Effectiveness of a Semi-Mastery-Based Learning Course Design

Dr. Galen I. Papkov, Florida Gulf Coast University

Dr. Galen Papkov is a Professor of Statistics at Florida Gulf Coast University where he founded the minor in statistics and currently serves as the Graduate Program Coordinator for the M.S. Program in Applied Mathematics. His collaborations have resulted in publications in engineering education, agriculture, and health sciences. Originally from New York, he earned his Ph.D. in Statistics from Rice University. Galen's research interests include experimental design, survey design and data analysis, nonparametric density estimation and inference, multivariate analysis, and regression modeling. His adventurous spirit led him to complete two marathons, earn a black belt in tae kwon do, and live in Zhuhai, China, for two years, where he taught statistics and improved his Mandarin-speaking skills.

Dr. Jiehong Liao, Florida Gulf Coast University

Dr. Jiehong Liao is an Assistant Professor of Bioengineering at Florida Gulf Coast University (FGCU). She earned a Ph.D. in Bioengineering from Rice University and a B.S. in Biomedical Engineering from Rensselaer Polytechnic Institute (RPI). Originally from Hawaii, her journey into academia began with the Rensselaer Medalist award and being selected into the inaugural class of Gates Millennium Scholars. Before joining FGCU, she was a visiting Assistant Professor of Biotechnology in the Division of Science and Technology at the United International College (UIC) in Zhuhai China. She has trained with ASCE's Excellence in Civil Engineering Education (ExCEEd) initiative, been exploring and applying evidence-based strategies for instruction, and is a proponent of Learning Assistants (LAs). Her scholarship of teaching and learning interests are in motivation and mindset, teamwork and collaboration, and learning through failure and reflection. Her bioengineering research interests and collaborations are in the areas of biomaterials, cellular microenvironments, and tissue engineering and regenerative medicine. She serves on leadership teams for the Whitaker Center of STEM Education and the Lucas Center for Faculty Development at FGCU, and is a member of the Biomedical Engineering Society (BMES) and the KEEN Engineering Unleashed Network as an Engineering Unleashed Fellow.

Investigating a Flipped-Mastery Design with a Hierarchical Letter Grade Structure

Abstract

A traditional course design, where the instructor sets the pace for the course, assumes all students learn at the same rate. A flipped mastery design gives students more ownership of their learning and allows for individualized pacing of the course content. This design was applied to a 16-week long course on Probability & Statistics, where students had some leeway with respect to the rate at which they learned content, and a hierarchical grading scheme was used to assign final letter grades according to how much material they covered and their level of proficiency. With greater autonomy, students frequently chose to learn more than they needed and an increase in the passing rate was observed.

Introduction

Course content is typically covered at the same pace for all students in a traditional group-based classroom; however, some students need more time to learn than others. The mastery learning approach allows for individual learners to progress at their own pace. It is based on the premise that most students can and will learn if given the time, and that both the teacher and the learner share responsibility for the desired learning (Anderson, 1975). In a review of mastery learning, Winget and Persky (2022) explain that mastery learning may result in better performance because it establishes an environment that supports motivation, offers regular opportunities for testing, and provides repeated feedback. The challenge is to find practical ways of implementing mastery learning, or incorporating aspects to support individual needs within a course, while covering required content within a set time span (e.g. semester), and devising a grading system that matches students' level of competence with flexibility to acknowledge those that go beyond expectations (Guskey, 2007).

In addition to time, students need practice and feedback to develop proficiency in skills and knowledge before assessments. A flipped classroom design shifts instruction out of the classroom so that class time can be utilized to actively engage students in practice with guidance, discussion, reflection, and feedback through interactions with peers and the instructor. Bergmann and Sams (2012) introduced the flipped mastery classroom as a way to make mastery learning feasible through a flipped classroom design. This model teaches students to take responsibility for their own learning, facilitates personalization and

differentiation with learning as the focus, and provides students with timely guidance and feedback. Although a learning management system populated with online learning materials and class time devoted to practice and feedback addresses the need to give students flexibility in time and space for learning, difficulties lie in the logistics of carrying out individual assessments and awarding grades that represent effort and proficiency. Deddeh et al. (2010) contrast traditional grading with standards-based grading, in which practice does not count against students but rather provides formative feedback, and that standards-based grading solely measures content mastery through summative assessments when students are ready.

