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Research article

Use of Online Formative Quizzes to Enhance Long-Term Retention of Knowledge in Chiropractic Students

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Abstract

This study aimed to assess if online formative quizzes affect academic performance and retention. A total of 251 3rd-quarter students participated in the study across 4 consecutive iterations of a 3-credit class presenting immunology and endocrinology content. Each student was assigned to an immunology cohort (IC) or endocrinology cohort (EC). The students in IC were required to do weekly immunology quizzes while the students in EC were required to do endocrinology quizzes. Two topic-specific exams were given at the conclusion of each topic (immunology or endocrinology), the final exam was given at the end of the course, and the recall exam was given at beginning of the f 6^{th} quarter approximately 7 months after the final exam. Both the final exam and the recall exam equally covered those two topic areas. The mean scores of the immunology exam (37.59 vs. 35.77, $p < .001$) and the immunology part of the final exam (26.39 vs. 25.06, $p = .001$) in IC were statistically greater than those scores in EC. There were positive relationships between quiz participation rate and scores of the immunology exam and the final exam ($p < .05$). The correct answer rates of the recall exam in both cohorts were lower than 65%. An average of the quiz scores was a significant predictor of the final exam ($p < .01$, $R^2 = 6.4\%$) and recall exam ($p < .05$, $R^2 =$

6.0%) in EC while an average of the quiz scores was a significant predictor of the recall exam ($p < .05$, $R^2 = 5.7\%$) in IC. The online spaced quizzes improved academic performance, but long-term retention was not affected as expected.

Keywords: formative quizzes, retention, chiropractic; education, Performance

Introduction

Programs in chiropractic and medical schools are known for their challenging classes and heavy credit burdens each term (Christensen, 2010). In addition to completing the summative exams at the end of each term, chiropractic students are expected to take and pass board exams administered by the National Board of Chiropractic Examiners (NBCE). Both positions necessitate great capacity for long-term memory.

Research on knowledge retention has been conducted in a variety of disciplines (Arzi et al., 1986; Custers, 2010; Malau-Aduli et al., 2013; Goshu, 2022). German psychologist Hermann Ebbinghaus performed meticulously designed experiments in 1885 to ascertain the relationship between memory and learning. From these experiments, he developed a "forgetting curve" that shows "rapidly occurring huge quantities of forgetting, followed by a gradual and continuous drop in retention" (Boneau, 1998). Previous research showed that the basic science knowledge acquired through the existing medical education techniques was not very well retained (Custers, 2010; Ling et al., 2008). Custers found that medical students forgot roughly 25–35% of basic science knowledge after one year, more than 50% by the next year (Custers, 2010). As compared to the Step 2 United States Medical Licensing Examination (USMLE), examinee performance in biochemistry, microbiology, and pharmacology at the Step 1 USMLE dramatically declined in 2008, according to Ling et al. Gains in physiology, anatomy, and pathology that were seen seemed to be connected to the practice of the material during clinical clerkships (Ling et al., 2008). Such poor retention begs the crucial question of whether instructors can employ strategies to increase student's retention of the knowledge they are taught (Kerfoot & Brotschi, 2009). To our knowledge, only a few studies have looked at chiropractic students' retention of knowledge (Hulme et al., 2020; Cade et al., 2018). We think that looking into how well chiropractic students retain their knowledge could help educational planners at chiropractic schools evaluate and address the level of student learning.

There are many factors that influence students' learning and thus affect knowledge retention in different ways (Wilhelmsson et al., 2011; Bergman et al., 2015; Emke et al., 2016). Therefore, one may need to expand the testing beyond just assessing acquired knowledge content (Morton & ColbertGetz, 2017; Bechtold et al., 2018). It is increasingly common for educators to use formative assessments as a supplement of traditional summative exams. The act of taking a test itself often enhances learning (Buchanan, 2000; Urdanata, 1992; Dobson, 2008). Dobson (2008) discovered that giving students formative online quizzes before each class improved their performance on summative exams by encouraging them to read and study. Regular online quizzes have a significant and advantageous effect on student learning, according to a study by Angus & Watson (Angus & Watson, 2009). Peat and Franklin (2003) found no correlation between formative test results and the performance of novice biology

students on summative exams, even though formative evaluations had favorable effects later in their program (Peat & Franklin, 2005). This emphasizes the importance of the audit use and effectiveness of formative assessments tool.

