A FIGHT AGAINST THE FORGETTING CURVE

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ABSTRACT

With the rapid growth of digital education, e-learning has become essential for offering accessible and flexible learning opportunities. This paper investigates strategies to achieve long-term learning outcomes and reduce study time in e-learning. It explores various techniques, including self-testing, spaced repetition, and the serial position effect, tailored to both visual and auditory learners. The study compared the effectiveness of these strategies, revealing that self-testing and spaced repetition improve learning and combat forgetting. However, in this context, the serial position effect did not show a noticeable impact on learning outcomes.

KEYWORDS

Didactics, e-Learning, Forgetting Curve, Serial-Position-Effect

1. INTRODUCTION

The COVID-19 pandemic posed numerous challenges across various domains, necessitating innovative solutions to overcome them (Pratama et al., 2020). Particularly, the education and industry sectors experienced major changes as they shifted towards remote learning and telecommuting to keep their activities going. For instance, a research (Agency, 2021) conducted in Austria highlights that, during the pandemic, approximately 45% of primary and secondary schools and 60% of high schools transitioned to distance learning. One of the main difficulties students faced during this shift was organizing their courses, effectively managing their time, and understanding the course material.

In response to these challenges and to uphold educational quality, institutions increasingly relied on video conferencing tools and e-learning applications. The application of e-learning tools in particular became increasingly popular during the pandemic (Lynch, 2020), as they enable students to interact with course materials according to their individual schedules. Moreover, e-learning applications offer distinct advantages beyond traditional learning methods, such as facilitating self-assessment and identifying areas of weakness. Another limitation of traditional learning is the issue of forgetting. Ebbinghaus (Ebbinghaus, 1913) addressed this issue by conducting multiple case studies to illustrate the forgetting curve, which shows that a significant portion of acquired knowledge is lost within 24 hours.

Taking advantage of the widespread use of smartphones, which provide flexibility regarding location and time, enhances the effectiveness of e-learning applications even more. Motivated by these advantages, we have developed a mobile e-learning application that supports students at an Austrian university during their course. Due to the fact that the pilot study of the application takes place in Austria, an Android application was developed, as this is the most frequently used mobile operating system (Statista, 2024).

The goal of our E-Learning application is to help students prepare for exams and remember course material in the long term. But developing such applications presents significant challenges, as they must adapt to various contexts such as the type of learning material, learning types (visual or auditory), question formats (single or multiple choice), and numerous other factors. To address these challenges and meet learner requirements, multiple versions of the application were developed and tested.

Initially, the application was tailored to different learning types. According to Vester (Vester, 1992), there are four main learning types: auditory, visual, haptic, and intellectual, whereby auditory and visual being the most common (Özbaş, 2013), (Bradford, 201AD). Consequently, two distinct applications were designed for these predominant learning types, each differing in their approach. For visual learners, correct answers were visually highlighted, while for auditory learners, correct answers were acoustically repeated multiple times.

Furthermore, an effective learning strategy was developed to counter the forgetting. For example, systematically repeating incorrectly answered questions has proven highly effective (Ebbinghaus, 1913), (Hartwig and Dunlosky, 2012). Moreover, the way in which this repetition is done, significantly impacts its effectiveness. For example, the order of the individual questions or answers can influence forgetting. The psychological phenomenon "serial-position effect" (Murdock Jr, 1962) states that the first and last items in a long list are generally memorised more effectively than those in the middle. This phenomenon was also used in our app to counteract the forgetting curve. The incorrectly answered questions were placed at the beginning and end of the question list to make it easier to remember the correct answers.

This paper is organized as follows: In Section 2 we review related work and give insights on the background for the ideas used in the e-learning application. Section 3 describes the setup for the pilot study and how different strategies were employed to fight the forgetting curve. In Section 4 the data obtained from the pilot study is analyzed and gives insight into potential future improvements on the application. We conclude in Section 5.

2. BACKGROUND / RELATED WORK

Despite controversy about the importance of learning types (Looß, 2001), (De Bruyckere, Kirschner and Hulshof, 2015), (Kirschner, 2017) we focus on two of the four suggested learning types (German term: *Lerntypen*) by Frederic Vester. Learners which are said to be of visual learning type constitute 65% of the population followed by auditory learning types. The influence of visual versus auditory learning on recall, analysed using a memory test, is discussed in Lindner, Blosser and Cunigan (2009). Ebbinghaus investigated the human process of forgetting information (Murre and Dros, 2015, p.4-11). Items shown first or last within a series of items can be remembered best. Concerning forgetting, the term *Ebbinghaus Speed* was coined by Subirana, Bagiati and Sarma (2017).