The efforts reported in this paper are based on flipped mastery methods that align with the core beliefs stated in the article "Eight Steps to Meaningful Grading" by Deddeh et al. (2010) that, a grade should communicate mastery of learning standards, homework is essential for learning but should not be included in the grade, and learning may take more than one attempt. With these guiding principles, faculty at a mid-size, primarily undergraduate institution, investigated the effectiveness of a flipped mastery design with a hierarchical letter grade scheme that rewarded those that went beyond the minimum amount of course content assigned. Learning analytics, data visualizations, and statistical analysis were used to answer the following questions:

1. Are students likely to stop learning once they achieve a passing grade for the course?
2. What motivates students to go beyond the minimum amount of course content?
3. Does a flipped-mastery approach with a hierarchical grading scheme result in superior passing rates compared to a more traditional course design?
4. How do students feel about the flexibility offered via a hierarchical grading scheme employed for covering different amounts of course content?

Methods

Sources of Data

Data were collected from a junior-level Probability & Statistics course with 18 students (11 F, 7 M) during the Fall 2023 term at a mid-size, primarily undergraduate institution. Specifically, quiz scores, dates when students attempted each quiz, and average homework scores for those that attempted the optional assignments administered via WebWork were recorded.

Comparisons were made using a data set obtained for the same course taught during the Fall 2022 term. This course was face-to-face, using the same materials, and taught by the same instructor in a more traditional manner. Eighteen students were also enrolled in this course, which covered the equivalent of Modules 1-6.

Course Design

The course was conducted over a 16-week semester and met twice a week for 105 minutes per session. Content was split into seven modules, where Modules 1-6 represented the typical content of the course. Module 7 is an add-on for further depth, whereas up through Module 5 is the basic minimum level of expected proficiency. A standards-based hierarchical grading scheme was employed such that students completing Modules 1-6 could earn the typical 'A-F' range of letter grades on a standard scoring scale. Students completing Modules 1-5 could only earn a maximum of a 'B' letter grade with scores in the 90s since they learned less than what is usually covered in the course. However, students completing Modules 1-7 could earn an 'A' even with a numerical score in the 80s because they covered more content than is normally taught. A grade of 'C' or better was required to pass the course. Modules had to be completed in chronological order, with up to three weeks allotted for each of Modules 1-4 and four weeks for Module 5. The time spent on each module is shown in Table 1 with the traditional schedule for comparison.

Table 1: Number of weeks spent on each module in a traditional 16-week, face-to-face course, compared to the flipped-mastery design. The last week is left for review in the traditional design.

Module	1	2	3	4	5	6	7
Flexible	3	3	3	3	4	optional	
Traditional	2	2.5	2	2	3	3.5	None

Modules contained topic handouts with example problems, worksheets with additional practice problems, and were available on the Canvas learning management system. Each module contained 1-2 quizzes, 15-30 minutes long each, that were administered in class once the instructor was notified by the student at least 24-hours in advance of the next class meeting, that they were ready to take a quiz. Students taking a quiz were placed in a corner or on the side of the room, and were encouraged to wear ear plugs or head sets to minimize the chance of them hearing pertinent information being discussed with other students while they were sitting for a quiz. Once completed, quizzes were not returned until all students had attempted the quiz. There was no final exam. Instead, the scheduled final exam period was used as the last opportunity for students to attempt quizzes. Students were allowed to redo one quiz of their choice from among the first five modules. Quizzes for second attempts were of a comparable level of difficulty to the original quiz. Verbal feedback was given as soon as possible to those that did poorly on a quiz. Quizzes with written feedback were returned once all students had attempted it.

Additional resources to aid in student learning included the course text and optiona online homework assignments via WebWork. If a student's homework average was better than their quiz average, then their overall grade was a weighted average based on 80% of their quiz

average and 20% of their homework average. Otherwise, their overall grade was simply their quiz average. Letter grades were based on how much material a student covered and how well they learned the material per their overall grade. The rubric for assigning letter grades is provided in Table 2.

Table 2: Matrix used to assign letter grades based on how much material a student covered and how well they learned it.

		Average Performance				
		0-59	60-69	70-79	80-89	90-100
Modules Covered	1-5	F	F	D	C	B
	+6	F	D	C	B	A
	+7	D	C	B	A	A

Statistical Analysis

Statistical analyses were conducted at the 5% level of significance using R statistical software (R Core Team, 2021). Bootstrapped confidence intervals were used to compare male and female quiz performance to whether proficiency differed by gender. The binomial test was used to investigate if most students stop learning once they achieve a passing grade for the course. The passing rate for the flipped-mastery design was compared to that of the traditional design using the z-test for the difference of proportions to determine if students are more likely to be successful in the flipped-mastery design.

