Test-enhanced learning in a pharmacy therapeutics course

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Abstract

Objective: To confirm the effect of test-enhanced learning in pharmacy students and to assess students' perceptions of additional graded tests in a therapeutics course.

Methods: The number of graded tests were increased from two to four in a pharmacy therapeutics course during 2017. The authors compared the median score change from the first to the last test between the 2016 and 2017 student cohorts. The 2017 cohort was surveyed to determine student perceptions of additional graded tests.

Results: The median test score increased significantly from the first to the last test in the 2017 cohort (84.0% vs 76.9%; $p<0.0001$), but not in the 2016 cohort (76.7% vs 76.3%; p=0.95). Students reported improved time management skills and reduced levels of stress and test anxiety with a greater number of tests.

Conclusions: Increasing the number of graded tests from two to four in a pharmacy therapeutics course may enhance academic performance, improve time management skills, and reduce stress and test anxiety.

Keywords: *Test-Enhanced Learning, Pharmacy Education, Time Management, Perceived Stress*

Introduction

Learning associated with test-taking has gained interest among health professions education (Schuwirth & Van der Vleuten, 2011; Schuwirth, Valentine & Dilena, 2017). Within this context, learning results from the process of information retrieval, which increases recall, retention, and knowledge transfer (Wheeler *et al.*, 2003, Green *et al.,* 2018). In addition to this direct effect, tests can indirectly enhance learning by positively influencing study habits (Newble & Jaeger, 1983). These effects are described as 'test-enhanced learning' (Larsen, 2013).

Test-enhanced learning has been clearly demonstrated in health professions education (Larsen *et al.,* 2009; Larsen *et al.,* 2013; Hernick, 2015; Raupach *et al.*, 2016; Spreckelsen & Juenger, 2017). In one pharmacy education study, online modules with self-test questions were offered to students in an infectious disease pharmacology/medicinal chemistry course (Hernick, 2015). Student performance on module questions increased with repeated attempts and module performance predicted summative test performance. However, the number of module attempts did not correlate with exam performance. A recent systematic review, which included only controlled studies that compared test-enhanced learning with studying the same material or a different test-enhanced learning strategy,

reported that tests improve recall and retention as well as transfer of knowledge and skills (Green, Moeller & Spak, 2018). In addition, the effect of test-enhanced learning was consistent and robust across different health professions, learner levels, and learning outcomes extending to clinical applications (Green, Moeller & Spak, 2018). One study included in this review compared the number of tests administered with learning outcomes (Ali, 2014). In this particular study, three non-graded tests increased short-term knowledge retention compared with one non-graded test, however long-term knowledge retention was not significantly different (Ali, 2014). Despite this lack of association reported between the number of test attempts and performance, a prior study had demonstrated the positive effect of repeat self-testing on summative test performance in pharmacy students (Shin *et al*., 2018). Based on these data as a whole, the authors of the systematic review recommend educators incorporate test-enhanced learning within health professions education curricula (Green *et al.,* 2018).

Within the health professions education literature, only non-graded self-tests have been studied as mechanisms for test-enhanced learning (Larsen *et al*., 2009; Larsen *et al.,* 2013; Ali, 2014; Hernick, 2015; Raupach *et al*., 2016; Spreckelsen & Juenger, 2017). High-stakes, graded tests may also promote test-enhanced learning. Compared

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with non-graded tests (*i.e.*, self-tests), students may be more motivated to complete and prepare for graded tests, providing additional opportunities for feedback. More frequent graded, high-stakes exams may also help students manage their time more efficiently. Time management is particularly important since cramming for tests reduces knowledge retention and spacing tests benefits student learning compared to consecutive testing (Bahrick, 1992; Cepeda *et al.*, 2006; Custers, 2010). Finally, additional graded tests may provide course directors with more data on student academic performance to assess for competency.

Conversely, additional graded tests may increase stress and negatively influence student well-being. Poor mental health among pharmacy students has been well-documented (Marshall *et al.*, 2008; Beall *et al.*, 2015). In a survey of 3rd year pharmacy students, the mean mental health-related quality of life score of pharmacy students was about ten points below the United States (US) mean score for individuals of similar age. Importantly, tests were identified as a stress trigger in this study (Marshall *et al.*, 2008). In another survey study of pharmacy students, test anxiety was positively correlated with course load (Sansgiry & Sail, 2006). Since additional graded tests are likely to increase course workload, the level of student test anxiety and stress may also increase.

