REDESIGNING WITH SPACED REPETITION

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Abstract

Spaced repetition or distributed practice strategy is frequently used to help medical students not to forget what they learned their classes and during their rounds in the hospitals. Research has shown that this strategy mitigates forgetting of learned information. It could be one of the solutions to the issue that instructors often see, which is, students do not remember key concepts from prerequisite courses. So, why students forget key concepts? It may not be easy to figure out the reasons underlying this, but we can certainly assume that (for example) when students' study habits involve cramming information right before the examination it can cause forgetting them right after that examination. Additionally, if instruction doesn't repeat important concepts several times it may not help students to remember them. We also suggest not to rely solely on high-stake assessments at the end of the course to support the spaced repetition strategy.

Keywords: Spaced Repetition, Distributed Practice, Calculus I, Memory Retention

Introduction

Instructors frequently mention that students don't remember key concepts from prerequisite courses. This could be due to students' study habits of cramming information right before exams. Cramming is an inappropriate practice, especially, in mastering concepts and skills in mathematics. It may cause negative consequences that students may not be aware of. Moreover, many instructors teaching math. courses often depend on high stake tests such as the final examinations. These tests are usually time-limited and cumulative which worry many students because these can affect greatly their final grades if their performance is not as anticipated. Hence, what can we do to alleviate all these challenges? A recurrent question that is necessary to unravel after the COVID-19 pandemic made the conditions worse. Instructors had to suddenly change from face-to-face instruction to remote instruction during the pandemic, which was difficult to do with a sudden closure of campuses, and they needed major rearrangement of teaching strategies and assessments (Maalem et al., 2020). They also were required to be able to think outside standard boxes of practice to generate various possible solutions (Hodges et al., 2020).

In this article, we examine modeling and promoting spaced repetition, known also as distributed practice, as a key strategy to support retention of learning. We also suggest decreasing the weights on the so-called high-stake tests at the end of the course to allow for engagement with students throughout the term. The instructor needs to **plan to repeat important concepts** for better learning outcomes and to help improve the situation of retaining key concepts and skills in the minds of our students.

Methodology

The proposed and experimented strategy is called spaced repetition or distributed practice, which started with Ebbinghaus's famous experiment of forgetting curve (1880-1885). Ebbinghaus's goal was to find a legitimate relation between memory retention and time-since-learning (Murre & Dros, 2015). Reasonably, retention decreases with elapsed time after reading a topic (Subirana et al., 2017). Hence, to support the memory, one must do an intervention (shown as open book in Figure 1) to retrieve what was memorized. It may sound plausible, but many doubted its effectiveness until several experiments were later conducted and established its validity. As shown in Figure 1, first learning (of a concept) starts at a higher level but diminishes with time. It then increases to the earlier state after an intervention. Figure 1 shows how the sequence repeats. The rate of deterioration slows down with the number of interventions, and we get a better retention towards the end. This phenomenon is described as improved retention. The more the involvements the better improved retention. Those interventions are the spaced repetitions, and they can take many forms of reinforcements such as reading, reviews, discussions, reflections, practice, feedback, etc. The overall idea is illustrated in Figure 1.