As we mentioned earlier, tests are themselves learning events. The ability of testing to promote learning and knowledge retention is known as the "testing effect" or "retrieval practice" (Roediger & Karpicke, 2006[1]; Larsen et al., 2008; Roediger et al., 2011). Test-triggered retrieval processes enhance subsequent recall, sometimes to a greater degree than comparable opportunities to restudying relevant information (Roediger & Karpicke, 2006[2]). Psychological and educational research has investigated the use of testing to increase long-term memory of knowledge learnt (Roediger & Karpicke, 2006[1]; Larsen et al., 2008; Butler, 2010). Thompson and colleagues found that restudying seems to be better than testing short term, whereas the advantage of the testing appears in longer retention interval (Thompson et al., 1978). In a different Roediger and Karpicke study, participants studied a set of short prose paragraphs for 5 minutes before restudying them for three additional 5-minute periods, being tested on their free recall of the paragraphs in three separate periods or restudying the paragraphs for two periods before being tested in the final period. Free recall was stronger in the event of restudying when the final test was taken after only a 5-minute delay, but repeated test circumstances produced the best final memory when the final test was delayed by a week (Roediger & Karpicke, 2006[1]). Interestedly, testing is not always better than restudying.

There is still little research on how test-enhanced learning and knowledge retention affect chiropractic students. In the current study, we examined the impact of weekly online formative quizzes on students' summative written test scores in a class within our chiropractic training program. We hypothesized that: 1) Students who completed the weekly online formative quizzes during the course would perform better than non-participants on topic-specific exams (immunology, endocrinology), as well as on the final exam as a whole; and 2) The weekly formative quizzes would enhance long-term retention over 10 months after initial learning.

Materials and Method

Prior to implementation, the study protocol was reviewed and approved by the Institutional Review Board.

Student Participants

A total of 251 3rd-quarter students participated in the study across 4 consecutive iterations of a 3-credit class presenting immunology and endocrinology content (July 2019 to June 2020). Each class offered 20 lectures of 50 minutes each.

Two classes (126 students) served as an Immunology Cohort (IC). The other 2 classes (125 students) served as an Endocrinology Cohort (EC). The students who were in IC voluntarily completed web-based immunology formative quizzes at the end of week 1 to week 3. The students who were in EC voluntarily completed endocrinology formative quizzes at the end of week 5 to week 8. Each quiz consisted of 17 to 26 single-best-answer, multiple-choice questions (MCQ). These assessments contain the material covered that week in the lecture. The students took the quizzes without supervision.

Our campus uses the quarter system, in which the academic year is divided into four terms: Fall, Winter, Spring, and Summer. Each term lasts 11 weeks. During a given academic term, the classes were divided into two discrete

topic presentations, Immunology (week 1 to week 3) and Endocrinology (week 5 to week 8). The instructor and course content were identical in each iterative presentation of this course. A topic-specific exam was given at the conclusion of each topic (immunology or endocrinology) and a cumulative final examination was given at the end of each course. Each topic-specific exam consisted of 40 MCQs while the final exam consisted of 60 MCQs that were equally divided across the immunology and endocrinology topic areas. All students were asked to take a voluntary recall exam approximately 7 months after the final exam (See Table 1). The recall exam comprised 50 MCQs chosen randomly from the final exam and equally covered those two topic areas. Since this study was partially conducted during the COVID pandemic, the students who were in one class of IC took the final exam without supervision while the students who were in one class of EC took both topic-specific exams and the final exam without supervision.