With this in mind, the authors sought to determine the effect of more frequent, high-stakes exams on test performance and self-reported student well-being. Within the University of California San Francisco (UCSF) Doctor of Pharmacy curriculum, four Therapeutics courses (*i.e.*, Therapeutics I-IV) are required. Starting in 2017, Therapeutics II, which is offered to second year pharmacy students during the Spring quarter, increased the number of graded written tests from two to four. The authors compared the median score change from the first to the last test between students who took the course in 2016 (control group) and 2017 (experimental group). The authors also surveyed the 2017 cohort about their perceived stress, test anxiety, time management skills, and preference for four verses two graded written tests.

Methods

This prospective study was declared to be exempt from full review by the UCSF Institutional Review Board.

Overview of the Therapeutics II course

Therapeutics II is part of a four-year Doctor of Pharmacy programme offered by the UCSF. As in many Doctor of Pharmacy programmes in the US, this is a professional degree programme with the first three years focusing on didactic education and the final year on experiential training. Therapeutics II is a ten-week required course that discusses the treatment and management of common cardiovascular diseases such as hyperlipidemia, venous thromboembolism, and heart failure (Table I). Since 2014, this course has employed a flipped classroom model; prior to each class, students are required to review a pre-recorded lecture and take an ungraded, online quiz. Time spent in class focuses on discussion of patient cases.

In both 2016 and 2017, topics covered, class time allotted for each topic, and class format were identical. In addition, with the exception of heart failure, each topic was taught by an identical instructor in both years.

Graded written tests

In 2016, UCSF offered two graded written tests during week five and week eleven (Table I). Each three-hour test had four-six cases and primarily consisted of multiple-choice questions. The authors offered a test review 20 days after the midterm test and immediately after the final test.

Table I: Comparison of Graded Written Tests between 2016 and 2017

2016					2017				
Name	**Week number**	**New topics covered***	**Test composition**	**Total course grade (%)**	**Name**	**Week number**	**New topics covered**	**Test composition**	**Total course grade (%)**
Midterm	Week 5	Dyslipidemia, DM, HTN, VTE, anticoagulation reversal	6 cases; 25 Qs with 5 SAQs	35	Test 1	Week 3	Dyslipidemia, DM, HTN	4 cases; 25 Qs with 2 SAQs	15.6
					Test 2	Week 5	VTE, anticoagulation reversal	4 cases; 19 Qs with 3 SAQs	17.9
Final	Week 11	Stroke, CAD, HF, arrhythmias	4 cases; 26 Qs with 5 SAQs	40	Test 3	Week 8	Stroke, CAD	3 cases; 19 Qs with 2 SAQs	21.1
					Test 4	Week 11	HF, arrhythmias	3 case; 22 Qs with 2 SAQs	23.4

*: all tests were cumulative except for the first test in each year.

DM=diabetes mellitus;   HTN=hypertension;   CAD=coronary artery disease;   HF=heart failure;   Qs=questions;   SAQs=short-answer questions.

In 2017, UCSF increased the number of graded written tests from two to four. A written test was administered every two-three weeks to allow adequate time for study. Each two-hour test included three-four cases and was made up of 19-25 questions that were primarily multiple-choice. A test review was offered immediately after each test to increase the effect of test feedback on learning (Wojcikowski & Kirk, 2013).

In both years, all written tests were cumulative. As a result, the second and fourth tests in 2017 had coverage of topics which were identical to those covered on the midterm and final tests in 2016, respectively. All patient cases on the test in both years included at least four co-morbidities and five medications. Tests were administered using the computer-based software Examsoft (Examsoft, Boca Raton, FL). Although test questions were not identical, the cases and questions were similar in type, style, and level of difficulty in both years.

Calculation of written test scores

In both 2016 and 2017, the maximum score a student could achieve on each test was 100%. The authors calculated the student's test score using the following formula: The total points that the student actually earned $\times$ 100 $\div$ the maximum points that could be earned.

