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PAPER

Embracing Mobile-Based Spaced Learning to Enhance English Scientific Vocabulary Mastery and Academic Performance among ESP Students

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ABSTRACT

Mobile-based spaced learning, an educational approach that divides learning into time-spaced periods, has been widely studied in language education, particularly English. However, research on its application in English for Specific Purposes (ESP) contexts, especially within mobile-based spaced learning environments, and its differentiated effects on vocabulary mastery and academic performance remains limited. This study aimed to investigate the impact of mobile-based spaced learning (equal or expanded) on English scientific vocabulary mastery and academic performance among ESP students, specifically scientific lab majors. Sixty students were divided into two groups: those who learned in an equal-spaced style and those who learned in an expanded-spaced style. Data was collected through vocabulary and academic tests, and a quasi-experimental method was employed. The study found that both equal-spaced and expanded-spaced learning enhanced vocabulary acquisition, but only the expanded-spaced learning method significantly boosted academic performance. While both methods improve vocabulary, the extended reinforcement of expanded spaced learning may enhance cognitive activities and long-term retention. The findings suggest that expanded-spaced instruction may particularly benefit cognitively demanding subjects within ESP courses. Further research is needed to examine the long-term effects and applicability of these strategies to different courses and students and to investigate the interaction between spaced learning strategies and learner characteristics.

KEYWORDS

Mobile-based spaced learning, education, English vocabulary, academic performance

1 INTRODUCTION

Mobile-based spaced learning, which reviews educational content over time to improve long-term retention in the learner's memory, is a learning method that

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combines the principles of spaced repetition and virtual learning environments [1]. Mobile-based learning environments use modern technologies and digital features to provide content organized according to a specific strategy based on the spaced learning method. This approach allows the learner to combine the characteristics of spaced learning with the characteristics of the mobile-based environment, which affects the persistence of the learning effect [2] and improves the targeted learning outcomes [3].

The mobile-based spaced learning method has proven to have a notable impact on the educational outcomes of English language courses. [4] demonstrated the superiority of spaced learning compared to group learning in memory retention and performance on post-tests assessing the ability to match the meaning and form of English vocabulary. Recent research has consistently demonstrated that reviewing material at progressively longer intervals improves long-term retention and recall [5]. The "spacing effect" approach is founded on the concept that reviewing content shortly before it is forgotten enhances memory and solidifies the significance of the information [6]. Spaced repetition techniques, such as digital flashcards or vocabulary lists with periodic reviews, can significantly enhance vocabulary acquisition and overall academic proficiency [7].

This study investigates the impact of the mobile-based spaced learning method and focuses on identifying the best approach for content delivery. Specifically, it examines the time intervals that enhance learning outcomes. The research also considers how these intervals align with the characteristics of university students. Ultimately, it aims to meet this learner group's educational needs effectively. This characteristic distinguishes it from other studies. It seeks to answer the following questions:

What is the impact of mobile-based spaced learning in an (equal) style on English for Specific Purposes (ESP) students' mastery of English scientific vocabulary and academic performance?

What is the impact of mobile-based spaced learning in an (expanded) style on ESP students' mastery of English scientific vocabulary and academic performance?

What is the impact of the difference between the two types of spaced learning (equal, expanded) on ESP students' mastery of English scientific vocabulary and academic performance?

Building on this background, the subsequent sections will review the existing literature on mobile-based learning environments, mastery of English scientific vocabulary, and its impact on academic performance. This review will establish the foundation for the present study, which investigates the influence of English scientific vocabulary acquisition through mobile-based spaced learning on academic performance.

2 LITERATURE REVIEW

2.1 Mobile-based spaced learning environments

Spaced learning is an educational strategy that breaks learning into intervals. It enhances long-term retention and understanding and reduces cognitive overload, improving academic performance. It has been demonstrated that spaced learning is a successful teaching and learning strategy that enhances long-term memory retention. The following are the main ideas of spaced learning:

Spaced learning involves repeated exposure to information with pauses, allowing the brain to create stronger neural connections and integrate the information [8].

This approach promotes topic interleaving, allowing the brain to link related concepts. Test-taking and retrieval practice are vital components of spaced learning, helping students actively remember material. Research shows that spaced learning and repetition result in superior long-term retention [9]. Spaced repetition has been successfully integrated into educational software and flashcard applications. It is a practical, research-based strategy that can significantly enhance instruction and learning outcomes in various fields, including medical education [10].