Exam questions were identical but in modified order for all study cohorts. The weekly quizzes and recall exam did not contribute to the student's final grades in the 3rd and 6th quarters, respectively.

Table 1: Study Timeline

	Week										
Cohort	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**40**
IC n=126	Immunology instruction					Endocrinology instruction					
	IFQ1	IFQ2	IFQ3	IX					EX	FX	RC
EC n=125	Immunology instruction					Endocrinology instruction					
				IX	EFQ1	EFQ2	EFQ3	EFQ4	EX	FX	RC

IC, Immunology Cohort, EC, Endocrinology Cohort
IFQs, immunology formative quizzes (IFQ1–3); EFQs, endocrinology formative quizzes (EFQ1-4)
IX, immunology exam; EX, endocrinology exam; FX1, final exam; RC, recall exam.

Data Analysis

Results were summarized and analyzed using SPSS version 22 (IBM Corporation, Armonk, NY).

We applied an independent *t*-test to evaluate weekly formative quiz effects on topic-specific summative exam scores (immunology exam, endocrinology exam), the final exam scores, and the recall exam scores between two study cohorts. All exam scores were normalized to a percentage scale, with a minimum score of 0% and a maximum of 100%.

Pearson correlation was used to evaluate the relationship between the quiz participation rate or quiz performance and major exams, such as the topic-specific exam scores (immunology exam, endocrinology exam), and the final exam scores across the study cohorts.

For all quantitative measures, effect sizes would be estimated, and 95% CIs would be reported. Statistical significance would be evaluated at $p = 0.05$.

Results

Demographic information

Students were equally divided between IC and EC (126 and 125, respectively). Of those, 59% in IC and 49% in EC were male students. Most students (97%) held bachelor's degrees, with very few in either study group having graduate degrees. Most students in both study groups were Caucasians (65% in IC and 63% in EC) and younger than 30 years old (94% in IC and 90% in EC) (See Table 2).

Table 2: Demographics for all study subjects (n = 251)

Cohort		Immunology Cohort (IC)	Endocrinology Cohort (EC)
Student Count*		126	125
Age	<30 yrs.	118	112
	30 – 40 yrs.	5	12
	>40 yrs.	3	1
Gender	Male	74	62
	Female	52	63
Ethnicity/race	Caucasian	82	78
	Hispanic	21	29
	Black	15	8
	Other	8	10
Academic degree	Bachelor	122	121
	Graduate	4	4

Immunology Cohort: students were required to do weekly Immunology formative quizzes.
Endocrinology Cohort: students were required to do weekly Endocrinology formative quizzes.

Effect of the weekly quizzes on the topic-specific test score and the final exam score

Out of 251 students, 98 (78%) in the IC took the Immunology weekly quizzes while 89 (71%) in EC took the Endocrinology weekly quizzes. In the topic-specific exams, the IC Immunology exam scores were statistically greater than that of the EC scores (93.98 vs. 89.43, p = .000). Similarly, the IC final exam scores in the Immunology part were significantly higher than that of the EC scores (89.97 vs. 83.53, p = .001). However, contrary to expectation, there was no statistically significant difference in the Endocrinology exam scores (89.15 vs. 90.58, p = .18) and the final exam scores in the Endocrinology part (80.97 vs. 84.13, p = .057) between the IC and EC although the EC had higher scores (See Table 3).

