RESEARCH ARTICLE

Assessment of Mock Exam Utility: A Correlative and Comparative Study in a Pharmaceutical Calculations Course

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Objective. Faculty at MCPHS University's School of Pharmacy, Worcester/Manchester are engaged in continuous quality improvement of their teaching and assessment methods to prepare students for successful careers in pharmacy. This study evaluated the impact of a formative mock exam on student performance in an actual summative exam (Exam) administered during the spring 2020 semester of a pharmaceutical calculations course.

Methods. A retrospective analysis of student test scores in a summative assessment (Exam) was performed across two cohort years (2019 and 2020) where students were not administered and administered a formative mock exam, respectively. Central tendency and comparative analysis measures were performed to assess differences in student performance.

Results. Out of 237 students enrolled, 221 students participated in the optional mock exam and all 237 students participated in the Exam, with average scores for the mock exam and the Exam being 67% and 94%, respectively. Ninety-two students who received grade C or better on their mock exam had an Exam average score (98%) that was significantly higher than those who received a D or F (n=129, 92%); and the average score in 2020 Exam was significantly higher when compared to the 2019 Exam where no mock exam was offered (94% versus 77%).

Conclusion. This was a descriptive, cross-sectional study to understand the differences in student performance in a summative assessment across two cohort years with and without a formative mock assessment. The results demonstrated an association of the formative mock exam with better performance among students, without establishing a causal relationship.

Keywords: mock exam, formative assessment, testing familiarization, pharmacy, pharmaceutical calculations

INTRODUCTION

The School of Pharmacy – Worcester/Manchester (SOP-W/M) at the Massachusetts College of Pharmacy and Health Sciences (MCPHS) University prepares students for successful careers in pharmacy through a 34-month accelerated Doctor of Pharmacy (PharmD) curriculum. The curriculum is divided into three academic terms (fall, spring, and summer) during the first two years of professional pharmacy training, whereas the third and final year is dedicated to Advanced Pharmacy Practice Experiential (APPE) training. The Pharmaceutical Calculations course (PSW 312 Pharmaceutics II) is a foundational science course that is offered to students during their first academic spring term (January to April), over a 15-week period. The course design relies on students' background knowledge in college-level mathematics (arithmetic and calculus) as foundational principles for accurately performing calculations across a range of pharmaceutical/pharmacy concepts, including but not limited to calculation of medication/dosage form to be dispensed, calculation of ingredients for compounding, altering of drug product concentration/strength, and conversion of doses and units of measurements. Assessment of student performance in the course is determined through three midterm summative assessments/exams and a final cumulative exam.

Successful completion of mathematics principles that are taught in courses such as math, computer science, calculus, and statistics are pre-requisites for admission into the PharmD program.¹ However, students matriculating into the program demonstrate different levels of knowledge and proficiencies in these foundational mathematic principles, which impact their level of understanding and performance in the pharmaceutical calculations course. Additionally, poor study skills, internalized fears of mathematics and mathematics-related subjects, insufficient opportunities for practicing exam-type problem-solving, and the potential lack of familiarity with an exam format could contribute to poor student performance in pharmaceutical calculations.²⁻⁵ Faculty at SOP-W/M are engaged in continuous quality improvement of their teaching and assessment methods to improve exam preparedness and enhance academic success. Thus, upon careful review and analysis of past student performances in the first midterm summative assessment, hereafter referred to as Exam (with the class averaging 70 - 75%, compared to the second and third midterm assessments with average class scores of 90 - 95% each), the course instructor proposed the introduction of a mock exam as a supplement to other formative assessment methods (eg, in-class quizzes, dedicated sessions for practicing problem-solving, and homework assignments with multiple attempts allowed). for improving students' learning, testing familiarity, and performance. This intervention was also informed in part by student feedback from prior years about how the exam format differed from what students encountered during in-class practice sessions and homework assignments. The purpose of the mock exam, therefore, was to provide students with familiarity with the exam format to best prepare them for the Exam. Due to the ethical challenge of administering the mock exam ("intervention") to only a subset of the class, participation in the mock exam was open to all students enrolled in the PSW 312 Pharmaceutics II spring 2020 course; administering the "intervention" to a select group of students as would have been done in a randomized controlled study could potentially enhance the academic performance and progression of one group to the detriment of the other. The mock exam was designed to closely recapitulate an actual exam in number of questions, level of difficulty, duration of exam, exam platform, physical space, and proctoring methods. The mock exam was optional and not included in the course grade, with students being under no obligation to participate.