Survey Methods

All students enrolled in Therapeutics II in 2017 were invited to participate in an online survey via Qualtrics (Qualtrics, Provo, UT, USA). Although the surveys were not anonymous, students were informed that the course director would not be able to access the survey data until responses were de-identified. The authors surveyed the 2017 cohort at the start and end of the Therapeutics II course. Prior to this course, students had taken a therapeutics course (Therapeutics I) that included two graded, written, cumulative tests. Each survey contained between two-eight items (see Appendix A). Both surveys included items that asked whether students followed a study plan or procrastinated before a written test during the two therapeutics courses. In the second survey, the authors included additional survey items assessing perceptions and preferences for four graded tests.

Statistical analysis

The authors used descriptive statistics to determine frequency distributions, percentage distributions, means, standard deviations, and inclusive ranges as appropriate.

Chi-squared, Fisher's exact, and Wilcoxon rank sum tests were used to compare baseline characteristics between 2016 and 2017 cohorts where appropriate. The authors used McNemar test to compare the proportion of students who reported cramming before a written test and those who reported following a study plan between Therapeutics I and II in 2017. Since test scores were not normally distributed, the Wilcoxon signed test was used

to compare the median score change from the first to the last test in each cohort. Since differences in baseline characteristics, such as grades and average written test scores in Therapeutics I, may confound the score change from the first and the last test, the authors used multivariable linear regression analysis. In this analysis, the score change from the first to the last test was treated as the dependent variable, and the cohort (2016 vs. 2017) as the main predictor of the score change. In addition, the authors added the following potential confounders to a multivariable linear regression model: grades, average score of graded tests in Therapeutics I, and sex. Since the grade of the Therapeutics I course was made up of two graded written tests (*i.e.*, midterm and final tests), quizzes, and an oral test score, the authors considered both grades and average score of two graded written tests in these analyses.

The Spearman correlation coefficient was calculated to assess a correlation between the score change from the first to the last test and changes in the level of time management, stress, or test anxiety. In addition, the authors divided students into three groups (improvement, no change, and worsening) according to the change in reported time management, stress, and test anxiety. The median score change between these three groups was compared by using the Kruskal-Wallis test. The authors used SAS 9.3 (SAS Institute, Cary, NC, USA) and considered a *p*-value < 0.05 as statistically significant.

Table II: Comparison of Characteristics between 2016 and 2017 Cohorts Taking Therapeutics II

Item	2016 (n=124)	2017 (n=119)*	*p*-value
Male (%)	37 (29.8)	42 (35.3)	0.82
Students repeating the course (%)	4 (3.2)	2 (1.7)	0.56
Median average score of written tests in Therapeutics I*	80.2 (72.8-85.8)	83.9 (78.6-88.0)	0.002
Therapeutics I grade (%)†			0.40
A	11 (9.1)	5 (4.3)	
B	53 (43.8)	60 (51.3)	
C	37 (30.6)	37 (31.6)	
D	18 (14.9)	12 (10.3)	
F	2 (1.7)	3 (2.6)	

*: data are expressed as median (interquartile range)

†: A total of 121 students took Therapeutics I in 2016 and a total of 117 students took Therapeutics I in 2017.

Results

Comparison of written test scores in Therapeutics II between the 2016 and 2017 cohorts

There were 124 and 119 students enrolled in Therapeutics II in 2016 and 2017, respectively (Table II). Although the overall distribution of Therapeutics I grades was not significantly different between the cohorts (p=0.40), the median average score of two written tests in Therapeutics I was 3.7 points higher in the 2017 cohort than in the 2016 cohort (p=0.002).

Figure 1: Changes in median test scores of Therapeutics II over time in the 2016 and 2017 cohorts
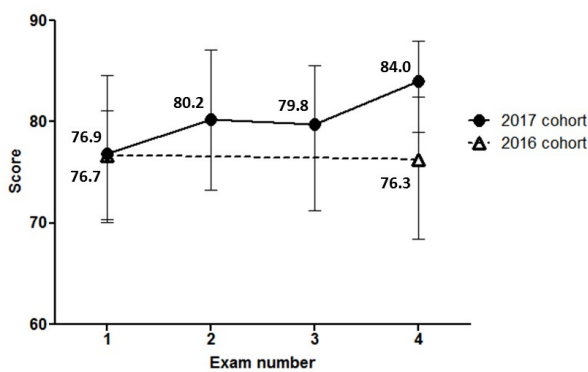
The empty triangle represents median test scores in the 2016 cohort and the filled circles indicate median test scores in the 2017 cohort. Bars represent the interquartile range. While the median score of the last final test was not significantly different from that of the first test (p=0.95) in the 2016 cohort, the median test scores of the 2017 cohort increased significantly over time (p<0.0001).