Results

Rate of Progress

In general, students would need to attempt quizzes faster if they wanted or needed to cover more modules. Higher-performing students tended to complete quizzes faster than lower-performing students. These trends can be seen in Table 3. None of the students that completed six modules received a B grade. Likewise, no students were assigned an F grade after finishing Module 7.

Table 3: Median number of classes between quiz attempts based on the number of modules completed and final letter grade. Two classes is equivalent to one week.

	F	C	B	A
5 Modules	6	6.5	6	NA
6 Modules	5	5.5	ND	4
7 Modules	ND	5	4.5	4

No students received a grade of D.
ND = no data

Pursuing Mastery

While the design allowed for students to progress somewhat at their own pace, it did not require that they actually achieve proficiency or mastery in each module before moving on to the subsequent module. Per Table 4, three modules had a median quiz performance below the traditional benchmark of 70%.

Table 4: Median performance on quizzes by module. The last column reports the percentage of students that achieved an average quiz score worthy of being deemed as being proficient in the material for that module.

	# Complete	Median	% Achieved Proficiency
Module 1	18	80.0	72.2
Module 2	18	85.0	83.3
Module 3	18	80.0	77.8
Module 4	18	67.5	44.4
Module 5	18	55.6	44.4
Module 6	14	61.2	42.9
Module 7	6	77.5	66.7

Modules 6 and 7 were optional.

Benefit of a Quiz Redo

Thirteen students chose to redo a quiz. Most of them (11 of 13, 85%) selected a quiz they did incredibly poor on (i.e. below 50%). The distribution of quizzes chosen to be redone is shown in Figure 1. The median improvement was 67.5 points (IQR=42.5). Among the five students that did not take advantage of the opportunity to redo a quiz, two received a passing grade after Module 5 and were not motivated to try to improve their letter grade, two were high-performing students that did not need to redo any quiz, and one was low-performing and gave up on trying to pass early on, but never withdrew from the course.

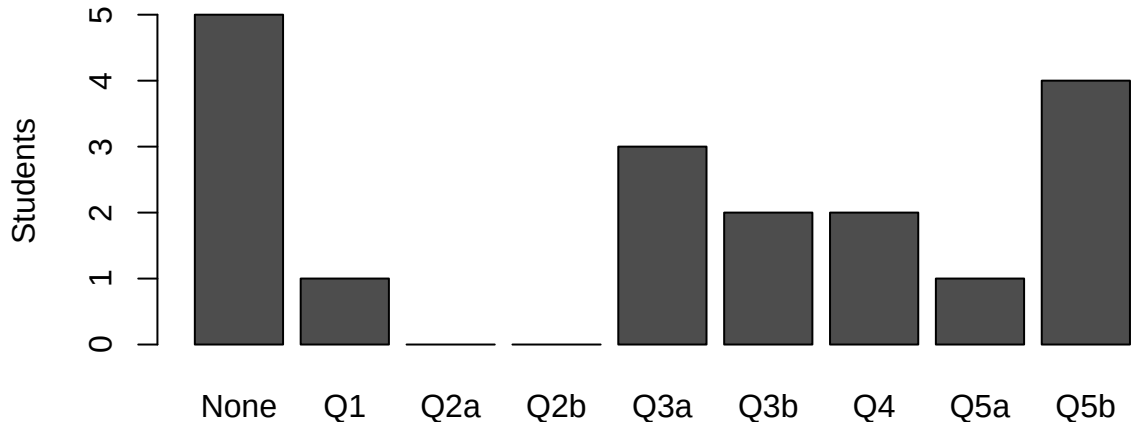

Figure 1: Distribution of quizzes selected by students to be attempted a second time. Five students chose not to improve any of their quizzes.

No significant difference was found in quiz performance between genders. This was based on 95% confidence intervals for the difference of median performance between males and females, generated from 5,000 bootstrapped samples for each quiz shown in Figure 2.