To confirm success of learning, assessments are used. Self assessment, as discussed in Hartwig and Dunlosky (2012), is an important way for feedback and reflection. This can be supported by mobile apps. Hence, we try the same approach as discussed in Schimanke, Mertens and Vornberger (2014): maximise learning outcomes with a mobile game or an e-learning app in our case. The positioning of questions influences the process of remembering. This phenomena is called *serial positioning effect* (Murdock Jr, 1962) and can be a means to mitigate Ebbinghaus' forgetting curve. Even before Covid the life long learning (LLL) was found to be necessary in modern society (Schäfer, 2017, p. 4-5). Since then, the way of learning has shifted into an foremost remote and an even more selfdirected process.

For e-learning applications, the use of gamification elements enhance the motivation of learners (Zecri, Ouzzif and El El Haddioui, 2021). One important approach is to provide mobile personalised learning environments (mPLEs) on smartphones (Humanante-Ramos, García-Peñalvo and Conde-González, 2016). The implementation of an Android mobile app, as discussed in the upcoming Sections, was designed according to core features needed to ask questions according to the relevant algorithms, but also to motivate usage by providing push-notification. For improved usability and user experience (UX) the interfaces have to be designed in a human suitable way. To create accessible and usable GUIs see the ten heuristics by Nielsen (1995).

3. METHOD

The concept and implementation of the mobile app seeks to answer the two following research questions:

1. Has the use of the e-learning application improved the understanding of students?
2. Has the serial positioning effect aided the understanding?

In order to evaluate these questions, we conducted a pilot study. To quantify the effectiveness of the app, participants of the study should diligently make use of the app on a daily basis and subsequently participate in an independent examination of the learned material to assess how much information was retained. Thus, a group of students should be selected, who have to take an exam independent of the app. The provided learning application then supports students during the two week studying phase prior to the exam. The learning app itself supports both auditory and visual learning types by switching to either an auditory (spoken answers) or a visual (questions and answers as text) mode for the quiz, depending on the learning type of the participant.

3.1 Target Group & Preparation

For this pilot a cohort of 37 students from the part-time degree program "Software Design and Cloud Computing" at the University of Applied Science "FH JOANNEUM" was selected. Together they participated in the course "Webtechnologies", where the mobile app was designed to help them prepare for the final exam. Prior to the learning phase, the students had to take a test (Philognosie, 2023) to identify which type of learner they are. As a result of the test, every student got a percentage showing their affiliation to each of the learning types. They were subsequently classified as either an auditory or a visual learner according to the results of this test, which then influenced the setup for the learning app.

3.2 The Pilot Study

The pilot study started on 14th of January 2023 and lasted until 27th of January 2023. The final exam for the course was held on 28th of January 2023. The students were exhorted to use the mobile app every day during this timeframe to help prepare for the exam as a form of a distributed practice learning strategy (Ebbinghaus, 1913). Questions were organized in "Learning Units" or "Quizzes", each of them consisting of ten questions. To avoid cheating, each question had to be answered within thirty seconds. To discourage students from studying only during the last few days prior to the exam, one could only complete a singular learning unit per day. This also homogenizes the dataset and allows for more comparability between each students improvements over time. Thirty-two persons took part in the study by using the application at least once. These participants were separated into four groups in order to differentiate the results according to their learning type and the impact of the serial positioning effect. First, the participants were split into two groups according to their learning type. To isolate any impact of the serial positioning effect, these two groups were both further split into two groups, where one group had their questions arranged to use the serial positioning effect and the other's questions were arranged randomly. In order to fight the forgetting curve, questions may be repeated in subsequent quizzes, which is known as spaced repetition (Schimanke, Mertens and Vornberger, 2014). Thus, the same question is typically reviewed more than once, though not necessarily in consecutive learning units.

