Flexible Assessment in Math During (and After) COVID

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Abstract

In this paper, we describe the design and development of a formative assessment plan with a mastery-based grading approach, implemented in one college-level math course offered during the pandemic, to reimagine the purpose of assessment in transforming exams into learning experiences. A retrospective study of this implementation indicates that this assessment strategy has psychological and academic impacts on student achievement. It enhances student learning by changing the negative perceptions of failure on assessments into an opportunity for growth. The outcome of the study also demonstrates how different groups across the university work collaboratively to innovatively implement teaching and learning strategies with effective pedagogical practice to promote student success. The working model can be generally applied to varying disciplines to support educational transformation in the post-pandemic era.

Keywords: mastery learning, mastery-based grading, assessment, mathematics education

Background

The Impact of the coronavirus pandemic on higher education

Institutions of higher education and enrolled students experienced substantial difficulties last year due to the COVID-19 pandemic. In response to this crisis, the shift to online learning preserved academic continuity. While this transformation has been challenging, much has been learned from this experience that can guide educators to rethink teaching and learning through the exploration of new pedagogical strategies and philosophies to progress through unprecedented educational disruption.

The quick turn-round to an online mode of delivery raised many concerns about the quality of education being offered. For example, the use of conventional assessments with high-stakes examinations to test remote learners lacks the flexibility that frustrated both instructors and students during the pandemic (Fuller, et al., 2020). High stakes testing has also been questioned in regards to the limitations of reliability and stability in accurately assessing student learning (Knight, 2002; Zimmerman & Dibenedetto, 2008). These deficiencies still remain within the context of online examinations.

In facing the uncertainties of such a global pandemic, educators must consider alternative methods to address potential problems when evaluating learning and offer required assistance in accordance with the skill level of the students to promote their success. Instead of relying heavily on conventional assessment approaches, it is imperative for educators to reimagine teaching and learning experiences to employ exceptional pedagogical practices to advance education to the next level.

Learning Assessment during COVID-19

Online assessment in the time of COVID-19 is an example of why educators need to integrate new methodological and technological strategies to provide flexibility in evaluating student learning outcomes, while also transforming assessments into learning experiences.

The traditional summative assessments at this time were faced with challenges of transferring in-class exams into online quizzes. As students shifted to remote learning, there was a greater need for flexibility, understanding, trust, and compassion to keep them engaged amid the COVID-19 pandemic. However, maintaining a more conventional approach to assessment, with limited schedules and means for students to access and respond to the questions, lead many students to struggle with taking online examinations (Fuller, et al., 2020; Tuah & Naing, 2021).

The scores for these high-stakes tests were also criticized due to issues of validity and reliability in determining students' performance (Tuah & Naing, 2021). The performance-oriented assessments focused heavily on memorization, rather than critical thinking and overlooked individual student differences in learning styles, as well as their varying levels of test anxiety (Harsy, et at., 2020). Students' perceptions of these examinations affected their study behaviors, encouraged them to overemphasize the importance of exam scores, and even worse, caused cheating on the test. This further demonstrates the issue of academic integrity, which remains a worry of educational equity in remote education (Gamage, et al., 2020; Lanier, 2006).

The faculty at our university revealed similar concerns about using summative assessment with high-stakes examinations during the pandemic semester. Their feedback, in conjunction with the existing barriers for summative assessments, highlights a need for alternative options that concurrently evaluate how students are doing with remote education and provide assistance for individual difficulties to support their learning. Developing such an assessment strategy that truly reflects student achievement with an emphasis on student well-being, ensures the quality of assessment, as demonstrated by this case at our university during the COVID-19 pandemic. The working model provides flexible, humanistic, and practical approaches to enhance learning innovation and support the transformation of higher education in the post-pandemic era.

This paper explores a theory-based practice derived from mastery learning that allows students to choose their own "adventure" and master the topics progressively with scaffolded feedback in the Introduction to Linear Algebra and Differential Equations course. This strategy aligns with the principles of empathy, flexibility, pragmatism, and simplicity to provide multiple opportunities and ways of learning to accommodate different student needs in preparing for the semester amid the pandemic.