Formative assessment tools are essential for enhancing student learning by reinforcing and improving retention of important concepts.⁶ Formative assessments such as mock exams, can be used as summative assessment preparation tools, helping to improve student performance, with their impact augmented the more closely the formative assessment (mock exam) parallels the summative assessment (actual exam).⁷⁻⁸ Additionally, formative assessment opportunities can help students identify areas for improvement, as well as provide insight into how questions on an exam would be structured.⁹ Whereas mock exams have been shown to be effective for improving student performance on application-based and short-essay exams, the role of mock exams in improving students' exam preparedness and performance in pharmaceutical calculations has not been demonstrated.¹⁰ Our working hypothesis was that the administration of a mock exam that simulates an actual exam format would facilitate students' familiarity with test-taking to the end of enhancing their exam preparedness by clarifying expectations and identifying areas for improvement, ultimately improving their learning and exam performance. Importantly, demonstrating the effectiveness of mock exams would provide inferential evidence in support of the efforts towards effective quality improvement in teaching, learning, and student performance assessment. This study retrospectively evaluated the impact of a mock exam on student performance in an actual exam during the spring 2020 term. The study also compared student performance in an exam taken with a mock exam component (2020) versus a similar exam without a mock exam component (2019). The results of this study provide logical evidence of the potential usefulness of mock exams in improving student learning, exam preparedness, and overall performance and competency in pharmaceutical calculations.

METHODS

This was a retrospective observational study that reviewed student test scores in a pharmaceutical calculations course at SOP-W/M, and examined the impact of a formative mock exam on student performance in a summative Exam. The PSW 312 Pharmaceuticals II course offered in spring 2019 consisted of a summative assessment (Exam) that was only preceded by in-class exercise and quizzes, and homework assignments as formative assessments. In spring 2020, an optional mock exam was introduced as a supplemental formative assessment. The mock exam was designed to simulate the Exam in number of questions, level of difficulty, duration, and topical content, and exam-delivery and exam-taking conditions. Both exams were administered as closed-book, proctored assessment. The expectation was that the mock exam would serve as a prospective exam review tool to help familiarize and clarify the exam format for students, as well as identify their content and topical areas of weakness, so they could refine their study habits and test taking strategies, and to best prepare and improve their performance. The mock exam and Exam each consisted of sixteen calculation-type, multiple-choice questions, with the mock exam being administered the day prior to the Exam. The questions in the mock exam and actual Exam while different in content were similar in format and topical selection. Both assessments were administered via the electronic-testing/computer-based ExamSoft platform (ExamSoft Worldwide LLC, Dallas, TX) with a testing duration of 55 minutes. The complete mock exam file was released to all students immediately following the mock exam. The mock exam file contained all sixteen questions with the correct answers selected, but without the worked solutions. The file showed the students' scores as well as other central tendencies including the mean, median, and class percentile. Although the mock exam score did not count towards a student's final grade, scores from the mock exam and the Exam were collected and analyzed. Data analysis was performed using Microsoft/Office 365 Excel v16.0 (Microsoft Corporation, Redmond, WV). Central tendency measures (mean/average, median, and range) and comparative statistics (p value and Pearson correlation coefficient) were calculated. An average test score was calculated for both exams and compared using a t -test. The p value was calculated and considered to be significant if $p < 0.05$ (CI = 95%). To assess if the mock exam was associated with any changes in performance, the Exam averages between 2019 and 2020 were compared.

The retrospective nature of the study did not allow for the collection of participant demographic information as would have been done in a prospectively designed study. We recognized the potential impact of a number of confounding factors in participant demographics regarding the study outcomes; for example, age, gender, type of college attended for pre-requisite course credits (eg, four-year university vs two-year community college), previous degree earned (bachelors vs associates), when pre-requisite courses were taken (math and science course must be taken no more than ten years to the time of matriculation), etc. However, we considered both cohorts to be generally comparable based on their meeting the same pass grade requirements (grade C or better) for three math-related admission pre-requisites (eg, calculus, statistics, and math/computer science). On the same basis, we considered students who participated in the mock exam ($n=221$) vs those who did not ($n=16$) within the 2020 cohort as generally similar and comparable. This research project was approved under an exempt status by the Massachusetts College of Pharmacy and Health Sciences University Institutional Review Board (IRB121020A). All the students who were enrolled in the course and participated in the mock exam were included in the study. There were no exclusion criteria.