Table III: Percent of students reporting studying as planned and cramming before a written test at least once during a Therapeutics course

Item	Percent of students		*p*-value
	TPX I	**TPX II**	
Studied learning materials as I planned (%)			0.004
Strongly disagree	3.6	1.8	
Disagree	24.6	10.0	
Neutral	34.6	19.1	
Agree	30.0	49.1	
Strongly Agree	7.3	20.0	
Crammed before a written examination at least once (%)	46.6	29.1	0.001

Abbreviations: TPX, Therapeutics.

Table IV: Students' perceptions of having four examinations compared with two examinations

Item	Number of students (%)
Helpful aspects of having four exams	
Adjust my study strategy early in the course	87 (79.1)
Additional opportunities to recover	87 (79.1)
Stay on track of study materials	101 (91.8)
Retain knowledge longer	99 (90.0)
More confidence in application	86 (78.2)
Fairer test	77 (70.0)
Other	6 (5.5)
Unhelpful aspects of having four exams	
Reduce time to study for the other courses	55 (50.0)
Harder to keep track of study materials	7 (6.4)
Stay on track of learning materials	0 (0)
Decrease time for relaxation and social gathering	62 (56.4)
Increase academic workload	66 (60.0)
Reduce ability to retain knowledge longer	3 (2.7)
Other	7 (6.4)
How did four examinations change your level of stress?	
Improved substantially	54 (49.1)
Improved slightly	36 (32.7)
No Change	6 (4.6)
Worsened slightly	13 (11.8)
Worsened substantially	2 (1.8)
How did four examinations change your level of test anxiety?	
Improved substantially	54 (49.1)
Improved slightly	42 (38.2)
No Change	10 (9.1)
Worsened slightly	3 (2.7)
Worsened substantially	1 (0.9)
How did four examinations change your time management skills?	
Improved substantially	73 (66.3)
Improved slightly	25 (22.7)
No Change	7 (6.4)
Worsened slightly	3 (2.7)
Worsened substantially	2 (1.8)
I prefer more than two examinations in a Therapeutics course	
Strongly disagree	3 (2.7)
Disagree	1 (0.9)
Neutral	4 (3.6)
Agree	24 (21.8)
Strongly Agree	78 (70.9)

In both cohorts, the first test score in Therapeutics II was comparable (median 76.7% in 2016 and 76.9% in 2017; Figure 1). In the 2016 cohort, the median score of the last final test was not significantly different from that of the first test (p=0.95). In contrast, the median test scores of the 2017 cohort increased significantly over time (84.0% on the last test vs. 76.9% on the first test; p<0.0001).

In multivariable linear regression analysis, the cohort was the only variable that was significantly associated with the score change (parameter estimate, 5.4; p=0.0005). None of the other variables (*i.e.*, grades, average score of two written tests in Therapeutic I, and sex) were significantly associated with the score change.

Surveys in the 2017 cohort

One hundred and ten students completed both the pre-course and post-course surveys in the 2017 cohort (response rate: 91.6%). By the end of this course, a greater proportion of students reported following a study plan compared to responses at the beginning of the course (p=0.004; Table III). In addition, there was a significant reduction in the percentage of the students who reported cramming within two days before a written test at the end of this course (46.6% vs. 29.1%; p=0.001). More than 90% of respondents reported that four written tests helped them stay on track with study materials and retain their knowledge for a longer time (Table IV). On the other hand, at least 50% of students reported increased academic workload and decreased time for relaxation and social gatherings with four written tests. Over 80% of students reported improvements in stress, test anxiety, and time management skills with the increased number of tests and more than 90% of respondents preferred having more than two written tests.

Test score change and survey responses

The median score change was not statistically significantly correlated with test cramming, changes in the level of time management, stress, or test anxiety (data not shown).

Discussion

There were two main findings observed by this study. First, compared with the 2016 cohort (*i.e.*, historical control) who received two graded written tests in a therapeutics course, students who took four written tests showed a significant increase in median test scores over time. This finding was confirmed by the multivariable linear regression analysis. Second, students overwhelmingly preferred having more than two tests in a pharmacy therapeutics course and reported improved time management skills and reduced levels of stress and test anxiety with more tests.