This experience shows a deep collaboration between experienced instructors, academic researchers, learning designers, and learning analytics specialists in assessing the effectiveness of such a mastery-based approach to instruction and assessment. Through a post-course survey and students' performance, we derived the academic implications of this strategy through data-driven results. The findings can also inform ongoing improvement of mastery-based assessment to ensure its effectiveness and sustainability.

Transformation Measure to Turn Exams into Learning Experiences

Mastery learning

Given the evidence found by previous studies and our faculty members' feedback, traditional summative assessments with high-stakes tests did not align with our educational goals to support and enhance student learning during the pandemic. Finding an alternative approach to design a new assessment plan became critical. We began with a theoretical basis for the purposes of teaching and learning, finding a student-centered educational strategy called mastery learning to design the assessment activities. The idea of mastery learning is not new to Western educational thinking and the mastery-based approaches also have been implemented in pedagogical settings for many years (Block & Burns, 1976; Guskey, 2010; Kulik, Kulik & Bangert-Drowns, 1990). John B. Carroll (1963) initiated the conceptual model of mastery learning based on the premise that students can achieve the desired level of mastery in a given subject with sufficient time to practice. Then, Benjamin Bloom (1968) carried on and transformed this concept into a working model to outline a number of specific steps to achieve a distinct level of mastery. Other educators continued refining and elaborating on Bloom's Learning for Mastery model to make it more systematic and practical (Block & Burns, 1976).

Mastery-based assessment

In mastery learning, the assessment attempts to address students' deficiencies of needed concepts and skills through regular formative tests and provides them opportunities to develop proficiency and confidence to achieve the desired level of mastery on the learning topics (Block & Burns,

1976; Guskey, 2010; Kulik, et al., 1990). To gain such an improvement in student performance, a mastery-based assessment includes pre-and post-tests, formative measures, corrective instruction, and enrichment activities to scaffold student learning (Guskey, 2010). A well-designed assessment plan based on mastery learning could minimize individual differences in their aptitude for the subject and provide assistance to equip each student with a confident command of the fundamental concepts to progressively master the learning content at their own pace (Block & Burns, 1976). This assessment type is individually based and permits multiple chances for testing to cater to individual needs to support student learning.

Self-perceptions of learning

The essential criterion of success in mastery learning is how much improvement individual students display. Mastery-based assessments can mitigate the risk of test anxiety and related test perceptions on a student's performance in summative measures, such as final examinations and other end-of-instruction tests (Block & Burns, 1976). For students with a fixed mindset, the failure of those performance-oriented exams infers that they are not smart enough to succeed and then they quickly give up (Boaler, 2013). Therefore, the use of high-stakes examinations could aggravate the notions of limited intelligence or fixed ability in learning. The assessment in mastery learning is not a one-shot or do-or-die test experience. It focuses more on the progress students make in learning (Block & Burns, 1976; Guskey, 2010; Kulik, et al., 1990). The opportunities to grow help students believe their knowledge or skills can be developed via learning (Boaler, 2013).

Motivational and academic supports

In addition to encouraging students in the learning process, mastery-based approaches to assessment and instruction also have motivational benefits for instructors in connection to increased responsibilities for students' learning outcomes and higher expectations for students' academic success. (Zimmerman & Dibenedetto, 2008). The progress students demonstrate makes instructors feel rewarded and are then more willing to contribute their time and effort to help pinpoint topics that students struggle with and provide personalized instruction to support their learning. Furthermore, previous studies have indicated that using mastery learning techniques has positive effects on student academic achievement (Block & Burns, 1976; Guskey, 2010; Kulik, et al., 1990). Given the mental and academic benefits of mastery learning, this pedagogical approach could help address the challenges we faced during the COVID-19 pandemic in assessing students' performance while also preparing for the change needed to transform higher education in the future.

