

THE IMPACT OF DIGITAL FLASHCARDS BASED ON SPACED REPETITION SYSTEMS (SRS) ON VOCABULARY ACQUISITION AND RETENTION FOR L2 LEARNERS: A SYSTEMATIC LITERATURE REVIEW

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Abstract: This study aims to bridge the knowledge gap regarding the effectiveness of digital flashcards based on Spaced Repetition Systems (SRS) in improving second language (L2) vocabulary acquisition and retention in long-term memory. Methodologically, the paper adopted the Systematic Literature Review (SLR) framework according to "Kitchenham" guidelines, conducting a comprehensive survey of six major academic databases covering intellectual production from 2015 to 2025. Through a rigorous screening process of 210 research papers, 27 empirical studies that met quality and inclusion criteria were extracted and analyzed. The results showed that SRS algorithms statistically and pedagogically outperform traditional intensive memorization methods, particularly when integrated with multimodal inputs, significantly enhancing receptive vocabulary. However, the analysis revealed fundamental challenges represented by the limited impact on productive skills (speaking and writing) and the phenomenon of "excessive reliance on visual cues". The study concludes that the maximum effectiveness of these tools is only achieved by shifting from ready-made cards to "User-Generated Content" and integrating "Gamification" strategies to ensure learning sustainability and overcome the boredom of repetition.

Keywords: Digital Flashcards, Spaced Repetition Systems, Vocabulary Acquisition, L2 Learners, Systematic Literature Review

Introduction

Vocabulary learning is considered a central pillar in second language acquisition because the breadth of lexical knowledge is directly linked to the learner's ability to construct meaning during reading, and it appears as a strong factor supporting reading comprehension among bilingual learners (Fraser et al., 2017). In listening, evidence indicates that lexical knowledge (alongside grammatical knowledge when measured by receptive auditory tasks appropriate to the nature of listening) explains a large portion of the variance in performance on academic listening tests (Cai, 2020). Additionally, "auditory vocabulary" and the ability to segment speech streams into words (lexical segmentation) contribute to predicting listening comprehension, which clarifies that vocabulary is not merely formal knowledge but rather a rapid processing skill that supports fluency and real-time comprehension (Lange & Matthews, 2020). Nevertheless, the learner faces a dual lexical challenge: a large number of words

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required to be acquired versus limited exposure opportunities in daily input, which drives much of the learning to be incidental based on exposure (Bisson et al., 2015). The difficulty increases due to high forgetting rates, as delayed tests show a decline in recall after a period, which highlights the need for repeated exposure and supporting learning with multimodal inputs to improve retention (Bisson et al., 2015).

Learners tend to lose an increasing portion of information as more time passes after learning if memory is not supported through subsequent review, which captures the general idea of the forgetting curve without going into technical detail (Murre & Dros, 2015). Therefore, relying on incidental exposure to vocabulary or last-minute cramming may improve immediate performance, but it often fails to secure durable knowledge because the learning effect typically weakens quickly over time (Murre & Dros, 2015). Learning research indicates that massed practice (cramming) can appear effective in the short term, whereas review distributed over time provides a stronger basis for building longer-lasting memory (Smolen et al., 2016). For this reason, planned, systematic review—especially when it involves repeated retrieval rather than rereading alone—is more efficient for resisting forgetting and strengthening retention (Kang, 2016). In L2 vocabulary learning, studies show that temporally distributed review outperforms cramming on delayed recall measures, supporting the need for long-term retention strategies rather than short-term solutions (Lotfolahi & Salehi, 2017).

Digital spaced-repetition tools (SRS) are systems that use algorithms to automatically adjust review intervals based on the learner's performance in retrieval (correct/incorrect), so that difficult cards are presented sooner and easy ones are postponed to longer intervals (Settles & Meeder, 2016). They have become widespread because they address the problem of forgetting that increases over time through planned reviews rather than relying on incidental exposure (Murre & Dros, 2015), and because they embody the principle that practice distributed over time supports more stable learning than intensive review (Kang, 2016). Their digital advantage lies in personalization, performance tracking, reminders, flexibility of time and place, and the ease of creating vocabulary sets according to the goal (Seibert Hanson & Brown, 2020a). Digital flashcards are used in practice in a front/back format (the word versus the meaning/translation), with examples, audio, and images when needed, which supports active retrieval, feedback, and repeated exposure, and regular study through a mobile spaced-repetition tool has been associated with improvement in vocabulary learning/performance among second-language learners (Seibert Hanson & Brown, 2020).

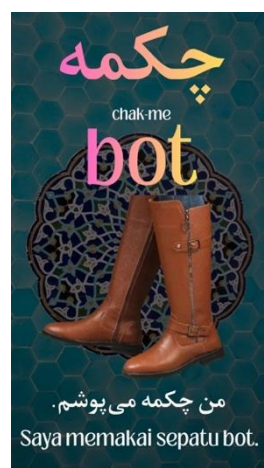


Figure 1: language Flachcard's Example.