Table 1. Classification of participants for the pilot study

Group	Learning Type	Learning Strategy
AS	auditory	serial positioning
AR	auditory	random positioning
VS	visual	serial positioning
VR	visual	random positioning

3.3 Creating a Learning Unit

A learning unit or quiz is comprised of ten unique questions, which are chosen from a predefined questionnaire. For a learning unit questions are selected by an algorithm, which assures that each question is used conforming to a uniform distribution. In order to implement the depicted learning strategies as in Table 1, questions are organized for each user into queues by their status. The status is either "new" which means this question has not been used in a prior learning unit, "correct" which means the question was answered correctly before or "false", which means the answer was last answered incorrectly. Initially all questions (a subset of the questionnaire) will be put into Queue1 ("new" questions). Figure 1 shows the queue structure used to organize questions for a specific user.

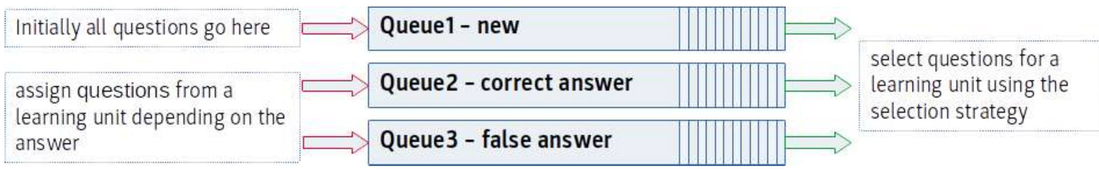

Figure 1. Queues used to manage questions

Building a learning unit consists of these steps:

1. Select questions using a selection strategy.
2. Position questions within a learning unit using serial positioning or random positioning.
3. Execute learning unit.
4. Send answered questions to queues dependent on the respective answer (correct/incorrect).

Question Selection Strategy

Questions for a new learning unit are selected using FIFO (First-in First-out) queues. The selection of questions from these queues is controlled by the following algorithm:

```
//Find 10 Questions for a learning unit
1. take (a) questions from Queue3 (0 <= a <= 2)
2. take (b) questions from Queue1  (0 <= b <= 10-a)
if (b < 10-a)
  take (c) questions from Queue2 (0 <= c <= 10-a-b)
  if (c < 10-a-b)
    take (d) questions from Queue3 (3 <= d <= 10)
```

The operation `take (n)` removes `n` questions from a queue and appends them to the quiz. After the questions for a quiz have been selected, their order in the learning unit is determined. Questions from Queue3 (wrong answer in previous quizzes) will be positioned within the learning unit using either serial or random positioning. The learning unit is ready for use when selection and positioning of the questions have been completed. The user runs the quiz and has to answer the questions, depending on the answer the questions will be reassigned to Queue2 (correct answer) or Queue3 (wrong answer) for further usage in later learning units.

4. RESULTS

The application was tested on a group of students enrolled in a class on Webtechnologies, with the goal to support them in the two weeks prior to their final exam. Predictably, out of the 37 enrolled students, eight motivated students used the app more than six times, 15 less than six times and 14 students refused to use the app at all. Only the set of eight students which used the app frequently and the 15 students which used the app infrequently are considered in our results. Motivating students to participate in the quizzes was done using push-notifications, which proved to be effective on some students. It is important to recall, that the application was not the same for all students. Participants were separated into groups according to their learning type affinity (visual or auditory), in line with the results of a prior taken affinity test for their learning type, i.e., each student was assigned the learning type that scored higher in this affinity test. Furthermore, in order to assess the effectiveness of making use of the serial positioning effect, the participants were again split into two groups. Groups AS and VS utilized the serial position effect by placing incorrectly answered questions at the beginning (primacy effect) or at the end (recall effect). Incorrectly answered questions from members of Groups AR and VR appeared without a concrete placement strategy in subsequent tries. This leads to a dataset with four distinct groups, which we will be analyzing in this chapter.

In total, 116 test attempts are recorded and available for analysis. Each test attempt contains ten questions and a score between 0 and 100 which reflects number of correctly answered questions.

4.1 Data Analysis

In this subsection, we aim to investigate two major questions:

1. Has the use of the e-learning application improved the understanding of students?
2. Has the serial positioning effect aided the understanding?