A Mastery Learning Intervention in a Mathematics Course

At our institution, two experienced professors from the Department of Mathematics proposed to initiate a new assessment approach using a mastery-based grading system to replace high-stakes testing for their Introduction to Linear Algebra and Differential Equations course (see Appendix A for more detail). The original assessment of the course was mostly based on a few high-stakes tests, including three midterm exams (20% each) and one final exam (30%). The instructors attempted to replace the existing assessment model with mastery-based assessment approaches to enhance learning and reduce stress in students during the pandemic. They provided a series of low-stakes quizzes for each topic to allow students to practice and used a mastery-based grading

system to authentically evaluate student achievement. The design and development of this assessment model was fueled in the pursuit of an urgent need to ensure students were learning the requisite material while simultaneously maintaining student engagement, satisfaction, and access to quality assessment.

The new grading system, using more frequent low-stakes formative assessments with a mastery-based grading strategy, allows students to evaluate their own knowledge of learning topics and continue to progress toward proficiency to build the required math skills and understanding. Faculty engage students with performance feedback and provide assistance based on the students' level of understanding. This ongoing assessment and adaptation of support enabled both students and instructors to monitor progress and then the instructor was able to provide tailored feedback and scaffolds to help further learning. Scores in this model, unlike those of more traditional exams, serve multiple functions in communicating student performance. Scores provide motivation and feedback to students and guide faculty towards appropriate modifications to the course content and relevant instructional materials.

The implementation of this assessment plan adhered to the common essential feature of mastery learning, including clear learning goals and expectations, credit only for mastery, and multiple low-stakes tests to progressively reach mastery (Table 1). In this course, students took 13 quizzes, two take-home assignments, and one final reflectional quiz instead of midterm and final examinations. This low-stakes assessment strategy provided students with frequent opportunities to practice in order to develop and master the content. The professors graded student learning outcomes through a mastery-based grading system as opposed to a percentage grade of correct questions on each individual quiz. After each learning topic, students had six opportunities to demonstrate their understanding of the topic. They were required to achieve the desired level of mastery, which was at least four correct answers. Students could recognize earlier that they had a developing, but not proficient understanding of the objectives and the instructors offered extra instruction to scaffold students and then gave them additional opportunities to display mastery. This mastery-based grading technique was the assessment of learning objectives for each topic as a prerequisite for advancement.

Table 1
Summary of the mastery-based assessment method employed in the course

Low-Stakes Assessment	Mastery-Based Grading
• Based on frequent assessments with each counting less. • This course shifted to 13 quizzes, two take-home assignments, and a final reflective exam to make up 84% of the course grade. • Student effort is spread throughout the semester.	• Students had six different questions on each of 21 topics spread across at least three assessments during the semester. • They needed to get four questions right to have "mastery" of the topic. • Students received feedback after each quiz and then could improve for the next time they saw that topic.

Study Focus and Methodology

To examine the impact and perceptions on student success, retention, and satisfaction of the mastery-based assessment approach employed during the pandemic, we compared students' average GPA scores with the historical data from past course sections without a mastery-based approach to understand any changes in student academic achievement. We also surveyed the students and the instructors regarding their feedback on this course to explore the perceived impact of this assessment technique in order to answer the following research questions:

- Q1. What's the impact of the mastery-based grading approach with low-stakes assessments on student academic achievement in an undergraduate mathematics course during the pandemic semester?
- Q2. What were the perceptions of students regarding the use of low-stakes assessments and mastery-based grading approaches?