RESULTS

Out of 237 students enrolled in PSW 312 Pharmaceuticals II course during the spring 2020 semester, 221 (93%) students took the optional mock exam that was administered the day before the Exam. As the Exam was mandatory and counted towards the students' final grade, all students participated in the Exam. The mock exam average score was 67%, and the Exam average score was 94% (Table 1).

Ninety-two students (42%) who received a passing grade (letter grade C or better) on their mock exam had an Exam average score that was significantly higher than those who received a failing grade (letter grade D or F) on their mock exam ($p < .001$) (Table 2). There was a moderate anti-correlation (Pearson correlation, $r = -0.65$)¹¹ between mock exam and the Exam scores, with the number of students with strong performance (grade B or better) skewing higher in the Exam (92%) compared to the mock exam (30%) (Table 2, Fig 1).

When student exam scores were stratified by letter grades, there was about an eight-fold increase in the percentage of students with letter grade A (defined as an exam score of 90-100%) in the Exam compared to the mock exam (78% vs 10%). Overall, individual student performance was higher in the Exam compared to the mock exam (Table 3). A significant number (69.7%) of students outperformed their mock exam grades (Table 3). A total of twenty-five students (11.3%) did not see any grade change between their mock exam and the Exam (A, $n = 20$ [8.4%]; B, $n = 3$ [1.3%], and D, $n = 2$ [0.8%]). Only one student who participated in the mock exam underperformed in the Exam. Of the

16 students who did not participate in the mock exam, 15 (94%) had a grade C or higher in the Exam while one student received a failing grade.

The spring 2019 PSW 312 Pharmaceuticals II course had 215 students enrolled. All students enrolled in the spring 2019 course participated in the Exam, which was not preceded by a mock exam. The Exam average scores for spring 2020 were significantly higher compared to the spring 2019 Exam average scores (94 versus 77%, $p < .001$) (Table 4). In order to determine how student performance was sustained after the first exam, we compared student performance in the subsequent summative assessment between the 2019 and 2020 cohorts. The 2019 cohort performed nominally better on exams 2 ($95.07\% \pm 8.47$) and 3 ($95.80\% \pm 8.79$), and the final cumulative exam ($72.90\% \pm 15.38$) compared to the 2020 cohort ($92.38\% \pm 10.90$; $90.91\% \pm 11.98$; and $72.01\% \pm 15.80$ respectively). However, an objective comparison between the cohorts for these exams is complicated by the disruption caused by the COVID-19 pandemic which occurred just before these three exams were administered. Unlike 2019 where all teaching and exams were offered in-person and on-campus, in 2020, only exam 1 reflected the same conditions of teaching and assessment.

DISCUSSION

This study provides some logical basis to infer - due to its observational, non-interventional design - that the administration of a mock exam prior to an actual exam may be associated with (but not necessarily be the *cause* of) improved exam performance for students enrolled in a pharmaceutical calculations course. The hypothesis of the study was that the administration of a mock exam with the chief goal of facilitating testing familiarity would improve exam preparedness for students by clarifying expectations and identifying areas for improvement, and thus help improve student grades. The theoretical framework of our working hypothesis is best captured by the concept of “test-wiseness”, which as defined by Millman et al. as “a subject’s capacity to utilize the characteristics and formats of the test and/or the *test-taking situation* to receive a higher score.”¹² Millman et al. also described test-wiseness as “logically independent of the examinee’s knowledge of the subject matter for which the items are supposedly measured.”¹² Central to our understanding of test-wiseness is the fact that the cause of a student’s poor performance in a test may not be due to the lack of knowledge of the core subject matter; as there may be a number other factors (e.g. time management and testing anxiety) besides the intended variable the students is being tested on that could affect their performance.^{2,4} The goal of the mock exam, therefore, was to simulate a *test-taking situation* which would otherwise not be fully addressed by any of the other formative assessment methods (e.g. repeated self-testing, quizzes, classroom test, and assignments).¹³⁻¹⁷ This simulated *test-taking situation* adds another skillset to the students’ test competency that is not only intellectual (knowledge-based), but also very experiential down to their emotive and psychological state, which makes this concept more novel in its application.