Table 3: T-test Assessing Summative Exam Score Differences

	Immunology Cohort (IC) Mean (95% CI)	Endocrinology Cohort (EC) Mean (95% CI)	*p-value*
Immunology exam	93.98 (92.95-94.98)	89.43 (88.18-90.68)	< .001
Endocrinology exam	89.16 (87.85-90.45)	90.58 (88.43-92.23)	> .05
Final exam			
Immunology part	87.97 (86.00-89.00)	83.53 (81.73-85.37)	.001
Endocrinology part	80.97 (78.70-83.23)	84.13 (81.80-86.47)	> .05
Recall exam			
Immunology part	61.12 (58.04-64.20)	61.28 (58.48-64.04)	> .05
Endocrinology part	60.00 (57.12-62.88)	64.40 (61.20-67.56)	< .05

Immunology Cohort: students had the option to do weekly Immunology formative quizzes.

Endocrinology Cohort: students had an option do weekly Endocrinology formative quizzes.
Immunology exam: summative examination at week 5
Endocrinology exam: summative examination at week 10
Final exam: summative examination at week 11
Recall exam: summative examination 7 months after the final exam

Furthermore, we sought to investigate whether certain parameters, such as the number of quizzes that students completed (participation) and quiz performance had any effect on the examinations. Pearson correlation for the relationship between these parameters and exams is shown in Table 4. The result of Pearson correlation showed positive relationships between the quiz participation rate and their scores in the exams (immunology exam: r = .18; final exam: immunology part (r = .18) and endocrinology part (r = .26), p < .05) excluding the endocrinology exam. Besides the endocrinology of the final exam, there were no statistically significant relationships between the quiz scores and major exams.

Table 4: Pearson correlations between different measurements of academic performance

	Participation		Quiz score		Immunology	Endocrinology	Final exam	
	(immu)	(endo)	(immu)	(endo)			(immu)	(endo)
	1	2	3	4	5	6	7	8
1					.18*		.18*	
2						.07		.26*
3					.06		.06	
4						.07		.25*

Participation: number of quizzes that students completed
Quiz score: the average of the quiz scores
immu: Immunology
endo: Endocrinology
*Correlation is significant at the 0.05 level (2-tailed)

Effect of the weekly quizzes on long-term retention

For the recall exam, 107 (85%) students in IC completed the immunology and 99 (79%) completed the endocrinology, while 104 (83%) students in the EC completed the immunology and 95 (76%) completed the endocrinology. Contrary to expectations, the mean of the recall exam scores in both cohorts were lower than 65%. An independent samples t-test showed that there was no significant difference between the IC and EC on the immunology exam scores (61.12 vs. 61.28, p = .86). By contrast, the mean of the endocrinology exam scores in EC was statistically greater than that of scores in IC (64.40 vs.60.00, p = .049) (See Table 3).

Discussion

In the current study, we found that web-based, online formative tests had a considerable impact on academic achievement. According to the study's findings, students in IC significantly outperformed students in EC in both the immunology exam (p = .001) and the immunology part of the final exam (p =.001). Even though there was no statistically significant difference between the two cohorts, the EC's endocrinology exam scores and final exam

endocrinology scores were both higher than those of the IC. The results current study are in line with those of previous studies (Ballard & Johnson, 2004; Graham, 1999; Kamuche, 2005; Zhang & Henderson, 2015), which found that students who took tests each week performed better than those who did not take any tests at all during the course. Surprisingly, given the conclusion, Haberyan's study showed no discernible difference in student performance in the classroom between the two weekly quiz groups and the no-quiz control group (Haberyan, 2003). Similarly, Derouza and Fleming (2003) studied science students and found that student performance was not strongly impacted.

