Building Educational Resilience in Mathematics Delivery and Assessment

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Abstract

Mathematics is a foundational subject in education. Learning outcomes in mathematics build on previous competencies and students are well-served by real-time intervention and feedback. However, contemporary math education is limited by technology, scalable learning, shareable experiences (both teaching and learning), and accessible modes of practice. Most assessment platforms do not have the functionality to support symbols and equations. During the pandemic we have diverted assessments in high enrolment mathematics courses from paper to electronic delivery. We developed randomized examinations for Introductory Statistics and Introduction to Calculus I and we developed an entire course with assessment using OERs (open educational resources) for Business Mathematics. Our team developed highly interactive, traceable, and intervenable content in math problem solving using the Möbius (https://digitaled.com/mobius) platform. We enabled an LTI integration of the platform into our LMS (learning management system) to provide seamless access for students. Möbius promotes cognitive learning through a powerful math engine, student feedback, analytics, and interactive STEM (science, technology, engineering, math) curriculum content. We are serving 3,000 learners with effective assessment and have relieved faculty and staff of administering and marking alternative examinations through a long pandemic. We have seen improvements in student feedback, increased accessibility, reduced administrative burden, and enhanced exam security. Möbius is a truly scalable and cost-effective platform for math educators and students that provides more efficient and effective management of educational delivery.

Keywords: mathematical resilience, Möbius, online delivery, assessment, accessibility, efficiency in education

Introduction

Mathematical resilience refers to the ability of a student to overcome barriers or challenges in their mathematical learning journey. Although resilience in education in general is important, mathematical resilience is a unique concept given the specific barriers it may present to learners, which may or may not be overcome, depending on how learning is facilitated (Johnston-Wilder & Lee, 2010). The four attributes of mathematical resilience are having a growth mindset, understanding the value, knowing how to work at learning, and knowing how to access supports (Johnston-Wilder & Lee, 2017).

Enhancing educational outcomes is faced with continual challenges in funding and increased demands for public money. It is important to ensure that realizing efficiencies in educational systems does not only produce quantity of students educated, but also quality in successful achievement of learning outcomes (Johnes et al., 2017). Efficiency must be balanced with effectiveness so that producing outputs uses resources most effectively to achieve the learning outcomes desired by society. One efficient and effective tool for realizing efficiencies while maintaining quality in evaluating outcomes is through online examinations. Online exams have become a widely preferred method of assessment in both traditional and online learning environments. Studies have shown that there is no statistically significant difference in achievement in online versus traditional exams (Ilgaz & Afacan Adanir, 2020). As an open and online institution serving over 40,000 learners, Athabasca University (AU), strives to provide flexibility and accessibility to learners through the removal of barriers to education through efficient and effective pedagogy (Anderson, 2008).

Möbius ([Möbius - Online Learning Platform for Mathematics-Based Courses | DigitalEd)](#) is an online learning and assessment platform for creating and deploying courses in the STEM disciplines, or in any discipline that relies on the use of mathematical equations and symbols. Möbius has a number of features and functions that provide students with an integrated and interactive learning experience. Möbius:

1. utilizes a world-class math-engine to deliver complex STEM disciplines
2. enables the use of powerful multimedia visualizations
3. provides students with feedback and instructors with data on student engagement and understanding

4. allows a range of randomized and algorithmically generated question types
5. includes access to high-quality curriculum content
6. permits seamless integration with any LMS

Möbius features open access course content in STEM that can be used and edited, to facilitate an ecosystem of creation, curation, and sharing, reducing the need for additional learning resources. Exam security is enhanced by the randomization of questions. Möbius can deliver flexibility in assessment, authentic assessment, and immediate feedback. The platform, developed with the University of Waterloo and in use by a number of institutions, offers evidence-based optimization of learning. A single student license gives the user unlimited access to resources and examinations for one year. Students have the ability to write multiple examinations and complete an unlimited number of courses and assessments for a single cost. Case studies have shown that Möbius can increase engagement and accessibility (Gustafsson, 2022) as well as student success (van der Post, 2022).

The Faculty of Science and Technology (FST) at AU sought Möbius as a solution to paper-based math examinations that could not be delivered through the existing online exam platform. This need became more urgent at the onset of the pandemic and the closure of AU invigilation centres. Mathematics is one of the highest enrolled disciplines at AU, with 5,500 course starts in FY2020 and 6,057 course starts in FY2021. MATH 215 is one of the top three enrolled courses at AU, with 2,167 and 2,674 course starts in FY2020 and FY2021 respectively.