A majority (93%) of the students enrolled in the 2020 Pharmaceutical Calculations course participated in the mock exam as a practice test tool for the Exam. The students who performed better on the mock exam (received a grade C or higher) had a significantly higher Exam average score than those who received a grade D or F on the mock exam. The findings in this study correlate with findings in studies using other forms of formative assessments involving Doctor of Pharmacy curriculum courses.¹⁸⁻²⁰ A retrospective study conducted by Stewart et al., (2014) found that 76 out of 79 pharmacy students (> 96% of the class) used the opportunity to self-test, and demonstrated a correlation between student performance on self-testing practice quizzes and subsequent examination scores.¹⁹ Ultimately, the results in this study align with studies on student self-testing in other disciplines (pathophysiology, pharmacokinetics, and clinical pharmacokinetics), which underscored the impact of formative assessment methods (eg, pre-exam quizzes, student self-assessment, and immediate feedback assessment) in improving student learning outcomes.¹⁹⁻²¹

There was a moderate anti-correlation ($r = -0.65$) between the mock exam and Exam scores, where the number of students with strong performance (grade B or better) skewed higher in the Exam (92%) compared to the mock exam (30%). The significance of this statistic is in its reinforcement of the observation that students who had underperformed in the mock exam did much better in the Exam. In quantitative terms, the improvement in student performance in the 2020 cohort was significant when compared to the 2019 cohort ($p < .001$). It is worth noting that most students who did not participate in the mock exam performed well in the actual exam. We speculated that the overall strong performance demonstrated by the students who did not participate in the mock exam may be attributed to this group of students being made up of those who felt adequately prepared for the Exam, and presumed they would not gain additional benefit from a practice opportunity. It is also possible that these non-participants in the mock exam were either confident in their high-performing abilities, relied on other self-testing tools, or did not consider the stakes high enough in participating in the mock exam. However, because the complete exam file was released to all students after the mock exam, it is also possible that these non-participants still benefitted from their own informal self-test, howbeit, without the constraints of the mock exam environment. Indeed, metadata from the exam platform showed that all students had accessed the exam file.

Overall, the strength of the study rests on the weight of data from the 221 students who participated in the mock exam, which provided a large sample size for appropriate analyses to be performed with high confidence (CI = 95%). This allowed for appropriate inferences to be made on the potential impact of the mock exam as a form of formative assessment on student performance in the Pharmaceutical Calculations course. These data support previous findings demonstrating the benefits of pre-exam assessments on overall student performance.^{9, 22-25} Another potential strength of the study was the timing of the mock exam. Because students may tend to wait until an exam is imminent before preparing, the scheduling of the mock exam a day before the actual exam ensured that the results of the mock exam were as accurate an indicator of the level of students' preparedness as possible. Taken together, the results underline how a nominal addition to the teaching and assessment design of a Pharmaceutical Calculations course in the form of a mock examination resulted in a real and positive impact on learning and student performance.

Several limitations were identified with this study. First, this was a retrospective observational study which lacked randomized and controlled study measures. However, while the 2019 Exam assessment data was not representative of the same student population as in 2020, it does serve as a useful quasi-control group, as the student population demographics at the macro level and Exam design were similar. It is worth noting that we relied on historic student exam data from 2015 to 2019 showing that the central tendency measures (mean and median) in the exam was consistently in the range of 70 - 75% (e.g., grade C) from year to year, thereby, serving as a useful baseline to predict future student performance. We relied on this evidentiary assumption as a useful internal control to allow for comparisons between groups. However, we are of the opinion that a thoughtfully designed prospective study that accounts for additional participant variables (eg, age, gender, degree earned, grades on math-related pre-requisites, etc.) would enhance the study goals and serve to further strengthen the study's conclusions. Finally, while the COVID-19 pandemic is an important confounder for many recent studies, it did not present any limitation to the comparative analyses of data from the 2020 cohort. This is because both spring 2020 assessments (mock and actual exams) were administered prior to the COVID-19 shutdown (January 29, 2020 and January 30, 2020 respectively).

Future studies could benefit from a multi-institutional and multi-program design (e.g. accelerated [2 + 3-year] vs regular curriculum [2 + 4-year]) that utilize other student variables (e.g. age, gender, degree earned, grades on math-related pre-requisites) in order to address how these variables may affect student performance in both mock (formative) and actual (summative) exams. Additionally, a study design that allows for a greater time interval (at least one week) between exams would add rigor to the data by clarifying expectations and facilitating students' retention of content, and also allow for the monitoring of students' emotive and psychological state at two independent time points. Finally, inclusion of a survey questionnaire as part of the study design that assesses students' perspectives about the content and format of the tested materials (e.g. number of questions, appropriateness of questions, level of difficulty, test duration) would yield data that would be useful in reinforcing the study results and provide valuable feedback for quality improvement of future assessments and studies.