Traditional flashcards originated in the 19th century as a teaching tool to enhance memorization

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through cards containing concise information. Their systematic application was later revolutionized by the introduction of the 'Leitner System' in the 1970s, which laid the theoretical foundation for spaced repetition. In the late 1990s and early 2000s, technology improved and digital flashcards were created. These cards use electronic applications that allow for structured repetition and interaction, which makes learning more effective by helping people remember information (Huang et al., 2025). The use of digital flashcards in foreign language learning has increased significantly in the past two decades, with the proliferation of smartphones and the launch of gamified platforms like Memrise (2010) and Duolingo (2012). These tools facilitated learning outside the classroom, particularly since the early 2010s (Saputra et al., 2025; Zakian et al., 2022a). Recent studies have shown that digital flashcards outperform traditional methods in improving vocabulary acquisition and long-term retention, and their use has expanded to include grammar learning since 2020 (Serfaty & Serrano, 2020). Since the late 2010s, early childhood education has utilized technologies like virtual reality-enhanced flashcards to improve children's vocabulary learning (Chen & Chan, 2019). Overall, the transition from paper to digital flashcards marks a significant shift in language learning tools, utilizing technology to improve interaction and information retention.

Studies of digital flashcards based on SRS typically measure “vocabulary acquisition” as the initial learning that appears in an immediate test after learning, while “retention” is measured through a delayed test (such as one week or one month) to monitor what remains after forgetting increases over time (Zaidi et al., 2020). The results also vary depending on the structure of the measurement itself: whether the requirement is recognition/reception (receptive) or recall/production (productive), and whether vocabulary is viewed as breadth or depth, because each test type captures a different aspect of lexical knowledge. The benefits sometimes appear strong and sometimes fluctuating due to differences in intervention length, learners’ proficiency level, the target language, the test format, content characteristics, and the degree of adherence to the review schedule that the algorithms regulate. Therefore, a research gap emerges in that evidence exists but is scattered, with a need for an up-to-date systematic literature review that determines when and for whom scheduling algorithms are more effective in supporting acquisition and retention.

To bridge this research gap, we formulated research questions that guide the systematic review to determine how the constructs of vocabulary acquisition and retention are measured, when scheduling algorithms are more effective, and how the type of assessment (receptive/productive, and breadth/depth) affects results across studies. Table 1 below shows the research questions, the objectives, and the analytics strategy.

Table 1: Research Questions, Objectives, and Analytical Strategy.

Code	Research Question	Objectives	Analytical Strategy
RQ1	What are the recent research trends in the use of SRS-based digital flashcards for L2 vocabulary acquisition and retention?	To map recent research directions and patterns on SRS flashcards in L2 vocabulary learning.	Use descriptive statistics to generate trend graphs and interpret them through narrative explanation.
RQ2	What are the reported benefits of using digital SRS-based flashcards for vocabulary learning?	To synthesize the learning benefits reported for SRS flashcards in L2 vocabulary study.	Identify and list the reported benefits across studies and synthesize them through narrative description in context.
RQ3	What are the reported challenges encountered in implementing digital SRS for vocabulary learning?	To identify the main barriers and limitations reported when using digital SRS flashcards for L2 vocabulary learning.	Identify and list reported challenges across studies and synthesize them through narrative description in context.
RQ4	What are the key factors influencing the effectiveness of digital SRS?	To determine the main learner-, design-, and context-related factors shaping the effectiveness of digital SRS for L2 vocabulary learning.	Code factors reported in each study (learner, SRS/flashcard design, learning context), then narratively compare how each factor is linked to outcomes across studies.
RQ5	What practical recommendations can be derived from the literature for SRS implementation?	To derive actionable guidance for learners and educators on implementing digital SRS flashcards for L2 vocabulary learning.	Collect all practice recommendations reported in the included studies, consolidate overlapping points, and present them narratively as organized,

Literature review

In this chapter, we will review prior literature on L2 learning and vocabulary retention, summarizing key research trends and findings and explaining them in detail in relation to the present study. The chapter aims to clarify the current research gap and show why this literature review is needed to better understand the impact of SRS-based digital flashcards on L2 vocabulary acquisition and retention.

The first study, *The Usage of MALL for Vocabulary Acquisition: A Systematic Review (2019–2023)* (2023), is a PRISMA-guided systematic review that synthesizes 15 articles on Mobile Assisted Language Learning (MALL) and vocabulary acquisition. However, it does not treat the spaced repetition system (SRS) scheduling mechanism as a primary analytic variable, meaning its conclusions do not directly evaluate the effectiveness of algorithm-driven review intervals (Mijan & Hashim, 2023). The second study, *Computer-Based Vocabulary Learning in the English Language: A Systematic Review (2022)*, also follows PRISMA and covers a larger body of evidence (40 articles) on computer-based vocabulary learning in English, yet it similarly does not isolate SRS as a core variable and does not provide a focused analysis of digital flashcards as a distinct tool with specific learning and assessment features (Regina & Anitha Devi, 2022). These limitations point to the need for a focused systematic review that explicitly links SRS-based digital flashcards to L2 vocabulary acquisition and delayed retention, while also clarifying the conditions under which algorithmic scheduling is most effective.