Expanding and equally spacing learning is a pedagogical strategy that enhances knowledge retention and understanding. It involves revisiting and reinforcing concepts over time rather than cramming all information into a single session. This procedure allows the brain to consolidate better and retain the material. Spacing out learning sessions at increasing intervals (e.g., 1 day, 1 week, 1 month) is more effective than mass practice [11]. Consistent, evenly distributed practice opportunities help learners build stable mental representations and avoid uneven knowledge gaps. Expanding and equally spacing learning improves long-term retention, enhances knowledge application and transfer, makes study time more efficient, reduces cognitive load, and reinforces knowledge organization. Instructors should design curricula and assessments that revisit key concepts at increasing intervals, with consistent spacing between practice opportunities [12].

Distance learning through mobile technology has become a cornerstone of modern education, offering unprecedented accessibility and flexibility [13]. Its significance lies in democratizing education by reaching geographically isolated or underserved populations [14]. Key features include on-demand access to multimedia resources (e.g., videos, podcasts), interactive quizzes, and micro-learning modules tailored for smaller screens, which cater to diverse learning styles [15]. Mobile platforms also integrate adaptive learning algorithms, enabling personalized pacing and real-time feedback [16]. Benefits encompass cost-effectiveness, reduced infrastructural barriers, and the ability to balance learning with professional or personal commitments.

Mobile interaction enhances participation through push notifications that prompt engagement, gamified elements (e.g., badges, breadboards), and social learning tools such as discussion forums or peer-to-peer messaging [17]. Studies showed that instantaneous interactions—such as responding to polls or collaborating on shared documents—foster a sense of community and accountability, increasing completion rates by up to 30% compared to traditional online courses [18]. By combining convenience with dynamic interactivity, mobile-mediated distance learning bridges gaps in global education access while sustaining learner motivation.

2.2 English scientific vocabulary in ESP classrooms

Including English scientific vocabulary proficiency in ESP classrooms has demonstrated effectiveness in improving students' educational achievements. [19] has emphasized the necessity of vocabulary skills in engineering for non-English department students, highlighting the importance of developing specialized vocabulary in ESP programs. Furthermore, implementing flipped classrooms has greatly enhanced vocabulary acquisition among Iranian students in ESP courses, highlighting the beneficial influence of innovative teaching approaches on vocabulary learning [20], [21]. Moreover, it has been proposed that analyzing the language used in science publications might benefit teachers of ESP. This analysis can help develop customized teaching materials that improve students' understanding of scientific subjects [22]. Incorporating English scientific vocabulary proficiency into ESP

courses using diverse methods and materials is advantageous in promoting successful student learning experiences.

As several study investigations have demonstrated, acquiring a solid command of scientific terminology is paramount in language acquisition. Research has also elucidated that implementing extensive reading programs that focus on nonfiction scientific material can lead to notable enhancements in vocabulary acquisition for individuals learning a second language [23]. Moreover, there is a positive correlation between high school students who view English content on platforms such as YouTube and their improved command of vocabulary. This evidence suggests that exposure to various language sources is crucial [24]. Research has shown that mobile applications built explicitly for language learning, focusing on acquiring vocabulary, are highly beneficial for English as a Foreign Language (EFL) learners. These apps provide flexibility and easy access to practice language skills [25]. Furthermore, there is a correlation between individual variations in learning styles, such as a predilection for auditory learning, the utilization of technology applications, and the adoption of more efficient vocabulary learning techniques by EFL learners [26]. This study highlights the importance of personalized teaching methods in vocabulary instruction. Research has demonstrated that using tools such as flashcards in online learning favors vocabulary growth, emphasizing the need for creative ways of virtual language training [27].

2.3 Mobile-based spaced learning with academic performance in ESP classrooms

Mobile-based spaced learning, such as the flipped classroom model with online video conferencing, has been demonstrated to improve academic achievement in ESP courses. Studies indicate that combining asynchronous and synchronous approaches in online learning can be as effective as traditional offline classrooms regarding interaction and information retention [28], [29]. The flipped classroom method, where students engage with pre-class materials before interactive sessions, has significantly improved listening skills and overall test scores among EFL students [30]. Furthermore, using virtual reality (VR) for experiential learning in ESP courses has shown better outcomes in vocabulary acquisition and student engagement than traditional techniques, demonstrating the value of novel ways of improving academic performance [31].

