calculus.

The data also highlights persistent challenges in foundational skills. Basic algebra, such as factoring and simplifying rational expressions, was added to the 2025 assessment because it was identified as a major barrier to student success. Even though students showed substantial

improvement in algebra, it remained one of the weakest skill categories by the end of the semester, alongside exponential and logarithmic functions.

Student feedback also sheds light on how the timing and structure of just-in-time review supported learning. The majority of students reported that just-in-time reviews helped them remember precalculus concepts, feel more prepared for calculus topics, and build confidence in problem solving. Practice-based materials and dedicated class time were especially valued, and students appreciated reviewing skills close to when they were needed.

Overall, these findings suggest that just-in-time precalculus review can meaningfully support student readiness and calculus performance when it is well aligned with course pacing and grading structure. However, persistent gaps in algebra and exponential functions indicate that some students need more sustained support. Addressing these foundational barriers remains an important direction for future iterations of the course.

Limitations and Future Work

Several limitations should be kept in mind when interpreting these results. First, precalculus skills were measured in different ways across the two cohorts, which limits the direct comparisons of mastery levels between Fall 2024 and Fall 2025. Second, only a small number of final exam questions depended mainly on precalculus skills, and these questions made up a small portion of the overall exam score, making comparisons of prerequisite-based calculus performance less precise.

In addition, this study cannot claim that the instructional changes directly caused the observed outcomes. The Fall 2025 course included seven sections taught by five instructors, while Fall 2024 had five sections taught by three instructors. Differences in teaching style and how the course was implemented may have affected student performance. A particularly important contextual factor is the policy change that took effect in Fall 2025, when our School of Engineering reinstated Calculus I as a required course for students without qualifying AP or transfer credit. This change significantly expanded and diversified the student population, bringing in students who may not have previously enrolled in the course, including some with prior calculus exposure through dual-enrollment courses that did not transfer. As a result, the Fall 2025 cohort was not directly comparable to Fall 2024 in terms of composition. While the similarity in precalculus diagnostic scores provides some evidence that the two cohorts were not substantially different in incoming preparation, it cannot rule out the possibility that Fall 2025 students had greater prior exposure to calculus content, which may have independently contributed to higher final exam performance.

Student feedback highlights several directions for refining the just-in-time precalculus review. Students consistently asked for more practice that closely matches assessment difficulty, earlier and more evenly distributed review across the semester, and clearer guidance connecting review materials to the assessment. In response, future iterations will expand and better align practice resources, improve assessment transparency, and adjust the timing and pacing of review activities to better support students with varied precalculus backgrounds. In particular, persistent difficulties with basic algebra suggest the need for stronger support for foundational algebraic

skills, delivered at the moment when the skill is required while working through problems. Future refinements will also place greater emphasis on helping students develop effective learning strategies, such as tracking mistakes, recognizing error patterns, managing time across attempts, and seeking support early.

Future work should also explore more direct ways to assess how precalculus interventions translate into calculus performance, such as incorporating a broader set of aligned calculus tasks.

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