To answer the first question, we consider two ways to evaluate a student's understanding: on the one hand, we may consider the overall score achieved in each attempt at the quiz and on the other hand, we consider the overall grade. The latter is determined by each student's performance in a final exam, whose questions may coincide with the questions of the learning units. However, the final exam also includes open ended questions, where the understanding of the subject is tested in more detail. As seen on the left of Figure 2, the mean of the exam score increases significantly with each attempt, showing a clear learning trend with the sharpest upwards slope after 3 attempts. Due to the diverse group of participating students, this curve may be biased by previous experience. As seen on the right of Figure 2, students who reported to "know a bit" prior to the class, started out with higher scores than their counterparts. One can however see that after the 4th attempt, the gap between students with and without previous experience has diminished clearly, indicating a success of the app to homogenize the knowledge level within the class. It must be emphasized again, that the app was only introduced towards the end of the class, two weeks prior to the final exam, and only two lectures followed after its introduction. Thus, the reduction of the gap between the score curves is not biased by lectures in between.

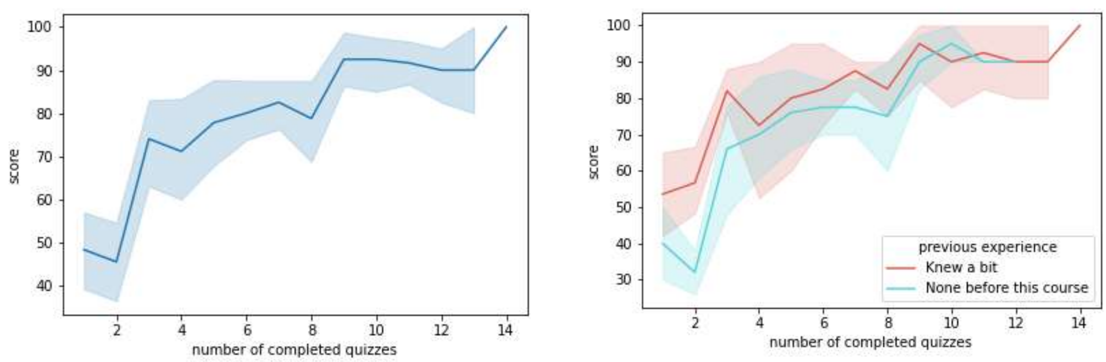

Figure 2. Mean improvement of quiz scores over attempts (left) and stratified by previous experience (right)

On the other hand, the influence on the final grade can be seen in Figure 3. As is clear on the left of the figure, the participants can be roughly separated in two groups. If a participant has taken the test more than 6 times, they are flagged as a *frequent_user*. The distribution of the grades between these two groups, as seen on the right of Figure 3, shows some differences. Indeed, infrequent users show a wider variance in their grades, while frequent users tend to mostly get the best grade (1), with one user each obtaining a different grade (2) and (4), respectively. Thus, while students who didn't frequently use the app didn't necessarily fail, they tended to show more variance in their final grades.

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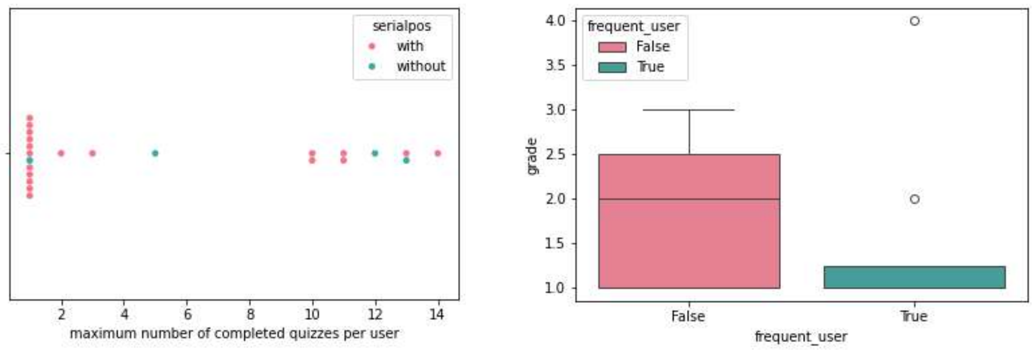

Figure 3. Number of quizzes per user (left) and resulting grades for frequent and infrequent users (right)

With respect to the serial positioning effect, the data cleaning unfortunately yielded a very imbalanced dataset. Out of the 23 remaining participants, only 4 had the chance to test the application without the serial positioning effect. Thus, it is not possible to give a funded statistical reasoning on whether the serial positioning effect has yielded a different distribution in grades than its counterpart. This was tested using a one-sided Mann-Whitney Test to test for equal distributions (p = 0.33). This test was chosen to accommodate the lack of a normal distribution in the data as well as the very small sample size.