Mobile-based spaced learning in ESP classes offers numerous benefits, including enhanced vocabulary, creativity, speaking skills, and learning flexibility. Studies have indicated that students prefer online chats via video conferencing platforms such as Zoom and Google Meet, significantly enhancing their language skills [32]. Using synchronous and asynchronous methods in online ESP classes has also proven effective in consolidating material, developing reading skills, and enabling direct communication between students and teachers. These approaches have resulted in successful learning outcomes [33]. Additionally, implementing a flipped classroom approach in ESP courses has shown positive effects. Students have improved their grades and critical thinking skills by engaging in problem-solving tasks during class time, demonstrating the effectiveness of this method in enhancing cognitive abilities and applying knowledge in practical contexts [34].

Despite the pedagogical benefits of implementing spaced learning through mobile technology, several challenges persist that may hinder its effectiveness. Technical limitations, such as device incompatibility and inconsistent internet connectivity,

can disrupt the continuity of learning sessions [27]. Integrating spaced learning technologies into mobile-based learning environments faces multifaceted challenges, including technical, behavioral, and pedagogical barriers. One key issue is the inconsistency of mobile device ecosystems, which vary widely in hardware capabilities, screen sizes, and operating systems, complicating the uniform implementation of spaced repetition algorithms [28]. Additionally, mobile learners often engage in fragmented, on-the-go usage patterns, which conflict with the structured intervals required for effective spaced learning [29]. Distractions inherent to mobile environments—such as competing app notifications and multitasking—further disrupt learners' focus, undermining the cognitive benefits of spaced repetition [30]. Privacy concerns also arise, as spaced learning systems that track and adapt to individual progress must securely manage sensitive learner data to comply with regulations such as GDPR [31]. Finally, designing adaptive algorithms that personalize interval timing without overwhelming users requires balancing computational complexity with intuitive user interfaces, a challenge noted in studies of mobile learning optimization [32]. Addressing these obstacles demands interdisciplinary collaboration to align pedagogical strategies with the practical realities of mobile technology.

2.4 The role of mobile interactivity and adaptive learning features

Mobile interactivity and adaptive learning functionalities markedly improve student engagement and academic achievement. The amalgamation of various technologies cultivates a more tailored and engaging educational atmosphere, essential for sustaining student engagement and enhancing results. The subsequent sections delineate the principal effects of these traits.

Impact on student engagement

1. **Increased participation:** Adaptive e-learning platforms have demonstrated a 10% increase in online discussion engagement and a 15% boost in assignment submissions [36].
2. **Positive cognitive and affective responses:** Students utilizing mobile learning media exhibited elevated cognitive and affective ratings, signifying improved comprehension and motivation [37].
3. **Gamification benefits:** Gamified educational settings are associated with heightened motivation and engagement, with customization options serving as a crucial element [33].

Influence on academic performance

1. **Improved learning outcomes:** Research demonstrates that students utilizing adaptive learning technology attain superior academic performance, with all participants in one study achieving the minimum passing score following the use of mobile media [37].
2. **Enhanced study habits:** Mobile learning applications have revolutionized study practices, resulting in elevated academic performance and retention rates among college students.

Although the advantages of mobile interaction and adaptable learning are apparent, difficulties including digital distractions and equity issues persist. Resolving these difficulties is crucial for optimizing the potential of contemporary instructional technology.

The role of adaptive learning in personalizing education. Adaptive learning systems employ data-driven algorithms to customize educational content according to the individual requirements of each student. These systems perpetually evaluate student performance and modify learning trajectories accordingly, guaranteeing that each learner is provided with content that aligns with their ability level, pace, and learning style. Studies have shown that adaptive learning algorithms can markedly enhance student engagement, retention, and academic achievement relative to conventional learning models [34], [35], [36].

Key features of adaptive learning systems

1. **Personalized learning paths:** Adaptive learning systems develop individualized learning pathways for each student, guaranteeing that the information is pertinent, difficult, and attainable [40], [42].
2. **Real-time feedback:** These systems deliver instantaneous feedback to students, facilitating the identification of strengths and weaknesses and allowing for prompt interventions [42], [37].
3. **Inclusivity and equity:** Adaptive learning systems can mitigate educational disparities by catering to varied learning demands, especially for marginalized and underserved student demographics [41], [38].

2.5 Benefits of mobile interactivity in education

1. **Accessibility:** Mobile devices are extensively available, providing high-quality educational information to pupils irrespective of their geographical location or socioeconomic status [39], [40].
2. **Interactive learning:** Mobile applications frequently integrate interactive components, including gamification, simulations, and multimedia content, which can augment student engagement and motivation.
3. **Personalized content:** Mobile platforms can provide adapted content according to individual student preferences, learning styles, and progress, hence assuring a more customized learning experience.