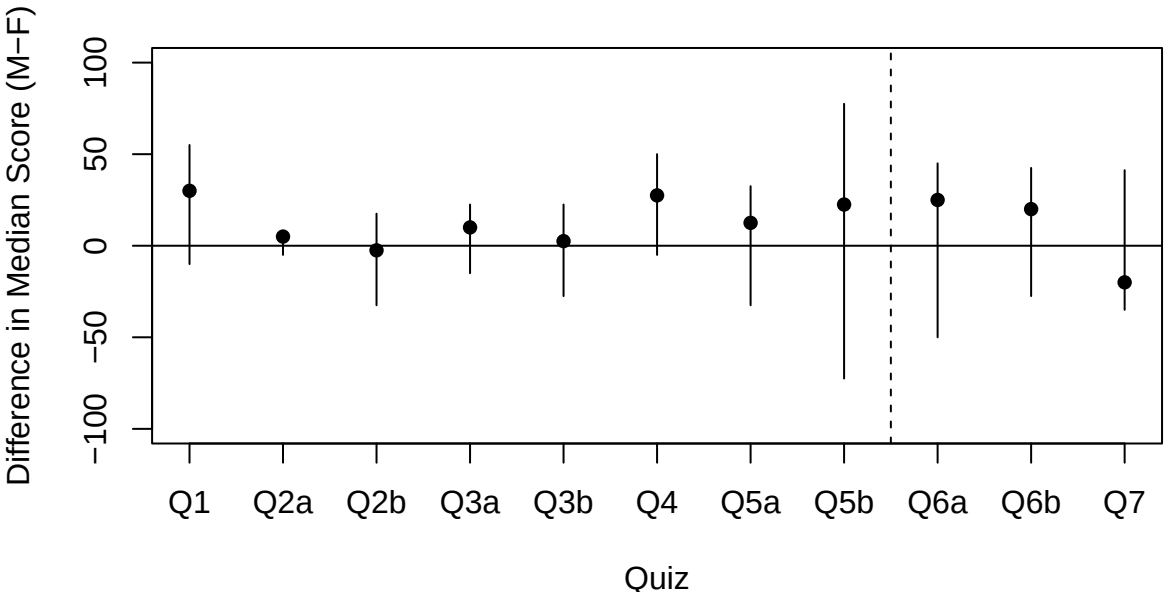

Figure 2: Bootstrapped 95% confidence intervals, based on 5,000 samples, for the difference in median performance between 7 males (M) and 11 females (F) on each quiz in Modules 1-5. Quizzes after the dashed vertical line were in optional Modules 6 and 7. Fourteen students (9 F, 5 M) completed the quizzes for Module 6 and six students (4 F, 2 M) also took the quiz for Module 7.

Paths to Completing the Course

Based on the design of the course, there were a number of ways a student might go about passing the course with a 'C' or better. They could be passing after completing the first five modules, choose to stop learning, and receive a passing grade. Or they might opt to continue learning, and likely receive a passing grade later. Students that are not passing after the first five modules may choose to quit or continue trying to pass by completing optional modules. Figure 3 depicts the pathways and indicates how many students took each path.

After completing the first five modules, seven (39%) students were passing. One student disliked the way the course was designed and gave up early, remaining enrolled in the course and accepting a failing grade. The remaining 10 students continued onto Module 6, joined by four students that already had a numerically-passing grade. The other three students that were passing after Module 5 opted to stop and receive their passing grade. Per the binomial test, this was not a significant majority ($p=0.7734$).