This report summarizes the outcomes of the Möbius pilot for MATH 215 examinations (midterm and final) and the development process for MATH 244 as an entire course. The requirements for successful implementation, benefits for learners, and recommendations for Möbius as an assessment platform going forward are provided in the form of lessons learned from participants, data from operationalizing the system, and student survey feedback. As the university moves forward with the Integrated Learning Environment, the Imagine Learning Framework, re-imagining assessment, and the digitization of examinations, it is important to carefully evaluate the role of Möbius in enhancing the digital experience for our learners and providing educational resiliency through efficient and effective means.

Methodology

In January 2021, the FST, AU and DigitalEd prepared to deploy Möbius for two courses, MATH 215 Introduction to Statistics and MATH 244 Business Mathematics. The FST decided to pilot Möbius for examinations for MATH 215 and for an entire course for MATH 244 (content, learning activities, and all assessments). The project was managed by the Examinations Unit and involved mathematics faculty and tutors, the FST course development and production team, front-line FST student support staff, FST leadership, DigitalEd, and Information Technology (IT). A seamless LTI integration from the LMS (Moodle) to the Möbius platform to facilitate student access was created. Random exam banks for MATH 215 were developed and MATH 215 examinations went live May 4, 2021. MATH 244 was developed as an entire course in Möbius (learning resources and all assessment activities) and the course is currently under production so will be evaluated separately when released.

The project was evaluated by gathering data on the number of exams processed as well as the reduction in student concerns and access issues. We also tracked efficiencies in administrative functions provided by the front-line student services team. Surveys were administered to students to determine satisfaction rates, competency, and functionality. Finally, the requirements for successful implementation of Möbius were determined to support further expansion to additional courses in the future.

Results

MATH 215 examinations are delivered though the Möbius platform, which is integrated into the course Moodle site (LMS) through an LTI integration. Students still order exams through the exam unit, but access to the online exam is provided through Moodle and delivered by Möbius, using ProctorU for invigilation. Alternate examinations for students unable to use ProctorU are provided through Accessibility Services and the FST Student Success Centre when the exam can be used, but alternate invigilation using Teams is required. If an online exam cannot be delivered, a paper take home exam can be provided for those students requiring this type of accommodation. The ability to generate random exams in Möbius greatly facilitates this process, as providing a take home exam to a student no longer compromises the limited number of exam versions for the course. The total

number of students that used Möbius is 1,228 and the total number of exams administered is 2,016. Table 1 shows the number of midterm and final examinations that have been administered.

Table 1. Examinations administered in Möbius for the course MATH 215 Statistics.

	Number of Completed exams
Midterm exam	970
Midterm supplemental exam	164
Final exam	830
Final supplemental exam	52

As shown in this table, exam administration in this high-enrolment course is demanding and the move from paper-based exams to an online system that can facilitate mathematical equations and symbols was necessary during the pandemic, but going forward to adequately evaluate learning outcomes, provide an accessible and effective exam delivery model for students, and reduce administrative burden in exam delivery and processing. The auto-marking capability of Möbius facilitates the ability to successfully evaluate student performance in a cost-efficient manner, while providing an effective and engaging format for students. The savings in cost by administering examinations this way also allows more academic support for students and interaction because time is not spent marking a high number of examinations.

The number of alternative assessments was also tracked. Some students may request alternative examinations due to technical issues or an inability to use the online invigilation provider, ProctorU. Overall, we have seen a large reduction in the number of alternative examinations requested. In the two months prior to the Möbius go live date, the FST processed 18 alternative assessments, however, in the six months following the implementation of Möbius only 8 alternative examinations were administered. This is a greater than 5-fold reduction, indicating that the Möbius platform is more accessible for students. We have noted that students have had few technical issues with Möbius, and the LTI integration of the platform into the LMS has reduced the requirement for students to sign into a separate portal to write exams. Furthermore, students are able to use the same login as their student portal reducing the issues with password resets and access.

The implementation of Möbius has greatly reduced the administrative burden on the FST student support team, FST administrators, as well as the AU Examinations Unit. Möbius has reduced the number of emails to be sent out to students by front-line student support staff significantly. It has resulted in a more stable environment from both a learner experience and an invigilation perspective with less process and technical issues to resolve. Improved connectivity has lessened the need for alternative assessments and any students that cannot write with ProctorU can be accommodated with invigilation using Microsoft Teams. There are substantially less learner complaints to the Ombuds Office regarding accessibility to MATH 215 exams, reducing administrative workload for the Ombuds Office, FST leadership in resolving cases, and the Office of the Registrar appeals process. In fact, the dean has not received a single case pertaining to this course since the platform went live.

Student satisfaction rates with Möbius demonstrated that overall students were satisfied with this exam delivery method (Table 2). Most students enjoyed using Möbius, with 53.66% that agreed or strongly agreed and 56.10% of the students agreed or strongly agreed they would use it again. Overall, students found the platform easy to use, but a significant portion of students found that they would benefit from some training in the system. Of the 41 students surveyed, 43.90% percent agreed or strongly agreed that the training would be favorable. Interestingly, a number of students were neutral about the platform, which indicates that students are most interested in the course content and learning outcomes, with an expectation that their examinations are delivered in an effective manner, regardless of the technology.

