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Supporting the Transition to University Calculus using MathMatize

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Abstract

*This paper reviews the development and implementation of low-stakes optional quizzes for an introductory calculus course (MATH*1200: Calculus I) at the University of Guelph using the education technology platform Mathmatize (mathmatize.com). These quizzes were created as a diagnostic tool that also provides support to students during the transition to university-level mathematics by reviewing crucial background concepts in a low-stress and accessible way. Quiz uptake was high, and responses provided insight on incoming students' background and ability. Furthermore, there are indicators that students who completed the quizzes found them helpful and reassuring. Student feedback was encouraging of the new format and points toward the potential for increased support by improving and expanding on these new resources.*

Keywords: *Math education, education technology, diagnostic testing.*

1. Introduction

The transition to university can be challenging and intimidating for many students. Mathematics anxiety, defined as feelings of tension and apprehension that can interfere with student performance in mathematics courses and tasks, is particularly common among first-year university students. The sources and impacts of mathematics anxiety have been investigated in the literature. For example, Luttenberger, Wimmer and Paechter (2018) identify a number of antecedents for math anxiety and explore its onset and presence across all age groups, from primary through post-secondary education. Khasawneh, Gosling, and Williams (2021) provide a meta-analysis that reveals intrinsic barriers related to math anxiety for university-level mathematics students. Other research has identified anxiety-related challenges specific to the transition from secondary to post-secondary education (for example: Ruberman, 2014; Thompson, Pawson and Evans, 2021; Worsley, Harrison and Corcoran, 2021). It is now pertinent for first-year instructors to implement strategies for mitigating mathematics anxiety and other transitionary challenges. As a preliminary step, first-year instructors may seek to better understand the knowledge and skills that students are equipped with as they enter their courses,

and corresponding diagnostic testing has been explored in a variety of formats. For example, Levere and Demers (2017) explored a first-year Warm-Up test format to specifically focus on prerequisite concepts and emphasizing feedback. Of course, any additional testing creates a risk of exacerbating mathematics anxiety, so it is worthwhile to consider diagnostic formats that prioritize student well-being.

Recent years have come with unexpected challenges as the COVID-19 pandemic necessitated a sudden shift in the way we teach and learn. In the semesters following the full return to campus, it was widely observed that the mathematical backgrounds among incoming first-year Calculus students at the University of Guelph were markedly less consistent than in previous years. These observations run parallel to studies that highlight some of the learning difficulties that may have been introduced or exacerbated among various groups of students during the pandemic (Whitley, Beauchamp & Brown, 2021; Colvin, Reesman & Glen, 2022; among many others). With more students leaning on an increased presence of hybrid or online learning, there was an opportunity to develop a more supportive approach to measuring the abilities of students entering into university calculus. This paper details and justifies resources that were developed in 2023 for MATH*1200 (Calculus I) at the University of Guelph using MathMatize.com (an education technology platform), shares student feedback following implementation of these resources during the Fall 2023 and Fall 2024 semesters, and explores ideas and opportunities for how this tool could be expanded.

2. Setting and Resources Used

We will begin by describing the context of this work, which was performed at the University of Guelph, in Guelph, Ontario, Canada during the Fall 2023 and Fall 2024 semesters. The study involved three sections of Calculus I (MATH*1200) and the focal point for this manuscript is discussion surrounding the introduction of course modules utilizing MathMatize, software that offers a variety of teaching and learning tools.

2.1. Calculus I (MATH*1200) at the University of Guelph

MATH*1200 is a standard first-year calculus course for university students. The course description is available online at www.uoguelph.ca, and reads as follows:

> This is a theoretical course intended primarily for students who expect to pursue further studies in mathematics and its applications. Topics include inequalities and absolute value; compound angle formulas for trigonometric functions; limits and continuity using rigorous definitions; the derivative and derivative formulas (including derivatives of trigonometric, exponential and logarithmic functions); Fermat's theorem; Rolle's theorem; the mean-value theorem; applications of the derivative; Riemann sums; the definite integral; the fundamental

theorem of calculus; applications of the definite integral; the mean value theorem for integrals.

Students in MATH*1200 are typically those in STEM programs wherein math will remain a central topic throughout their degree. Indeed, most students in MATH*1200 are enrolled in Engineering, Computer Science, Finance, or Mathematical Science degree programs.