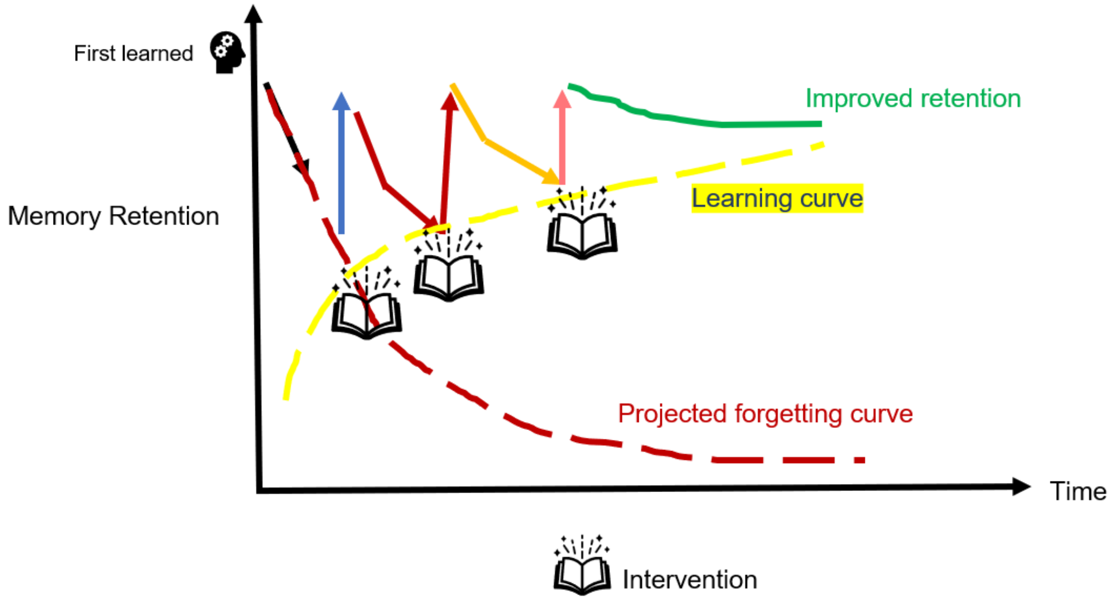

Figure 1. Projected forgetting curve concept based on Ebbinghaus

It was reported in research that spaced repetition is beneficial (Voice & Stirton, 2020), and it has been widely used in both medical and law education (Teninbaum, 2017). Accordingly, why not implement the same in mathematics instruction? The intention is to account for it in the redesign of instructional strategy which is the process to convert an existing course plan for a more successful plan that improves students' learning outcomes. The main purpose of the redesign is to model spaced repetition in teaching a mathematics course to help students retain main concepts. Since many students may not know how to study a discipline especially when they transition from high school to a college or a university. Even those who figure it out early may struggle with time management and stress towards the end of the course and do not know how to deal with high stake tests.

Modeling Space Repetition

The difficulty in implementing this strategy is due to instructors not having enough time to cover all that is required in the first place. So, we need to adjust how we cover the curriculum. The suggested model uses a survey method to account for all learning objectives, categorize them based on some desired criterion, sample from each category by prioritizing certain items, write interventions for those items, lower attention to other items based on criterion, and decide how prioritized items or concepts will repeat. The model is shown in Figure 2.

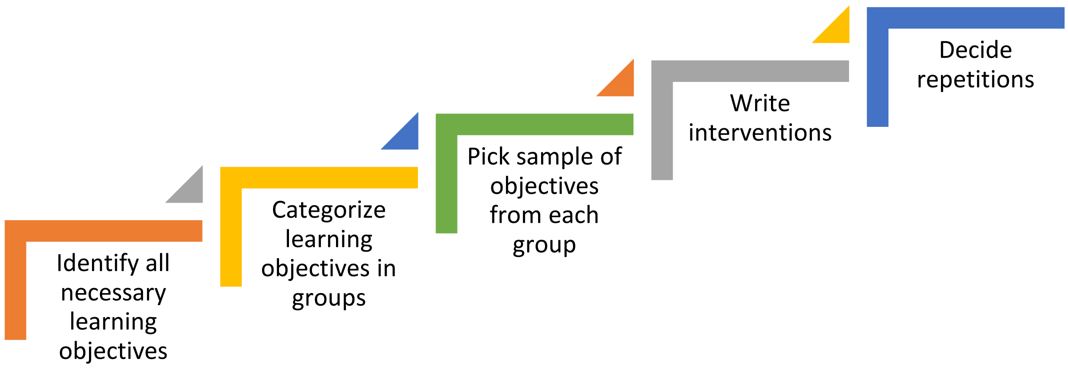

Figure 2: Suggested spaced repetition model

The instructor usually has a brief chance in each lecture to cover a topic and move on to the next one. As a result, a common path for the student is to see content during lecture, practice over homework, study for a midterm test, and probably will not revisit it until studying for final examination. How everything occurs affects retention; for example, retention decreases greatly when a student uses cramming to study for examination (forgetting curve in Figure 1). To clarify, we use the example of Calculus with Analytic Geometry I (Calculus I) course. The commonly known topics that students who pass the Calculus I may not remember well after they pass it are the chain rule, related rates, curve sketching, optimization problems, integration by substitution. The experimented model in a Calculus I course based on spaced repetition is shown in Figure 3.