Table 2. Student satisfaction and competency using Möbius as an exam delivery format.

	Strongly Disagree	Disagree	Agree	Strongly Agree	Neutral	Total Responses
I have enjoyed using Möbius	19.51%	17.07%	29.27%	24.39%	9.76%	41
I would use Möbius again	19.51%	9.76%	21.95%	34.15%	14.63%	41

I would like Möbius training	9.76%	29.27%	24.39%	19.51%	17.07%	41

The type of device used to access Möbius to complete examinations was determined and is illustrated in Table 3. Most students accessed and completed their exams from a laptop (90.24%), followed by a PC (12.20%). Out of the 41 students surveyed three completed their exams using a mobile phone and two with a tablet. It is interesting to note that although most students preferred a laptop or PC, mobile phones and tablets are an effective means for learners in any location, to complete examinations. The ability to administer examinations with significant reach and potential for access and flexibility is an important feature of the platform in the effective education of students globally, particularly in rural and remote locations.

Table 3. Type of device used to access Möbius for examinations.

	Percent Use	Number of Responses	Total Responses
Mobile phone	7.32%	3	41
Tablet	4.88%	2	41
Laptop	90.24%	37	41
PC	12.20%	5	41
Other	2.44%	1	41

Learner satisfaction with Möbius functionality was also measured and these results are shown in Table 4. Möbius offers a range of question types, and interactive features for assessment in STEM, and understanding the functionality of the system is important to evaluate how examinations are delivered. Similar to the other results, most students were satisfied with the three types of functions offered: math entry using text mode, math entry using symbol mode, and math visualization and graphs, indicating that the functionality of the platform is effective in supporting student assessment. Similar to the results in Table 2, quite a few students were neutral in their responses, which indicates that functionality is an expectation.

Table 4. Student satisfaction with Möbius features and functionality.

	Unsatisfied	Neutral	Satisfied	N/A	Total Responses
Math entry using text mode	19.52%	7.32%	65.85%	7.32%	41
Math entry using symbol mode	19.52%	17.07%	53.66%	24.39%	41
Math visualization and working graphs	17.07%	19.51%	56.10%	7.32%	41

In evaluating student satisfaction and functionality, qualitative data was also obtained in the survey. Students liked the system and noted the following: "*it was straightforward and intuitive*" and "*easy to use.*" Some students commented that "*I could take the exam at home and at a flexible time*" and that it was "*convenient.*" Many students indicated that they enjoyed the instant exam feedback. Similar to the results shown in Tables 2 and 4, some students were very neutral about Möbius, and this was evident in comments like, "*it was fine*" or "*I am not sure what Möbius is.*" Some students were less satisfied and included general comments like "*I do not like it*" or "*nothing.*" It is hard to know if these comments were specific to the platform or the content on the exam. However, some students made specific comments about the interface, training, and receiving information on what are acceptable symbols or inputs, which are important to consider in optimizing the system.

Discussion

Online MATH 215 exams had been prepared in the older version, MapleTA, prior to the pandemic, but this was not operational. When the pandemic hit and we were faced with the distribution of thousands of paper-based

exams without in-person capacity, these exams were made available as quickly as possible. However, issues with student access and integrating the online invigilation system ProctorU caused multiple concerns, which required a move to the new version, Möbius.

The implementation of the examination platform Möbius has realized a number of benefits to students as well as the institution in the delivery of mathematics examinations. Although the FST needed an online exam solution that the current online AU exam platform could not provide prior to the onset of COVID-19, the pandemic accelerated this development as we faced serving over 2,000 students and close to 4,000 exams per year of paper-based exams. Implementing this system served students, increased accessibility, reduced student concerns, reduced administrative workloads, and resulted in cost savings. The savings in cost due to the automated marking capability will allow us to increase quality instructional time and interaction with students. Both the system and the increase in interaction will promote mathematical resilience in our learners. Also, we have reduced exam security issues through the ability to build random exam banks that will generate a unique exam for each attempt. This has an added benefit in supporting accommodations for students when take home exams are required for some students through the Accessibility Services office.

A number of requirements were identified for successful implementation of Möbius. **Commitment and collaboration** among a diverse team involving examinations staff, faculty and tutors, course production staff, academic leadership, IT, and DigitalEd was essential. Project management leadership and an agile workflow process was effective and well-received by participants.