3 METHODOLOGY

3.1 Design of the study

The current research adopts a quasi-experimental research design, employing both a control group and an experimental group to evaluate the leveraging of a problem. To ascertain the effect of embracing mobile-based spaced learning to improve English scientific vocabulary mastery and academic performance among ESP students. Two groups depend on the time intervals to present equal and expanded content. The equal learning mode, in which distance learning is provided in sessions, is separated by equal time, seven days between sessions. In the second extended learning mode, distance learning content is presented in sessions separated by gradually increasing time. The mean extended break time equals the mean equal break time, which is seven days between sessions. This means it is possible to present a lecture for the first week after seven days, the following week for ten days, the third week for fourteen days, and so on, so that the mean is seven days. The study lasted for two months in the first semester of the university academic year 2024 to conduct this study.

3.2 Participants

The participants comprised sixty male ESP students enrolled in an English for Science course. The students were randomly assigned into two equal groups of thirty participants each to ensure a fair distribution. Randomization aimed to minimize potential biases and create comparable baseline characteristics between the groups. Both groups were balanced regarding gender distribution, age range, and initial academic performance, as measured by a pretest on English scientific vocabulary and prior course grades. These measures confirmed no statistically significant differences between the groups at the outset, ensuring comparability. The groups were structured around distinct learning schedules designed to evaluate the impact of different spaced learning strategies. In addition, the participants have a thorough understanding of using technology and digital applications through mobile phones, as the university system relies primarily on mobile applications in the learning and management process, specifically the Blackboard LMS learning system application, through which experimental treatment was implemented.

In the equal learning style, the first group engaged in distance learning sessions separated by consistent seven-day intervals. In contrast, the expanded learning style adopted by the second group involved sessions with gradually increasing intervals (e.g., seven days, then ten days, then fourteen days), maintaining a mean interval equivalent to the equal group. This division of participants allowed for a comparative analysis of how equal versus expanded spacing intervals affected the mastery of English scientific vocabulary and overall academic performance. By controlling group similarities and using randomized allocation, the study ensured methodological rigor in evaluating the spaced-learning interventions.

3.3 Study tools

The study used cognitive tests of academic performance and language vocabulary tests as pre-posttest to evaluate students' understanding of scientific vocabulary and English proficiency for specific purposes. These tools are incorporated into mobile-based virtual spaced learning environments to provide tailored interventions. Regular assessment and feedback mechanisms enable students to engage with course materials, reinforce their comprehension of scientific terminology, and enhance their academic achievement. The tests include vocabulary exercises, multiple-choice questions, and reading comprehension passages. They measure immediate recall, long-term retention, and the ability to use vocabulary in academic settings. These tools are crucial for enhancing cognitive development and academic performance. The "English for Science" course in the ESP curriculum uses an academic performance test to assess students' proficiency in using English in scientific contexts. The test evaluates critical skills such as scientific vocabulary, reading comprehension, and technical writing. The vocabulary part tests students' ability to match specialized terms with their definitions, while reading comprehension tests their ability to extract and interpret critical information. The writing component focuses on producing clear scientific reports and research proposals, preparing students for their scientific disciplines.

3.4 Data collection procedures

The study uses a systematic data collection process to assess the effectiveness of a mobile-based spaced learning program in the "English for Science" course. Pretests are

administered to establish baseline proficiency in scientific vocabulary and academic performance. Post-tests are conducted to measure improvements in these areas. The scientific vocabulary section requires students to match terms with definitions and use them in context. The academic performance test evaluates English scientific vocabulary, reading comprehension of scientific texts, and technical writing skills. The rigorous data collection process ensures robust and reliable findings, providing valuable insights into the efficacy of spaced learning in ESP contexts.

3.5 The intervention

At the beginning, it was explained to the students that they would be participating in a research study and that the approvals of the Scientific Research Ethics Committee had been obtained for the implementation. Moreover, to ensure effective implementation, students received an orientation on using the Blackboard LMS mobile app for spaced learning. Unlike face-to-face or desktop-based learning, mobile delivery enables anytime, anywhere access, reinforcing learning through spaced sessions, notifications, and interactive features. These elements enhance learner motivation and retention, demonstrating the added value of mobile technologies.

Steps of the intervention:

Orientation session: A warm-up lecture was conducted to introduce students to the two styles of spaced learning equally and expanded. This session ensured that participants understood the methodology and objectives of the study.

Preparation of study tools: A pre- and post-test were carefully designed to measure students' mastery of English scientific vocabulary and academic performance.

Pretest administration: The pretest was administered to all participants to establish a baseline for comparison.