Previous studies demonstrating test-enhanced learning in health professions education have used only non-graded tests (Bahrick, 1992; Cepeda *et al*., 2006; Custers, 2010;

Beall *et al*., 2015; Ali, 2014; Shin *et al*., 2018). In contrast, this study used graded tests. Specifically, in this study, four graded written tests significantly increased the median test score by more than seven points from the first to the last test, whereas two graded written tests did not result in a significant median score change. This finding may suggest test-enhanced learning with graded tests in pharmacy education, which is consistent with results of a study in undergraduate psychology students using graded tests (Leming, 2002). Since there is no direct comparison on student learning between non-graded and graded tests, however, it is unclear whether grading a test significantly influences student learning compared with a non-graded test. It may be worthwhile to evaluate the effects of both non-graded and graded tests on short-term and long-term student academic performance in future studies. In the meantime, pharmacy educators may choose to enhance student learning by considering advantages and disadvantages of implementing graded or non-graded tests in a course. Whereas non-graded tests may be easier to implement, not all students may take full advantage of this learning opportunity. In contrast, graded tests can motivate student participation and preparation.

The improvement in student academic performance associated with four graded written tests, but not two tests, suggests that frequent graded tests may be an effective learning tool. However, it is unknown how frequently graded tests may be administered to maximise test-enhanced learning, while maintaining a reasonable workload and preserving spaced practice. Other considerations include: rearranging course schedules, creating new test questions, and implementing a quicker turnaround for grading results.

Perhaps unsurprisingly, students in this study identified an increase in academic workload and a reduction in time for relaxation and social gatherings with additional graded tests. To help students manage increased academic workload, the schedule of tests and homework may need to be coordinated between courses. In addition to increased workload, pharmacy educators should consider timing of feedback and types of cases and questions on the test when planning to implement additional graded tests for test-enhanced learning. Since test-enhanced learning aims to prepare students for subsequent tests, timing of feedback on the test performance is important (Wojcikowski & Kirk, 2013). In this study, the authors implemented a test review immediately after each test in 2017. The feedback from the test review may have influenced student performance on subsequent tests. Another consideration is the types of test questions. Test-enhanced learning is maximised when short answer and context rich multiple-choice questions are employed (McConnell *et al*., 2015). The authors used complex patient cases designed to assess critical thinking and problem-solving skills *via* primarily multiple-choice questions.

Whereas previous studies on test-enhanced learning in health professions education focused only on student academic performance, this study also examined

students' perceptions and preferences with additional tests (Larsen, Butler & Roediger, 2009; Larsen, Butler & Roediger, 2013; Ali, 2014; Hernick, 2015; Raupach *et al.*, 2016; Spreckelsen & Juenger, 2017). In this study, having four graded tests improved perceived time management skills in about 90% of students and was associated with a reduction in reported cramming. In addition, the proportion of students who followed a study plan nearly doubled during Therapeutics II (69.1% vs. 37.3%) and over 90% reported that having four graded tests was helpful in staying on track with study materials. It was also found that increasing the number of tests positively influenced self-reported stress and test anxiety despite the increased academic workload. These results suggest that administering more graded written tests may not only improve time management skills but also decrease stress and test anxiety. Students also reported a preference for more than two written tests in a pharmacy therapeutics course. These data are in contrast to the results of previous studies reporting an association of an increased academic workload with an increased level of perceived stress and test anxiety in pharmacy students (Sansgiry & Sail, 2006; Marshall *et al.*, 2008). The previous studies were designed to identify factors contributing to stress and test anxiety in the context of the overall pharmacy curriculum. On the other hand, this study specifically assessed the influence of the number of graded tests on the level of stress and test anxiety. In this study, students may have felt less stressful and anxious about a test because they were given feedback, had more opportunities to influence their grade, and became comfortable with the format and style of tests. Since this study focused on stress and test anxiety in one course, future studies should address how an increased number of graded tests influences level of stress and test anxiety within the overall curriculum.

The authors found that there was no statistically significant correlation between the improvement in academic performance and change in the level of perceived stress, test anxiety, or time management skills. In addition, the median score change from the first to the last test in the 2017 cohort was not statistically different between those reporting improvement of, no change in, and worsening level of perceived stress, test anxiety, or time management skills. Since the course had six units and a large influence on their overall grade point average (GPA), students may have made efforts on the graded tests regardless of their levels of stress, test anxiety, or time management skills.