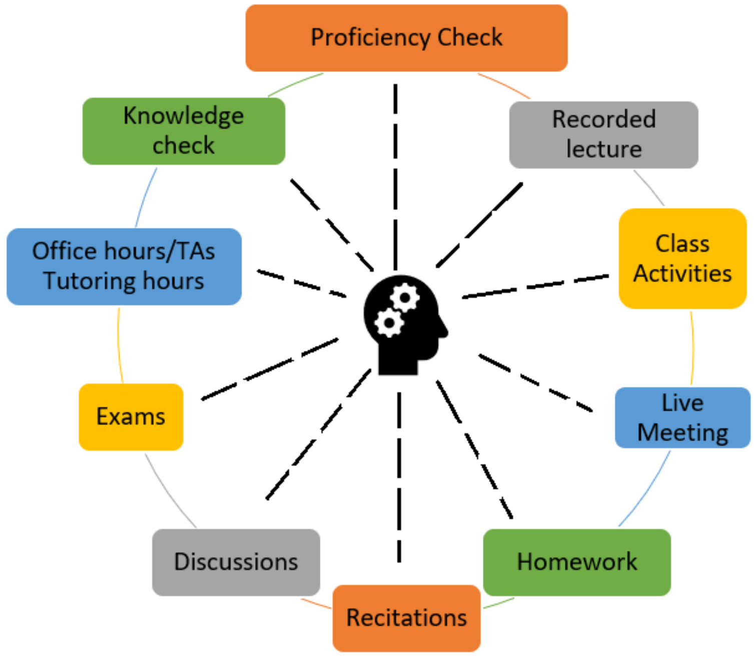

Figure 3. Spaced Repetition Redesign in Calculus I

Different interventions are planned and there is no single assignment's weight that is 20% (or higher) of the final grade. In other words, it was necessary for us to divert students' attention from one specific assignment to various assignments and their categories. An example of grading distribution that supports spaced repetition is posted in Table 1.

Assignment	Weight
Homework (due 11:00 pm)	13%
Calculus Proficiency Check	5%
Calculus Knowledge Check	5%
Lecture Activities (Quizzes)	7%
Four Exams	50%
Recitation and orientation activities, Discussions	15%

Table 1: Example of grading distribution to support spaced repetition

Both synchronous and asynchronous modes were adopted in this course that was taught via distance learning. Proficiency check is a diagnostic assessment that allows to evaluate students' prior knowledge and give them feedback on what they need to review; and it is helpful for the instructor to know topics to include in **just in time reviews**. Recorded lecture, discussions, recitation activities are asynchronous delivered via Learning Management System (LMS) and give the benefit of taking the time to prepare. Live meetings during assigned class times, assigned recitation (small groups) meetings, and scheduled office hours are synchronous. They are delivered via Zoom. They help build a community in the course. All those components allow to plan spaced repetitions of prioritized concepts.

Results

This strategy was first implemented during fall 2020 by the authors. Overall, results show an increase in success rate, and a better student engagement. Student perceptions were positive in the surveys; for example, one student wrote when asked about what they liked best about the course: "*Homework and discussions were helpful to understand topics.*" Another student wrote when asked about suggestions to improve the course: "*One suggestion would be to integrate more discussions about the various applications of certain concepts. For example, more questions related to engineering, medicine, etc. to reinforce the important applications of concepts in calculus.*" Therefore, with more planning, spaced repetition can also support relevance to future career goals of students. An encouraging result for further research is that students showed better self-efficacy in multiple submissions. Furthermore, when they were asked if they were confident in talking about Calculus in public; Among 238 students who responded to an anonymous survey delivered in LMS, 200 respondents (or 84%) agreed (Yes), 37 respondents or 16% disagreed (No), and 1 respondent chose not to answer. The 84% is a remarkable and an encouraging result. In spring 2022, we discussed self-efficacy with students and asked them about confidence in doing Calculus and speaking about it in public. Among 367 student 66% agreed (Yes) at the third week. However, after 10 more weeks 84% agreed (Yes) that they are confident and ready to speak about Calculus in public. Over 90% said that the course design helped them reinforce important concepts.

Conclusion

It is essential to provide rationale to students to justify reasons behind distributed practice, and it should account for it in instruction (CSUN Undergraduate Studies, 2021). Without a convincing rationale, students' perception to distributed practice may not be same as ours because they are not the ones who set up the course. It is important not to assume that multiple assignments are spaced repetition if they were not planned for that purpose. That is why writing rationale while redesigning the course helps in identifying how those assignments work together. Research proved that spaced repetition is helpful, and our experience gave positive results concerning success rate in the course and an increase of confidence in working with math. We are tracking the student's success in subsequent courses for further studies and iterations.

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