In the Fall 2023 semester, there was a total enrolment of 814 students at the beginning of the semester; this number dropped to 699 by the end of the semester (a drop rate of about 14.2%). This drop rate is fairly typical of recent offerings of the course. In the Fall 2024 semester, there was a total initial enrolment of 1341, and 1264 completed the course (a drop rate of about 9.4%, lower than is typical). Both the Fall 2023 and 2024 offerings of this course featured three "traditional" lectures per week following a custom course manual. These lectures were offered alongside a weekly lab in which extra practice problems or extensions to concepts were presented. Attendance for students was not mandatory nor recorded outside of exams, tests or quizzes.

2.2. MathMatize

MathMatize is an education technology platform that offers polling, assessment, and content creation tools with a particular focus towards math instruction. MathMatize has a community exercise catalog of over 20,000 exercises created by instructors around the world. Instructors can collaborate on question banks with their colleagues. Polling and assessment features offer a variety of settings to meet different pedagogical use cases. Importantly, MathMatize has gamified learning materials, which can encourage student engagement while bridging the gap from high school to university mathematics. These gamified materials are scaffolded, with progress updating as students answer questions giving them a better understanding of their areas of weakness.

MathMatize was made available to students in the course for a small fee of approximately $7 per student after a two-week free trial period. Despite the modest fee, it was made clear to students that accessing the software was strictly optional, given the extra cost. Students electing not to create an account were given an alternative grading scheme that did not include any Mathmatize-based assessments.

3. Quizzes

3.1. Quiz Structure and Generation

Important quiz criteria were established to create an online assessment framework that students would find both accessible and helpful. The thirteen quizzes:

- Were quite short, including just five problems or less (sometimes as few as two or three);
- Were unsupervised (and therefore, students were free to access their notes or other materials as they wished);
- Had no time limit;
- Were made available from the beginning of the semester for students to access when ready and interested;
- Could be taken at any time during the semester, and as many times as a student wished, with the deadline being the night before the final exam;
- Were low stakes, with each quiz accounting for roughly 0.77% of a student's grade;
- Always focused on materials prerequisite to the course and foundational to concepts within the course. Importantly, quizzes never featured new concepts presented at the university level, and entirely consisted of practice problems for relevant concepts from Grades 9 through 12;
- Were randomized, so that a different set of problems were included in the quizzes with each attempt;
- Were algorithmically generated, so that within any given problem, numbers or variables would differ from attempt to attempt;
- Featured a variety of styles of problems, including multiple choice, matching, and symbolic entry, and revealed the correct responses after the completion of each quiz.

Each quiz centered on a particular topic. For example, one quiz focused on Piecewise Functions, another on Graphs of Trigonometric Functions, and another on Factoring, etc.

3.2. Course Grading Scheme

Both the 2023 and 2024 offerings of the course offered MathMatize quizzes at a weighting of 10% of their overall grade; and a second grading scheme that did not include these quizzes. Grades were calculated using each scheme, and at the end of the course, the greater of these two grades was automatically assigned to each student in the course. The two grading schemes were designed so that students would feel minimal pressure to purchase access to MathMatize. For example, Scheme II shuffles the quiz weight across all other grades, rather than just moving weight to the Final Exam. Students were told about the software through class announcements and the course website and were encouraged to purchase access to MathMatize if they saw a potential benefit.

Table 1. Grading Schemes for Fall 2023 and Fall 2024 Calculus I.

Assessment	Scheme I Weighting	Scheme II Weighting
MathMatize Quizzes	10%	0%
Lab Tests	20%	25%
Midterm Test	30%	32.5%
Final Exam	40%	42.5%

3.3. Uptake and Grade Data

The same sets of quizzes were offered with the same format in both the Fall 2023 and Fall 2024 semesters.

Table 2. Uptake for MathMatize Quizzes in Fall 2023 and 2024

Semester	Total Number of Students	Students Accessing Quizzes	% of Students Accessing Quizzes	Average Grade
Fall 2023	699	622	89.0%	96.3%
Fall 2024	1264	982	77.7%	97.7%

A large majority of students opted to access the MathMatize quizzes in each semester, though significantly more in Fall 2023. This could be due to the larger enrollment in Fall 2024; anecdotally, it can be difficult to disseminate information effectively to larger numbers of students. For those students who did access the quizzes, the grades were high both semesters.