Implementation of the intervention:

First group (equal-spaced learning): During the first month, the intervention was applied to the first group using the equal-spaced learning style. Lectures were conducted consistently, for the same duration and timing throughout the month.

Second group (expanded spaced learning): In the second month, the intervention was applied to the second group using the expanded spaced learning style. In this approach, lecture intervals and durations gradually increased over time, reflecting the expanded spaced learning methodology.

Post-test administration: After completing the two-month intervention, the post-test was administered to all participants to evaluate the effects of the two learning styles on their academic performance and vocabulary acquisition.

Data collection and analysis: Results from the pre- and post-tests were collected and analyzed to assess the comparative effectiveness of the equal and expanded spaced learning styles.

4 RESULTS AND DISCUSSION

4.1 Results

After the fundamental research procedures were finished, the statistical analysis tool (SPSS) was applied in light of the data that had been obtained. The statistical analysis steps are as follows:

This study employs a quantitative research design, which is particularly suitable for examining the impact of mobile-based spaced learning on ESP students' mastery

of English scientific vocabulary and academic performance. Quantitative methods allow for the systematic collection and analysis of numerical data, enabling the researcher to measure variables, identify patterns, and establish relationships with statistical precision. By using pre- and post-tests to evaluate students' vocabulary acquisition and academic performance, this design ensures objective and replicable results. Additionally, the structured nature of quantitative research aligns with the study's aim to assess the effectiveness of a specific intervention—mobile-based spaced learning in an equal style—across a defined sample. This approach provides empirical evidence and facilitates comparisons and generalizations, thereby contributing to a deeper understanding of effective instructional strategies in ESP education. In this section, the authors will show the results of every research question in two parts: the first part is based on academic performance results, and the second part is based on English scientific vocabulary mastery. Every part has a statistical table, including its data, followed by clarifying the interpretation of these data.

To answer the first research question, *what is the impact of mobile-based spaced learning in an (equal) style on ESP students' mastery of English scientific vocabulary and academic performance?*

First: A paired sample T-test was employed to assess the disparity in the mean scores of the pre- and post-tests regarding the first group's English scientific vocabulary mastery. This group was exposed to an experimental treatment using the equally spaced learning style. The following table (refer to Table 1) shows the statistical results.

Table 1. Shows the difference between the mean scores of the equal-spaced learning group's pre- and post-English vocabulary test

T	N	Mean	Std. D	Std. Err	T	Sig
Pre	30	17.63	3.439	.628	3.407	.002
Post	30	18.53	3.126	.571		

Upon analyzing the data for the first research question regarding English vocabulary, we observe a statistically significant disparity between the mean score of the pre-test (17.63) and the mean score of the post-test (18.53) for the English vocabulary assessment at a significance level of (.002), where ($\alpha < 0.05$) favors the post-test. Subsequently, the impact of the evenly distributed learning pattern on students' attainment of English vocabulary was demonstrated.

Second: Concerning the participants' academic performance, a paired sample T-test was used to measure the difference between the pre-test and post-test mean scores for the first group, which was subjected to the experimental treatment in the (equally spaced learning) style. Table 2 shows the results of the analysis of the mean scores.

Table 2. Shows the difference between the mean scores of the equal-spaced learning group's pre- and post-academic performance test

T	N	Mean	Std. D	Std. Err	T	Sig
Pre	30	27.47	5.457	.996	2.732	.011
Post	30	29.10	5.047	.921		

Examining the data related to the first research question on the participants' academic performance: although there is a difference between the average pretest

scores (27.47) and the average post-test scores (29.10) for the cognitive test, this difference is not statistically significant. This conclusion is based on the significance level (.011), which exceeds the threshold of ($\alpha <= 0.05$). Therefore, the results indicate that the spaced learning style with equal intervals does not significantly affect students' academic performance in the cognitive domain.

To answer the second research question, *what is the impact of mobile-based spaced learning in an (expanded) style on ESP students' mastery of English scientific vocabulary and academic performance?*

First, A paired sample T-test was used to assess the disparity between the mean scores of the pre- and post-tests regarding English scientific vocabulary mastery for the second group. This group was exposed to experimental treatment in the expanded-space learning style. The following table (refer to Table 3) shows the statistical results.