The results of the study also showed that the participation rate of quiz-taking practices had a positive relationship with most major exams, such as topic-specific exams and immunology scores of the final exam. It seems that the more weekly quizzes the students took the higher scores they gained in the summative exam. The most influential benefit of the weekly quizzes is to motivate students to study regularly. Procrastination in academic work is a widespread problem for college students. A study crossing two medical schools revealed that 62.5% of students crammed for exams, only 17% would prepare a list of probable questions and answers before exams, and only 47.8% of students maintained a daily schedule of study hours (Vu & Galofre, 1983). In our study, the topic-specific exam and the final exam as traditional testing could be used to evaluate how well a student has learned; however, those exams could not be used as tools to aid and promote learning but rather measure it. Therefore, if instructors want to encourage better learning, the role of testing must be expanded. Larsen et al. recommend that "tests would no longer be considered neutral tools of measurement, but rather active instruments to aid in the acquisition and retention of knowledge" (Larsen et al., 2008). In our study since the weekly formative quizzes did not contribute to a student's final grade but had distinct purposes specific to the student and instructor. Students can use formative assessments to guide future learning by reflecting on feedback, identifying strengths and weaknesses, and understanding their instructors' expectations. On the other hand, instructors can use formative assessments to evaluate and modify their teaching and to monitor their students' learning (Larsen et al., 2008; Rolfe & McPherson, 1995). Whereas summative assessments associated with final grades may cause anxiety, formative assessments can foster a non-judgmental learning environment because students can learn without incurring an academic penalty (Rolfe & McPherson, 1995). In the present study, we also anticipated that those who performed well on these quizzes would be better prepared for the topic-specific exams and the final exam than those who didn't perform well. However, it was not fully supported by our findings. Our result showed that there was only a positive relationship between the quiz scores and the endocrinology scores of the final exam. It is possible that the students who were performing better on the weekly quizzes were also the ones who were keeping up with the readings, spacing their learning, and prepared well before taking the quizzes while the students who performed worse on the weekly quizzes were more likely to cram for the summative exams. In this study, on the other hand, the weekly quizzes were not mandatory, and the quiz score did not contribute to the final grades. Although some students did not treat the quizzes seriously others discovered content gaps by taking the weekly quizzes, which assisted them in studying for their summative exam. However, a combination of intelligence, study habits, and study motivation determined both formative quiz scores and summative exam scores.

Although the mean scores (65%) of the recall exam in both cohorts were lower than the final exam, the scores of the immunology and endocrinology with the quiz practice cohort were higher than the non-practice cohort. The results of the study showed that weekly quizzes produced better long-term retention of information learned from the classroom. The idea that testing improves retention is not new. It is a well-established psychological effect that the mere act of testing someone's memory will strengthen the memory, regardless of whether there is feedback. In 1620, Bacon wrote: "If you read a piece of text through twenty times, you will not learn it by heart so easily as if you read it ten times while attempting to recite from time to time and consulting the text when your memory fails" (Roediger & Karpicke, 2006[2]). As we mentioned earlier, a lot of students crammed for exams. Cramming may work well if the student's goal is simply to do well on one exam. But if chiropractic students want to perform well on an upcoming test and want to have good long-term retention for future board NBCE and clinical practice, they should space out their studying. If students are given more frequent formative assessments, such as weekly quizzes, they get the dual benefit of testing themselves without any potential penalty and adding an incentive to their studying.

Study limitations

Our study demonstrates the potential benefits of using test-taking practice to enhance long-term retention of knowledge, but it also has limitations. The test format between four classes was not even due to the study being conducted during the COVID pandemic. In both study cohorts, the students from one class took un-proctored summative examinations while students from another class took proctored summative examinations. A primary worry regarding the un-proctored online exams is that the test results will be skewed if students are allowed to consult course materials (Rovai, 2000). We should also note that our practice quizzes were limited to the use of multiple-choice questions in this study. We expect to find greater gains when we use test-taking practice in other forms of testing because studies have shown that production tests followed by feedback produce greater testing effects than simply doing multiple-choice tests with feedback (Kang et al., 2007).

Conclusion

We concluded students who chose to use formative online quizzes had better outcomes on summative examinations. Therefore, weekly testing should be considered for its potential impact on learning, not just as an assessment device. In this study, we also found that less than two-thirds of knowledge was able to be retained after a half year of nonuse. Therefore, we strongly recommend students actively participate in the school review course and frequently practice the questions from the NBCE question bank via the school Brightspace system before taking the NBCE.

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