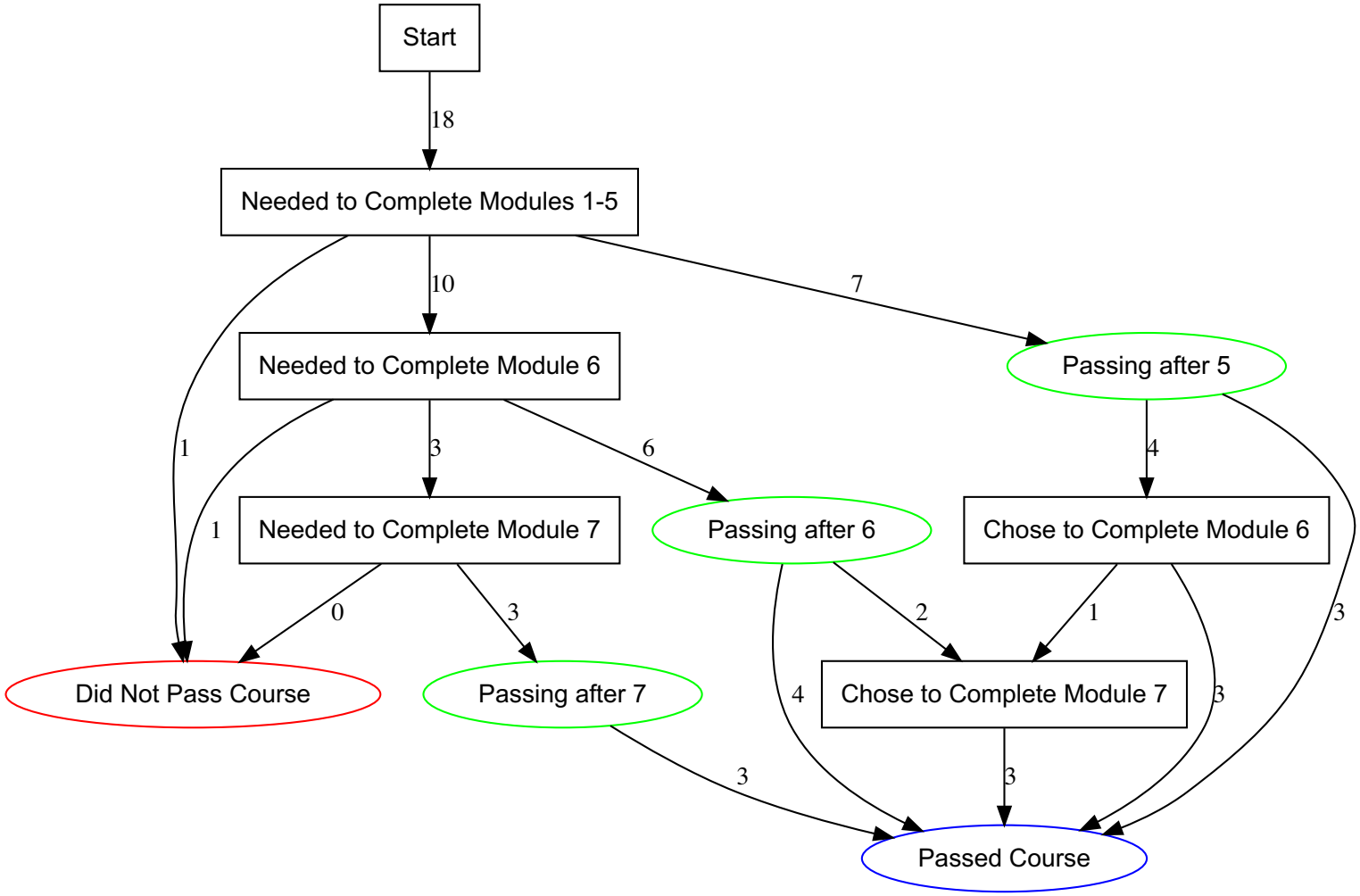

Figure 3: Flow chart depicting the number of students that took each path. The branches to the left of the green ovals correspond to students that had yet to achieve a passing overall grade. The section to the right of the green ovals represent students that achieved a passing grade and either stopped or continued learning.

Passing Rate

Students in the Fall 2022 course covered the equivalent of Modules 1-6, with traditional face-to-face instruction. The passing rate of 89% for the Fall 2023 section was not statistically greater than the passing rate of 78% for the Fall 2022 section (Z=0.89, p=0.1855).

Survey Results

All 18 students responded to the end-of-semester survey. While five students said the course design enabled them to ask lots of questions, retain information better, or feel less pressure than a traditional design, 56% still preferred in-person instruction. Seven students (39%) appreciated the course design enough that they would want other courses conducted the same way. Many students waited until the last day to finish quizzes in a module. So, it was not surprising that a third of the class felt rushed to do one or both of the optional modules. Based on feedback from the entire class, 56% felt that Modules 1 and 2 could be completed in two weeks each, allowing for more time on Module 5 (per 50% of respondents) and more time to do at least one optional module. In terms of how to improve the course, the most popular suggestions were to post more thorough solutions to problems on Canvas, provide videos, incorporate lectures either once a week, a brief review/summary at the start of each class, or a thorough review the class before a quiz. These suggestions came from no more than 22% of the class. A few mentioned removing the online homework; however, most students attempted some of the homework problems and eight students (44%) performed well enough to have it boost their final overall grade. Although about 67% of students regularly attended class sessions (as opposed to only showing up for quizzes), only one student mentioned incentivizing attendance.