Table 3. Shows the difference between the mean scores of the expanded-spaced learning group's pre- and post-English vocabulary test

G	N	Mean	Std. D	Std. Err	T	Sig
Pre	30	20.10	3.546	.647	20.449	.000
Post	30	24.73	3.183	.581		

The data analysis related to the second research question on English vocabulary reveals a statistically significant difference between the mean pre-test scores (10.20) and the mean post-test scores (24.73) on the English vocabulary test. This difference, with a significance level of (.000), is well below the threshold of ($\alpha <= 0.05$), indicating a substantial improvement in favor of the post-test. Consequently, the findings demonstrate the effectiveness of the spaced learning style with extended intervals in enhancing students' achievement in English vocabulary.

Second: Concerning the participants' academic performance in the second group, a paired sample T-test was used to measure the differences between the mean scores of the pre-test and post-test for this group, which was exposed to the experimental treatment in the (expanded spaced learning) style. Table 4 shows the results of the analysis of the mean scores.

Table 4. Shows the difference between the mean scores of the expanded-spaced learning group's pre- and post-academic performance test

G	N	Mean	Std. D	Std. Err	T	Sig
Pre	30	32.47	5.084	.928	8.290	.000
Post	30	39.13	4.659	.851		

The data analysis for Table 4 indicates a statistically significant difference between the mean pre-test scores (32.47) and the mean post-test scores (39.13) on the academic performance test. This difference, with a significant level of (.000), is below the threshold of ($\alpha <= 0.05$), highlighting a significant improvement. Therefore, the findings demonstrate the positive effect of the spaced learning style with extended intervals on students' academic performance in the cognitive domain.

To answer the third question, *what is the impact of the difference between the two types of spaced learning (equal, expanded) on ESP students' mastery of English scientific vocabulary and academic performance?*

First: For English scientific vocabulary mastery, an independent sample T-test was used to measure the difference between the mean scores of the two groups in the post-test. Table 5 shows the results of the mean scores analysis.

Table 5. Shows the difference between the mean scores of the equal and expanded spaced learning groups' English vocabulary post-test

G	Mean	Std. D	Std. Err	t	F	Sig	df	Cohen's d
Equal	18.53	3.126	.571	7.611	0.13	.000	58	1.97
Expand	24.73	3.183	.581					

The analysis of the data related to the third research question on English vocabulary mastery revealed a statistically significant difference between the mean post-test scores of the first group, which used the equal-spaced learning pattern (18.53), and the second group, which used the expanded spaced learning pattern (24.73). The significance level was (.000), which is below the threshold of ($\alpha < 0.05$), indicating a meaningful difference. These results demonstrate that the expanded-spaced learning pattern has a more pronounced effect on English vocabulary mastery among scientific lab majors compared to the equal-spaced style. Furthermore, the large effect size (1.97) underscores the superior efficacy of the expanded pattern in supporting students' academic performance.

Second: To evaluate the participants' academic performance, an independent samples t-test was conducted to compare the mean scores of the two groups in the post-test. The results of the mean scores analysis are presented in Table 6.

Table 6. Shows the difference between the mean scores of the equal and expanded spaced learning groups' academic performance post-test

G	Mean	Std. D	Std. Err	t	F	Sig	df	Cohen's d
Equal	29.10	5.047	.921	8.001	0.14	.000	58	2.06
Expand	39.13	4.659	.851					

The analysis of the data related to the third research question on academic performance reveals a statistically significant difference between the average post-test scores of the first group, which applied the equally spaced learning pattern (29.10), and the second group, which applied the expanded-spaced learning pattern (39.13). The significance level was (.000), which is below the threshold of ($\alpha < 0.05$), indicating a substantial difference. These findings demonstrate that the expanded-spaced learning pattern has a significantly greater effect on students' academic performance in the cognitive domain compared to the equal-spaced pattern. Moreover, the large effect size (2.06) further highlights the superior effectiveness of the expanded pattern in enhancing students' academic achievement.

4.2 Discussion

Before discussing the research questions of the current study, it is important to highlight the relevance of mobile-based spaced learning for ESP students. This approach, rooted in memory and learning theories, is crucial for mastering English scientific vocabulary, directly impacting academic and professional success.

By examining the effects of an equal style of mobile-based spaced learning, this study offers valuable insights into its potential to enhance vocabulary mastery and academic performance, contributing to advancements in technology-driven language education.

Discussion of the first research question results. Upon analyzing the results related to English scientific vocabulary mastery, the findings revealed a significant improvement, with a post-test mean score surpassing the pretest mean score. In contrast, the analysis of academic performance shows a slight increase in post-test scores compared to pre-test scores for the cognitive test. However, this difference is not statistically significant, as indicated by a significance level of (.011), where ($\alpha > 0.05$). Consequently, the equal-spaced learning technique enhances vocabulary acquisition but does not significantly impact students' academic performance in the cognitive domain.