> *"she has done an excellent job of managing the project that has a tight deadline and involves many groups and units (DigitalEd, academics, IT, student support, production team). The agile process that Patricia adopted works well in those necessary adjustments that have been made on how to proceed during the project."*

> *"The production team's dedication, diligence and collaboration are important to the success of Math215 project as well as the significant progress with Math244. It is amazing to see the team learn Möbius in such a short time."*

> *"The academics' passion and hard work are essential, as well as the support from the university and Dean."*

Implementing the platform requires an investment in ensuring competency. Möbius is a technical platform and there are requirements for using algorithms, producing content and assessments, using and managing the platform, and producing AU content in an effective and seamless interface. **Training** was necessary for all faculty and staff involved to ensure usability, integration, effectiveness, and administration.

> *"I appreciated the meetings and training. The team made a difference by meeting and sharing knowledge on Möbius."*

> *"There seems a bit of a learning curve for Möbius."*

Resources need to be considered in implementing Möbius. Möbius implementation required a significant amount of work on top of regular workloads. The development of random examination banks requires writing a large of number of exam questions that have to be tagged to units and learning outcomes. Workloads for course development and production staff, examinations staff, IT, and front-line staff involved in the project were also significant. Certainly, faculty and staff time in course development is very involved anyway, and so adapting Möbius as part of regular course development can be considered and does produce longevity in examinations and learning resources. For the implementation of MATH 215 exams, the FST provided additional financial resources to support the development of randomized exams, and the associated course development and production. However, the urgent move to Möbius meant a large amount of overtime was spent for all involved above and beyond already busy workloads. Comments on lessons learned were:

> *"Resources need to be allocated to develop a course properly."*

"Clearly defined roles in Möbius helped to prevent resource issues and throughput issues. Roles were defined on who does what in the process."

A significant amount of **support** from DigitalEd, the FST, and across AU was needed to implement Möbius. DigitalEd provided responsive support throughout the project, which was critical for users in navigation and functionality. A number of technical requests were accommodated by DigitalEd to make the platform functional for AU systems. DigitalEd provided training and facilitated access. Leadership from the Deputy Provost and IT was essential to set up the licenses and the LTI integration. The FST leadership planned the pilot, the outcomes, the survey, as well as the resourcing requirements. Participants remarked in the lessons learned on the importance of support:

"Team effort went well, team meetings, questions answered, and worked efficiently together."

"DigitalEd has been of great help to show/explain how Möbius works."

There are some **technical requirements** to use Möbius effectively with AU systems given our unique delivery model. The team had to work with DigitalEd to improve some functionality and adapt to AU processes. One issue that had to be resolved was fixing the Quit and Save button to prevent multiple grade reports. Others were creating a consistent theme, the scrolling function, integrating ProctorU, and adding functionality for exam reviews. In addition, there were technical aspects for consideration in the future such as designing for accessibility and the possibility of losing some LMS functionality in the Möbius environment. Some of these requirements and future considerations are highlighted below:

"Math 215 transition and communication was in limbo at times because of changing dates due to various factors such as ProctorU onboarding and formatting the exam."

"Course development team together from the beginning to ensure accessibility needs are met for the OER piece, requires testing by accessibility services on how content is read out (e.g., digits). Need to give thought to provide guidance to students in terms of instructions."

"AU able to take the information and adjust into processes. Happy to see the benefits. Quit & Save button can be removed if AU deems necessary."

The benefits to students and the operational efficiencies realized for faculty and staff are a major requirement for implementation. Möbius is effective when it is used in courses to **support student success and AU success**. Although the work involved is technical, Möbius allows for auto-marked, randomized, secure examinations in a seamless environment that can be integrated into Moodle and D2L. It also provides course content packs and interactivity that enable course development, reducing the reliance on learning resources for certain subjects. Moving MATH 215 exams resulted in immediate benefits to students. Access issues were resolved and student concerns around exams were eliminated. Front-line staff reported significant increases in efficiency and a significant reduction in administrative workloads. Faculty were relieved of having to administer login information and trouble shooting MapleTA exams. In addition, faculty have had fewer issues pertaining to exam security. Many of the comments from team members emphasized the success in student support and staff and faculty workloads:

"Exams are going well, less complaints and less technical issues."

"Math 215 exams are going well based on feedback from frontline members. There has been less stress for staff and students."

"Greatly reduced incidents coming into the exam unit regarding ProctorU issues. Stability of the system has significantly improved, creating an easier submission process for students taking Math 215 exams. No longer having to pre-authorize grades at the beginning."

We are now in the processing of expanding Möbius into MATH 265 and 266 Calculus I and II at AU as well as opening MATH 244 Business Mathematics as an entire course in Möbius. With continued support, training, and resources, we will continue to expand to other courses in STEM disciplines such as Physics, Astronomy, Chemistry, and Computing. As this system supports assessment in any discipline that uses mathematical formulas

and symbols, this would also be an effective platform for assessment in business, the health sciences, and some of the humanities. Finally, this is a system that will enhance educational resilience, while supporting operational efficiency and effectiveness.

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