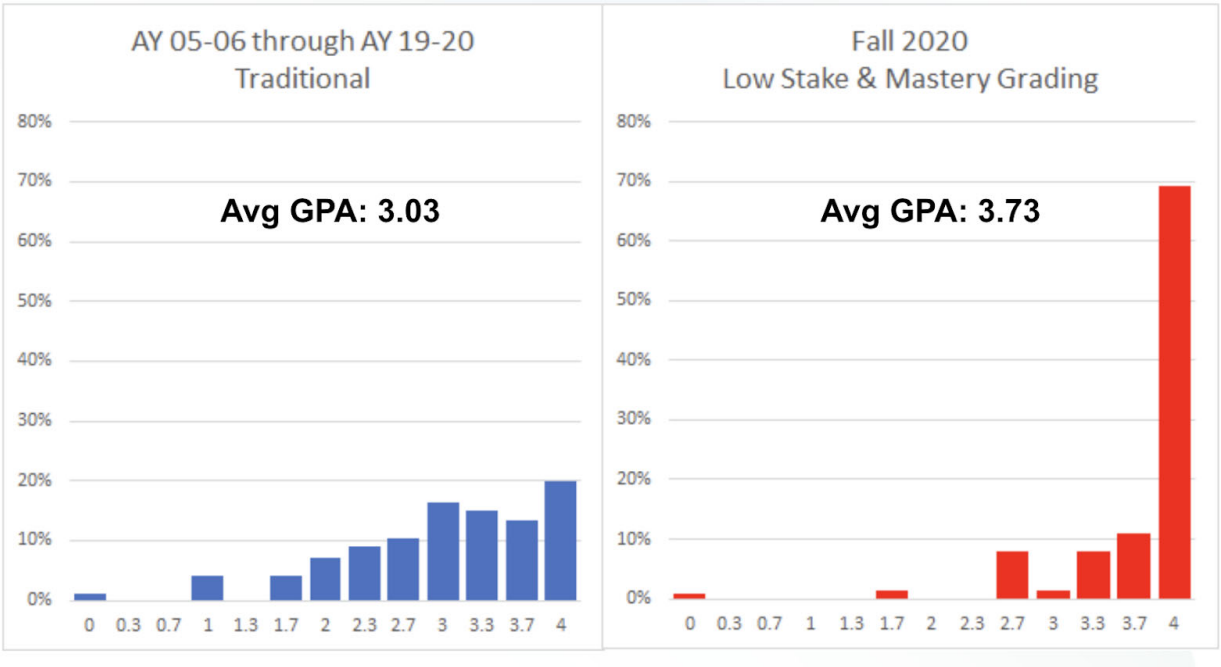
Results and Discussion

This mixed-method study was conducted to collect and analyse both quantitative and qualitative data to evaluate the impact of mastery-based grading with low-stakes assessments on student learning. We employed a descriptive statistics method to summarize the differences of the average GPAs between this course and past course sections without mastery-based assessment. The results help in showing whether this new assessment model could enhance student achievement. The data of the student survey and instructors' feedback were analyzed by experienced analysts to interpret the most common and overarching themes regarding both students' and instructors' experiences with this mastery-based assessment strategy to help understand the effectiveness of this approach from their perspectives. The main findings synthesized from both qualitative and quantitative data are presented in the following section.

Increased academic achievement

Based on the historical achievement comparison, the average GPA for the low-stakes and mastery grading class was higher than the previous courses, which used traditional summative assessment with high-stakes tests. When comparing cumulative GPA of the pandemic semester with the overall GPA of the same course from past semesters, the results (figure 1) show an improvement in students' academic achievement. The average GPA of fall 2020 (3.73) is 0.7 points greater than the average GPA (3.03) of the course from the past 14 years. This result echoes the argument from previous studies about the academic effect of mastery-based learning approaches on student achievement (Bloom, 1968, Block & Burns, 1976; Guskey, 2010; Kulik, et al., 1990).

Figure 1
Historical comparison of students' average GPAs of this course



Engaging learning experiences

To round out a thorough picture of the effects that mastery-based assessment strategies have had on student learning, we also analyzed student survey data to report the findings in more detail. We received a survey response rate of 41.91% (57/136). The findings revealed that students felt engaged with a mastery-based assessment approach. 97% of students considered this method to have had a positive impact on their learning (i.e., motivation, success, interest, confidence, fairness). 93% found it reduced stress, prevented procrastination, decreased test anxiety, and increased timely feedback. 79% reported they spent the same or more effort preparing for informative assessments as traditional high-stakes exams.

In addition, students studied more regularly in the semester and learned from their mistakes. For example, a student described this as follows: *"Getting questions wrong really is a chance to learn and improve, not just watch your grade drop."* The instructors also found students were more engaged and came to office hours more often and asked more questions outside of class. These findings were correlated to students' perceived usefulness of these assessment activities in the course in supporting their academic growth.