The current study's researchers believe that spaced learning strategies with equal intervals are more effective in improving English scientific vocabulary mastery than in enhancing overall academic performance in the cognitive domain. They think this disparity may be attributed to the nature of vocabulary learning, which benefits significantly from repeated exposure and retrieval practice, core principles of spaced learning. In contrast, academic performance, particularly in broader academic tasks, may require additional factors such as critical thinking, problem-solving, and contextual application, which are not solely addressed by spaced learning techniques. Furthermore, the lack of a significant impact on academic performance could be related to the short duration of the intervention or the specific design of the cognitive test, which may not have fully captured the potential benefits of spaced learning. These findings underscore the need to tailor spaced learning strategies to different educational outcomes and suggest that future research could explore modifications to the technique, such as varying the intervals or incorporating complementary instructional methods, to enhance its impact on cognitive performance. Furthermore, the first research question results align with the findings of [41], [42], and [43] which highlight the positive effectiveness of mobile-based spaced learning. Additionally, the results of this research question align with the principles of Cognitive Load Theory. This theory posits that learning is most effective when instructional design minimizes extraneous cognitive load while optimizing the intrinsic and germane loads necessary for meaningful learning. The study revealed that mobile-based spaced learning, when implemented in an equal distribution style, provided structured intervals for processing and retention, reducing the cognitive overload often associated with intensive learning sessions. This approach facilitated better mastery of English scientific vocabulary and enhanced academic performance by allowing students to consolidate and transfer knowledge more effectively. These outcomes underscore the importance of aligning instructional strategies with cognitive processes to maximize learning efficiency.

Discussion of the second research question results. To address the second research question (*what is the impact of mobile-based spaced learning in an (expanded) style on ESP students' mastery of English scientific vocabulary and academic performance?*), the following section examines the results obtained from the analysis. The data analysis related to the second research question reveals statistically significant improvements in English scientific vocabulary mastery and academic performance when utilizing the expanded spaced learning style. For English scientific vocabulary, the mean post-test score (24.73) was significantly higher than the pre-test score (10.20), with a significance level of (.000), indicating the effectiveness of this style in enhancing vocabulary retention and mastery. Similarly, for academic performance, the mean post-test score (39.13) was significantly higher than the pre-test score

(32.47), also at a significant level of (.000). These findings demonstrate the positive impact of the expanded spaced learning style on students' English science vocabulary mastery and academic performance.

Additionally, the theoretical underpinning of these results can be linked to the spacing effect, a well-documented phenomenon in cognitive psychology suggesting that information is better retained when learning sessions are spaced apart rather than massed together. This approach leverages the benefits of repeated exposure and reinforcement, which are critical for vocabulary retention and mastery. This improvement is consistent with findings from [41], who reported significant differences in cognitive achievement and statistical skills favoring expanded-spaced learning groups. The application of spaced learning can be understood through constructivist learning theory, which posits that learners construct new knowledge based on their experiences. Spaced learning enables students to progressively augment their prior knowledge, leading to more profound understanding and improved academic outcomes.

Moreover, these results align with the principles of the "Connectivism Theory." This theory emphasizes the role of technology and the formation of networks in facilitating learning, particularly in environments where knowledge is distributed across multiple platforms. The results demonstrated that virtual-spaced learning in an expanded style effectively enhanced students' scientific vocabulary mastery and academic performance. This can be attributed to the connectivism framework, which highlights the importance of learners actively engaging with diverse, interconnected resources and collaboratively constructing knowledge. By leveraging virtual tools and spaced repetition, students could form stronger cognitive connections, reinforcing their vocabulary acquisition and academic achievement. These findings underscore the relevance of connectivism in designing innovative and effective educational interventions for ESP learners.

Discussion of the third research question results. To address the third research question (*what is the impact of the difference between the two types of spaced learning (equal, expanded) on ESP students' mastery of English scientific vocabulary and academic performance?*), the results revealed significant differences in both English vocabulary mastery and academic performance between the two groups employing different spaced learning styles. For English vocabulary mastery, the second group, which applied the expanded spaced learning style, achieved a higher mean post-test score (24.73) compared to the first group, which applied the equal spaced learning style (18.53), with a statistically significant level of (.000) ($\alpha < 0.05$). Similarly, in the academic performance, the second group outperformed the first, with post-test scores of 39.13 and 29.10, respectively, also at a statistically significant level of (.000). These findings highlight the superior efficacy of the expanded spaced learning pattern over the equal spaced pattern in enhancing both vocabulary mastery and academic performance. The large effect sizes, 1.97 for vocabulary mastery and 2.06 for academic performance, further reinforce the substantial advantage of the expanded pattern.