The authors acknowledge the following limitations in this study. First, a historical control was used instead of a concurrent control. While a concurrent control with two graded tests would have been ideal, academic equity could not have been guaranteed for both groups. Second, test questions differed between the 2016 and 2017 cohorts, which could have impacted test scores. Since two additional tests were administered in 2017, new test questions were created. In addition, the authors did not recycle test questions because of test security. However, types and difficulty of test questions were similar between the cohorts. Third, although differences in academic performance in Therapeutics I were considered in the linear regression analysis, the influence of the Therapeutics I course may have not been completely accounted for because the course used different tests and instructors between the cohorts. Fourth, the authors surveyed only the 2017 cohort because they administered two tests in 2016. This limited the ability to compare survey results between the cohorts. Fifth, the authors did not have a formal validation study on the survey questionnaire although two investigators (JS and KG) independently reviewed and discussed the questionnaire for clarify. Finally, this survey relied on students' reports on their perceived changes in levels of stress, test anxiety, and time management skills instead of assessing these outcomes through more objective means.

In conclusion, the data may suggest test-enhanced learning with more than two graded written tests in a pharmacy therapeutics course. Specifically, increasing the number of graded tests from two to four in a therapeutic course may enhance student academic performance. In addition, these findings suggest that an increased number of graded written tests in a therapeutics course may improve time management skills, while reducing stress and test anxiety.

Acknowledgement

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Appendix A

Survey Instruments

Survey 1

1. During Therapeutics I, I studied learning materials as I had planned.

   ○ Strongly disagree (1)

   ○ Disagree (2)

   ○ Neutral (3)

   ○ Agree (4)

   ○ Strongly agree (5)

2. Because of difficulty in studying learning materials as I planned, I had to cram my studying within 2 days before a formal written test at least once during Therapeutics I.

   ○ Yes (1)

   ○ No (2)

Survey 2

1. During Therapeutics II, I studied learning materials as I had planned.

   ○ Strongly disagree (1)

   ○ Disagree (2)

   ○ Neutral (3)

   ○ Agree (4)

   ○ Strongly agree (5)

2. Because of difficulty in studying learning materials as I planned, I had to cram my studying within 2 days before a formal written test at least once during Therapeutics II.

   ○ Yes (1)

   ○ No (2)

3. Compared with having two formal written tests in Therapeutics I, how did having 4 formal written tests in Therapeutics II change your time management skills, if at all?

   ○ Improved substantially (1)

   ○ Improved slightly (2)

   ○ No change (3)

   ○ Worsened slightly (4)

   ○ Worsened substantially (5)

4. Compared with having two formal written tests in Therapeutics I, how did having 4 formal written tests in Therapeutics II change your level of stress, if at all?

○ Improved substantially (1)

○ Improved slightly (2)

○ No change (3)

○ Worsened slightly (4)

○ Worsened substantially (5)

5. Compared with having two formal written tests in Therapeutics I, how did having 4 formal written tests in Therapeutics II change your level of test anxiety, if at all?

○ Improved substantially (1)

○ Improved slightly (2)

○ No change (3)

○ Worsened slightly (4)

○ Worsened substantially (5)

6. Compared with having 2 formal written tests, what aspects of having 4 tests did you find helpful?   Check all that apply.

☐ It allowed me to adjust my study strategies early in the course. (1)

☐ It provided me with additional opportunities to recover my previous suboptimal performance on an test. (2)

☐ It helped me stay on track of study materials. (3)

☐ It helped me retain my knowledge for a longer time. (4)

☐ It provided me with more confidence in my ability to apply learning to patient care. (5)

☐ It offered a fairer test of my overall performance in the course. (6)

☐ Other: please specify (7)_____

7. Compared with having 2 formal written tests, what aspects of having 4 tests did you find unhelpful?   Check all that apply.

☐ It reduced my time to study for the other courses. (1)

☐ It made it harder for me to keep track of study materials. (3)

☐ It decreased my time for relaxation and social gatherings. (4)

☐ It increased academic workload. (5)

☐ It reduced my ability to retain knowledge for a long time. (6)

☐ Other: please specify (7) _____

8. I prefer having <u>more than</u> 2 formal written tests in a Therapeutics course.

○ Strongly agree. (1)

○ Agree. (3)

○ Neutral. (5)

○ Disagree. (6)

○ Strongly disagree. (7)