Implications (A Look at the Future)

The university was devoted to preventing coronavirus-related disruption for instructional continuity. The rapid shift to remote education challenged educators to maintain effective instruction using conventional pedagogical practices during the pandemic semester. For example, traditional summative assessment with high-stakes tests were criticized in regard to validity and

reliability in assessing learning performance while also increasing anxiety in learning, which hurt student mental health.

Given consideration of the issues with a traditional assessment model, the instructors adopted a mastery learning framework to redesign the assessment plan for the Introduction to Linear Algebra and Differential Equations course. They utilized (a) formative low-stakes assessments, (b) a mastery grading framework, (c) administered using take-home and proctored assignments, (d) and longer cumulative opportunities to create a flexible assessment model. The flexible assessment model asks students to master or fully understand the concept of assigned topics at their own pace before moving forward. This learner-centered practice opens up personalized learning paths and pace and allows educators to better scaffold individual needs to build teaching resilience amid a pandemic.

This paper discussed how this new pedagogical practice was developed and delivered to improve the flexibility in assessment. The follow-up study conducted by the faculty and learning specialists from the teaching and learning institute, indicated that this flexible assessment model has an impact on student success, and can inspire alternative pedagogical strategies to advance teaching and learning. We believe what we have done cannot just help the university to continue educating during the pandemic, but also promote learning innovation that supports the vision for the future of higher education.

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Appendix A

The Syllabus: Assignments and Grading Policies

This course uses a grading system developed based on Standards Based Grading. This will be graded in a way that is significantly different from other math classes you may have taken in the past. We have identified 21 skill sets (or standards) that we wish you to master by the end of the course. Standards based grading is that you just have to show mastery of these skills to get an A. This will be evaluated with weekly quizzes during TUTORIAL and a timed take-home midterm and a final examination. You will not receive credit as a percent grade. Rather each question will be evaluating a particular skill set. Each question on the quiz will be clearly marked which standard (skill) is being tested. If you do the problem and use the skill correctly then you get a point in that skill. (For fans of video games, think of it as levelling up your character and you need to level up each skill of that character). In order to show mastery of a skill, you will need to demonstrate successful use of the skill 4 times. You will get at least 6 opportunities to demonstrate each individual skill. The final will test each skill at least once. It is your final opportunity to demonstrate mastery.

There are 21 standards (skills) each worth up to 4 points and the homework is worth a total of 16 points.

- 88-100 pts A
- 67-87 pts B
- 47-66 pts C
- 26-46 pts D
- Below 25 F

+/- will be determined by the end of the semester. That means if you have a 90, that could be an A or an A- depending on the final.
** Note that failure to do homework and attend class can lower your final grade by as much as a full letter grade.

The Skills you will be acquiring in this course are as follows:

1. Use Gaussian Elimination to set up problem and express solution in parametric form
2. Be able to add, multiply, transpose matrices
3. Decide something is or is not a Linear Transformation and be able to construct Standard
4. Matrix
5. Understanding Linear Combinations and Linear Independence

6. Basis of Column Space & Basis of Null Space
7. Coordinates and the Change of Basis Matrix
8. Identify Vector Space and it's subspaces and then find its basis and dimension
9. Abstract Vector Space is or is not Linear Transformation
10. Find Coordinates for Abstract Vector Spaces and find basis for Kernel and Range.
11. Compute determinant and its properties.
12. Finding eigenvalue and basis for eigenspace.
13. Determine Diagonalizability
14. Use Gram-Schmidt to compute projections using orthogonal basis
15. Compute Least Square Solutions and use least square solutions to compute projections
16. Checking solutions and checking autonomous solutions
17. Solve Separable Equations and First Order Linear
18. Solve Exact and Almost-Exact
19. Be able to model systems with DifEq
20. Solve 2nd Order Constant Coefficient Homogeneous Differential Equations
21. Solve 2nd Order Non-Constant Coefficient Homogeneous Differential Equations
22. Solve 2nd Order Nonhomogeneous Differential Equations