Discussion

Students nowadays seem to strive for a passing grade, rather than pursuing the best grade possible. Because of this mentality, it was surprising to see more than half (57%) of the students continue learning after qualifying for a passing grade once they finished Module 5. While this percentage was not a significant majority, it suggests that, when given greater ownership of their learning, students may be likely to go beyond the minimum. Thus, there is no evidence that students will seek to pass a course by acquiring the minimum amount of knowledge required.

As for why students covered more than the required five modules, ten students (56%) had to in order to achieve a passing grade. Three others chose to cover more material in order to pursue an 'A' letter grade. The current end-of-semester survey did not inquire whether students would have stopped after five modules if they had been passing, but this might be a useful question to incorporate in a future study. Alternatively, it could be informative to have students rate their motivation for going further in order to distinguish whether their motivation is due to their passion for learning as opposed to their desire for a better grade.

Whatever their motivation, students were more successful at passing the course with the flipped mastery design with a hierarchical grading scheme than those enrolled in the in-person instruction course the previous fall term. About 89% passed compared to 78% the prior year. The 11-percentage point difference is encouraging, but not statistically significant.

In the end-of-semester survey, more than half of the class requested a return to a traditional classroom format. No follow-up survey was given to these students to investigate why they desired a more traditional format. About a third appreciated the novel course design, recognizing that it allowed them to progress at a more comfortable pace, ask as many questions as they want, learn collaboratively with peers, and experience less stress than they do in more traditionally-run courses. Unfortunately, these comments came predominantly from high-performing students, most of whom achieved an 'A' in the course. To improve the student experience, the following ideas should be implemented:

1. Emphasize to students that Modules 1-5 constitute *less* material than is historically covered and that is why a 'B' is the highest grade possible after completing these modules.
2. Provide more structure to improve student accountability and aid in student learning outside the classroom.
3. Scaffold learning resources to provide a more mastery-based design.
4. Set a quiz threshold, such as 70%, to ensure students are at least *proficient* prior to moving on to material for the next quiz.

There are a number of reasons for the suggestions above. The first item is because a handful of students felt it was unfair that the best grade they could receive after doing the minimum number of modules was a 'B'. Emphasizing the rationale behind the letter-grade matrix should alleviate any frustration felt by students who think it is unfair that they need to do Module 6 to be graded on a standard grading scale. The second item should increase the effectiveness of a flipped classroom. It was apparent throughout the semester that virtually all of the students that came to class regularly, did not attempt to learn the material in advance. They used class time to study, review the textbook, ask questions of the instructor, learning assistant, or peers, and collaborate with others on solving problems on the white board. While the latter two aspects met the vision of the course design, the fact that students were not trying to learn course content outside the classroom was disheartening. This indicates that more structure is needed to hold students accountable for their learning and better resources should be provided for students to adhere to a flipped class model. Videos would better enable students to learn content, or at least develop a familiarity, prior to class meetings. Another resource would be example problems with thorough solutions. Students were able to view solutions during class meetings, but posting solutions to the examples on the topic handouts would give students another avenue for developing their understanding. Incorporating these solutions and videos in a scaffolded manner would abide more faithfully to a mastery-based learning design. For example, students may read the topic handout and study the example

problems and solutions, take an assessment, and be allowed to progress if they demonstrate proficiency (70%). If they are not proficient, then they would be assigned lesson videos and online homework next, followed by a second attempt at the assessment. If a third attempt is needed, students must meet with the instructor or Learning Assistant for 1-on-1 study sessions before taking the assessment.

Allowing students to somewhat learn at their own pace appears to have its benefits. Students have plenty of time to ask questions and are often inclined to demonstrate active learning by forming small groups and solving problems in class. Furthermore, the hierarchical grading scale provides more pathways for students to successfully pass a course. Educators interested in using this mixed course design should consider the suggestions mentioned above in order to more effectively run a flipped classroom and ensure proficiency, if not mastery, is achieved by all across all attempted modules.

References

Anderson, L. W. (1975). Major assumptions of mastery learning. In *Annual Meeting of the Southeast Psychological Association*.

Bergmann, J. and Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Flipped Learning Series. International Society for Technology in Education.

Deddeh, H., Main, E., and Fulkerson, S. (2010). Eight steps to meaningful grading. *The Phi Delta Kappan*, 91:53–58.

Guskey, T. (2007). Closing achievement gaps: Revisiting benjamin s. bloom's "learning for mastery". *Journal of Advanced Academics*, 19(1):8–31.

R Core Team (2021). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Winget, M. and Persky, A. (2022). A practical review of mastery learning. *American Journal of Pharmaceutical Education*, 86:8906.