From the researchers' perspective, these results can be interpreted through the lens of learning theories, particularly the spacing effect, which posits that distributing learning sessions over progressively longer intervals allows for deeper cognitive processing and retention. By increasing intervals over time, the expanded spaced learning pattern likely provided students with more opportunities for retrieval practice and meaningful engagement with the material, thereby strengthening long-term retention and transfer of knowledge. Additionally, these findings align with constructivist learning theories, emphasizing the importance of active engagement and gradually building knowledge structures through repeated exposure and reinforcement. Furthermore, these results confirm the effectiveness of the expanded spaced

learning pattern and highlight its practical implications for instructional design, particularly in ESP contexts. By tailoring learning strategies to maximize retention and performance, educators can more effectively support students in mastering specialized vocabulary and improving academic outcomes. These findings contribute to the growing body of evidence advocating for adaptive and flexible learning techniques to enhance educational practices in diverse settings. Moreover, these results align with [4] and [44] studies that proved the positive effects of these strategies.

Furthermore, the findings of this study question align with Norman's Information Processing Theory. This theory emphasizes the importance of encoding, storage, and retrieval processes in effective learning. Moreover, the results indicate that expanded-spaced learning offers superior benefits in promoting long-term retention and application of vocabulary and academic concepts. These outcomes are consistent with the theory's assertion that distributed practice enhances the consolidation of information in memory, allowing for deeper cognitive processing and improved recall. The findings suggest that expanded spacing optimizes the encoding process by providing intervals encouraging reflection and repeated engagement with the material, thus strengthening mastery and academic performance.

The researchers of the current study think that the limitations and implications of this study are essential for enhancing its academic rigor and demonstrating a critical understanding of its findings. While the study provides valuable insights into the effectiveness of mobile-based spaced learning in ESP education, it acknowledges certain limitations. Specifically, the research was conducted with a limited sample size from a single institution, which may restrict the generalizability of the results. Furthermore, relying on specific virtual learning tools may not comprehensively represent all available technologies. These limitations, however, open avenues for further investigation. Future studies could address these constraints by including larger, more diverse samples across multiple institutions and exploring the effectiveness of various technological tools in different ESP contexts. Additionally, longitudinal research could examine the long-term impact of mobile-based spaced learning on vocabulary retention and overall academic performance. By expanding the scope and addressing these limitations, future research can build on this study's foundation, contributing to a more profound understanding of innovative teaching approaches in ESP education. Despite these limitations, this study offers a significant starting point for advancing the integration of mobile-based learning strategies and highlights promising directions for further exploration in the field.

5 RECOMMENDATIONS

While not directly measured, variations in prior ESP knowledge, motivation, and engagement were mitigated through pre-assessments and structured support. External factors such as study habits and tech familiarity were minimized using standardized LMS and uniform materials. Future research could expand the sample and explore these variables further. Considering the current research findings, the study recommends the following:

1. Integrating spaced learning into mobile-based learning environments to take advantage of their features and interactive benefits.
2. Designing mobile-compatible ESP modules with adaptive feedback loops.
3. Comparisons between mobile-based and desktop-based spaced learning methods.
4. Exploring AI-based adaptive spaced learning techniques for ESP learners.

6 CONCLUSION

This study revealed that mobile-based spaced learning significantly improves English scientific vocabulary acquisition in ESP students and enhances academic performance. Both equally spaced and expanded-spaced learning methods significantly improve vocabulary acquisition, but the expanded-spaced learning method significantly impacts academic performance. The researchers suggest that the intervals at which learning sessions are spaced may play a critical role in cognitive processing and long-term retention. The expanded-spaced learning method offers repeated reinforcement over a more extended period, leading to better integration of knowledge and skills and supporting more robust academic outcomes. The lack of significant difference between equally spaced and expanded spaced learning for vocabulary acquisition suggests that the spacing effect works effectively in both formats for language learning. However, the extended reinforcement provided by expanded-spaced learning appears to be more beneficial for complex cognitive tasks. This insight is crucial for educators designing ESP curricula, suggesting a targeted application of expanded-spaced learning techniques for subjects requiring deeper cognitive engagement. Future research should explore the long-term effects of these learning methods and their applicability to other subject areas and student populations. Understanding the interaction between spaced learning techniques and individual learner characteristics can help tailor educational interventions to maximize effectiveness.

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10 ETHICS

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