CONCLUSION

For students enrolled in the spring 2020 Pharmaceutical Calculations/PSW 312 Pharmaceuticals II course, the administration of a mock exam as a form of formative assessment prior to the actual exam served as an opportunity in facilitating students' understanding of the scope of the exam in order that they may self-assess their level of preparedness. Within the many limits that retrospective, observational (non-interventional) studies such as the current study present, the study results provide logical evidence of the potential usefulness of formative mock assessments in reinforcing learning and improving performance. While a prospective, randomized controlled design may not be ethically appropriate for such studies, we hope that more studies focused on this specific type of formative assessment would provide sufficient evidentiary bases to support a pedagogical framework for the thoughtful design of mock assessments to facilitate student learning and self-assessment, and help improve academic performance in Pharmaceutical Calculations courses.

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Figure 1. When stratifying student exam scores by letter grades, the Pearson correlation coefficient analysis of the association between mock exam and Exam grades showed a strong anticorrelation between students with grade B or better in mock exam vs Exam.

Table 1. Grades and Scores Earned by Students on the Mock Exam and Exam

	Mock Exam (n=221)	Exam (n=237)
Scores		
Average score, %	67	94
Median score, %	69	100
Letter Grades Earned by Students Determined by Score, n (%)		
Grade A (<i>Scores 90-100</i>)	21 (9.50) ⁺	184 (77.64)
Grade B (<i>Scores 80-89</i>)	45 (20.36) ⁺	35 (14.77)
Grade C (<i>Scores 70-79</i>)	26 (11.76) ⁺	6 (2.53)
Grade D (<i>Scores 60-69</i>)	63 (28.51) ⁺	10 (4.22)
Grade F (<i>Scores <60</i>)	66 (29.86) ⁺	2 (0.84)
Not Available	16 (6.75)*	0 (0)

⁺ Percentage of letter grade scores were calculated based on the total number of students who participated in the mock exam (n=221).

*16 students did not take the optional mock exam. Percentage of non-participants in the mock exam was calculated as a portion of the total course enrollment (n=237).

Note: The sum total of percentage grade scores for the Exam is 101 due to rounding error.

Table 2. Comparison of ^aExam Statistics Between Students Who Passed and Students Who Did Not Pass the Mock Exam, and ^bvice versa

^a Statistic	Passed Mock Exam (Grade C or Better)	Did Not Pass Mock Exam (Grade D or F)
Number of students, n	92	129
Average Exam score, %	98	92
Median Exam score, %	100	94
Range of Exam Scores	81 - 100	56 - 100
<i>p</i> value	< 0.001	
^b Statistic	Passed Exam (Grade C or Better)	Did Not Pass Exam (Grade D or F)
Number of students, n	224	11
Average Mock Exam score, %	68	48
Median Mock Exam score, %	69	56
Range of Mock Exam Scores	6 - 100	13 - 69
<i>p</i> value	< 0.001	

Table 3. Change in Letter Grade Earned by Students in Exam Compared to Baseline Mock Exam Grade

Mock Exam Grade	Exam Grade	N	%
A	A	20	8.4
B	A	42	17.7
C	A	25	10.5
D	A	49	20.7
F	A	38	16.0
DNP	A	10	4.2
Group Total		184	77.6
A	B	0	0.0
B	B	3	1.3
C	B	1	0.4
D	B	10	4.2
F	B	16	6.8
DNP	B	4	1.7
Group Total		34	14.3
A	C	0	0.0
B	C	0	0.0
C	C	0	0.0
D	C	2	0.8
F	C	4	1.7
DNP	C	1	0.4
Group Total		7	3.0
A	D	0	0.0
B	D	0	0.0
C	D	0	0.0
D	D	2	0.8
F	D	8	3.4
DNP	D	0	0.0
Group Total		10	4.2
A	F	0	0.0
B	F	0	0.0
C	F	0	0.0
D	F	1	0.4
F	F	0	0.0
DNP	F	1	0.4
Group Total		2	0.8
Class Total		237	100

DNP: Denotes students who *did not participate* in the mock exam.

Grade scores were calculated based on the total number of students who participated in both exams (n = 237).

Table 4. Comparison of Exam Average Scores between Spring 2020 and Spring 2019

	Spring 2020 (n=237)	Spring 2019 (n=215)
Average Exam score, %	94	77
Median Exam score, %	100	77
Range of Exam scores	56 – 100	15 - 100
<i>p</i> value	< .001	

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