Table 3. Grade Comparison Between Students Choosing to Access MathMatize Quizzes, and Students Electing not to

Semester	Final Grade for Students Accessing Quizzes	Final Grade for Students Opting not to Access Quizzes	Final Exam Grade for Students Accessing Quizzes	Final Exam Grade for Students Opting Out
Fall 2023	68.2%	59.5%	62.5%	51.3%
Fall 2024	73.5%	70.1%	68.8%	68.6%

Students accessing the quizzes performed at a significantly higher level than those that did not in Fall 2023, but these results were less pronounced or generally absent in Fall 2024. Comparing final grades should be approached with caution, since final grade data incorporates the MathMatize quiz grade itself, and it is true that the average grades for the MathMatize Quizzes were much higher than the average grades for the other tests and exam; this would introduce a bias in the comparison. Nevertheless, when the final exam averages alone are compared in isolation, we can see that considering the Fall 2023 semester, there exists a significant difference in student performance between those who accessed the quizzes and those

who did not, with students accessing the quizzes (earning an average grade of 62.5%) outperforming those who did not (earning an average grade of 51.3%). This was not well-demonstrated in Fall 2024, with quiz-taking students performing only marginally better than those opting out.

Importantly, in both offerings of the course, there were no problems on the final exam that mimicked the format or material of any of the MathMatize quiz questions. Additionally, the instructor was different for each of the two offerings of this course, which could help shed some light on the differences in results from semester to semester.

Ultimately, it will be useful to continue to gather data in future years to determine any more consistent patterns, as just two semesters of results will necessarily limit any conclusions that could be reasonably drawn with regards to performance and grades.

3.4. Student Feedback

Student feedback was collected through the usual Student Feedback Questionnaires at the end of the semester. Class reviews were generally quite positive, though MathMatize quizzes were infrequently mentioned. Feedback specifically regarding the course structure was also largely positive, with few suggestions or criticisms toward MathMatize specifically. Some specific critiques and feedback are provided here:

- The mathmetize [sic] is a great addition, it offers the possibility for students to earn points other than on tests. Great initiative (Fall 2023)
- Nice refresher on previously taught content, while going more in depth and smoothly integrating new content (Fall 2024)
- Mathmatize not challenging enough to be considered practice. (Fall 2024)
- Mathmatize could have been harder and on course materials. (Fall 2024)
- Not sure what was up with mathematize [sic] but it just felt a little odd as it was never used after the first week, despite it being a great way to provide feedback to students who wished to practice their skills. Utilization of this platform would be great for weekly assignments that could reduce the importance of the two lab tests and exam upon which so much of the course mark is based, and help to give students weekly feedback on their understanding of the course material. (Fall 2023)

Additional to these specific points, a common suggestion among students was to increase the number of course assessments in general, providing more opportunities for grades while perhaps reducing the stakes of each assessment.

3.5. Potential Future Developments

As only two semesters of information have been gathered associated with this new component of the course, it is disingenuous to draw any broad or general conclusions based on our experience. Nevertheless, reflecting on some of the student feedback, we pose some ideas for potential incremental changes in future semesters:

- A greater number and variety of quizzes could be developed.
- Some more difficult problems could be incorporated in different ways. For example, each quiz could have an introductory-level version (the existing quizzes and problems), and a more challenging version, with the completion of both contributing toward student grades.
- Students may benefit from some additional and clearer communication as to the motivation behind the quizzes: To exist as a supportive environment to practice background skills, rather than providing a source for regular testing of new course concepts (of course, there is the opportunity to explore both approaches during the same semester).

4. Conclusions

This paper presented an alternative approach to diagnostic testing and foundational practice for a first-year calculus course, using low-stakes optional quizzes on the MathMatize platform. Student uptake of these quizzes was positively associated with final exam performance and final grades in the Fall 2023 semester, but less significantly so in the Fall 2024 semester, and further data is needed before any broad generalizations can be made. Considering the generally positive student feedback with a few suggestions for improvement, it may be possible to implement some small adjustments to the scheme that has been employed to better support students in their transition to university calculus.

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