Nevertheless, it is possible to compare the answering accuracy of questions asked multiple times in order to gain insights related to the serial position effect. Figure 4 compares the serial positioning groups (AS + VS) and the random positioning groups (AR + VR) in terms of accuracy (y-axis) over the number of question attempts (x-axis). The blue line denotes the accuracy of questions placed at the beginning (primacy) or the end (recall) while the red line represents the accuracy of the remaining questions. The serial positioning groups show a steady increase of accuracy for primacy and recall questions which indicates a learning effect for wrongly answered questions in previous tries. The random positioning group does not reveal a noticeable difference between the primacy/recall and the remaining questions which should not be the case anyway as all questions are placed randomly in this group.

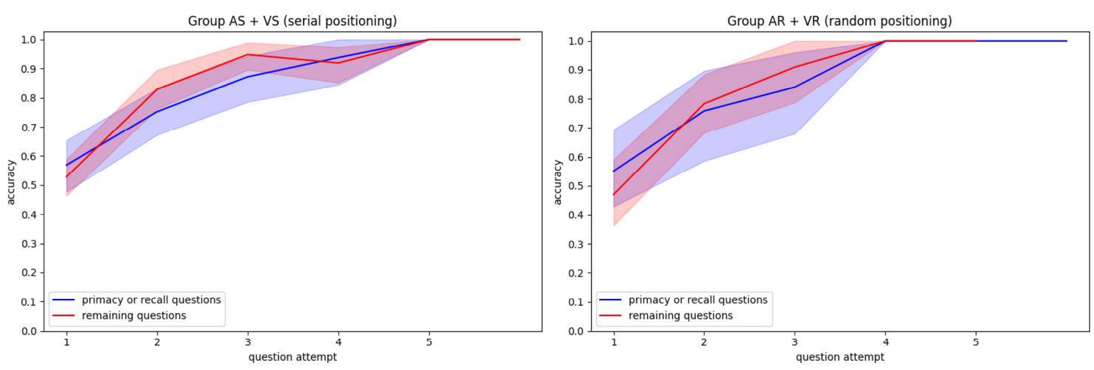

Figure 4. Comparison of the primacy/recall effect of questions answered multiple times in serial and random positioning groups

The Mann-Whitney Test was also used to investigate whether there was a difference in the distributions of the grades between frequent and infrequent users. This test also showed no strong significance (p = 0.13). This may be due to the fact that a bias in expertise lifted the average of the infrequent users. Only 4 out of 14 users, who indicated having some prior experience with the material, used the app frequently.

Among students who reported having no prior experience, 5 out of 9 were infrequent users, which is a much more even split.

All in all, while there appears to be very little statistical significance in these small groups, infrequent users showed larger variance in their final grades in comparison to frequent users as seen in Figure 3. Additionally, the use of the app helped bridge the gap between students who had prior experience and students who had none.

5. CONCLUSION AND OUTLOOK

In modern learning environments, using e-learning tools can provide great benefits to learners. The authors discuss an e-learning quiz app, that aims to counteract the forgetting curve by making use of the serial positioning effect. The app was tested on students preparing for an exam and results show clearly that students who used the app regularly had on average very good grades and students with little to no prior knowledge very quickly bridged the gap to more experienced students. Unfortunately, no clear statistical significant difference between including or excluding a strategy to use the serial positioning effect has been achieved. The authors believe that this is due to the very small sample size and lack of clear commitment of the participants. In order to improve participation and diligence by students, a more extended study could be performed in the coming year. The use of the application could be encouraged by allocating a small amount of bonus points that count towards the course. A larger dataset with more consistent participants could help get a clearer picture on potential serial positioning effects. Additionally, one could collect data regarding the students reception of the e-learning tool in an extensive study to investigate the differences in experiences within the groups. Besides, some researchers (De Bruyckere, Kirschner and Hulshof, 2015), (Kirschner, 2017) have criticized the validity of learning types as a learner characteristic, arguing that the emphasis should instead be placed on universally effective learning strategies. Future research should therefore focus on learning strategies that are effective regardless of individual learning styles.

In order to improve understanding, the handling of mistakes is crucial. This prototype does not expand upon falsely answered questions. An improved prototype could also include explanations as to why the given answer was wrong. This extention could result in faster improvements of the quiz scores and, subsequently, better scores on the final exam.

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