The third study, *Mobile-assisted ESL/EFL vocabulary learning: a systematic review and meta-analysis (2019)*, reviewed 33 studies and examined L2 vocabulary learning through mobile-assisted language learning (MALL), with particular attention to word retention and common delivery channels such as SMS/MMS and mobile applications. However, it did not define the spaced repetition system (SRS) scheduling mechanism as a primary analytic variable, so its synthesis does not directly test the contribution of algorithm-based interval scheduling; moreover, flashcards were not treated as a distinct intervention that could be evaluated separately from other MALL approaches (Lin & Lin, 2019). The fourth study, *A systematic review of empirical studies on computer-assisted language learning (2023)*, included 36 studies, followed PRISMA, and set out to document patterns in empirical CALL research in foreign language learning overall—for example, the technologies investigated, the variables examined, the duration of interventions, and the assessment instruments used. Consequently, it offers a broad mapping of CALL rather than a targeted evaluation of SRS-based digital flashcards for vocabulary acquisition and delayed retention, and it does not provide a focused analysis of algorithm-driven scheduling effectiveness (Saylan et al., 2023). Taken together, these reviews show that relevant evidence exists within MALL and CALL more generally, yet a focused synthesis is still needed—such as the present study—to connect SRS-based digital flashcards specifically to L2 vocabulary acquisition and retention outcomes.

The fifth study is a systematic literature review on smartphone applications for teaching English in EFL contexts (2022) that follows PRISMA and synthesizes 45 studies, focusing broadly on smartphone-based applications for English teaching and overall language skills rather than isolating digital flashcards or evaluating SRS scheduling as a primary analytic variable (Ibna Seraj & Rahmatullah, 2022). The sixth study, *Review of Studies on Technology-Enhanced Language Learning and Teaching (2020)*, surveys a very large evidence base (398 articles) across technology-enhanced language learning and teaching, organized using Creswell's review recommendations, and it similarly

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does not cover SRS as a primary variable or treat digital flashcards as a distinct analytical category (Shadiev & Yang, 2020). As a result, both reviews provide valuable high-level mapping of smartphone- and technology-supported language education, but they do not offer a focused synthesis of algorithm-driven spaced repetition mechanisms or flashcard-specific features and outcomes in L2 vocabulary learning. This leaves the evidence base fragmented for questions about how SRS-based digital flashcards relate to vocabulary acquisition versus delayed retention and under which conditions algorithmic scheduling is most effective.

The seventh study, *Recent developments in mobile-assisted vocabulary learning: a mini review of published studies focusing on digital flashcards* (2024), presents a mini review (rather than a full systematic literature review), discussing recent empirical work on mobile-assisted vocabulary learning (MAVL) with an emphasis on digital flashcards, spaced repetition, and vocabulary retention. However, its methodology is less transparent for systematic synthesis because it does not specify the total number of included studies and does not report a PRISMA-based selection process, which creates a methodological gap when trying to draw reproducible conclusions about SRS-based interventions (Teymouri, 2024). The eighth study, *A Review of Research on Technology-Supported Language Learning and 21st Century Skills* (2022), is a PRISMA-guided systematic review of 34 articles that maps technology-supported language learning in relation to “21st-century skills” (e.g., communication and collaboration) alongside language skills. While valuable for positioning technology-supported language education within broader skill-development agendas, it remains thematically broad and, as such, it did not cover SRS as a primary variable and did not provide a dedicated analysis of digital flashcards or vocabulary outcomes as the central analytic focus (Shadiev & Wang, 2022). This leaves a clear need for a more tightly scoped synthesis that directly evaluates SRS-based digital flashcards in terms of L2 vocabulary acquisition and delayed retention outcomes.

The ninth study, *Mapping the Evolution of Arabic Language Teaching and Acquisition: A Bibliometric and Systematic Review of Second Language Research (2013–2023)* (2024), applies PRISMA and synthesizes 30 articles to map publication patterns and research trends in Arabic language teaching, second-language acquisition, language education, and educational technology, with an explicit emphasis on describing trends rather than estimating instructional effectiveness (Alyaqoubi et al., 2024). However, because its analytic focus is trend-mapping, it did not cover SRS as a primary variable and does not examine digital flashcards as a focal intervention linked to vocabulary acquisition and delayed retention outcomes. The tenth study, *AI-Driven Vocabulary Acquisition in EFL Higher Education: Interdisciplinary Insights into Technological Innovation, Ethical Challenges, and Equitable Access* (2025), is a PRISMA-guided systematic review of 58 studies that surveys AI-driven approaches to vocabulary learning in higher education and foregrounds issues such as innovation, ethics, and equity in access (Elmahdi et al., 2025). Nevertheless, its scope remains broad in terms of AI tools and considerations, and it did not cover SRS as a primary variable; additionally, flashcards are not treated as a core analytic variable for explaining vocabulary outcomes across studies.

Taken together, these ten reviews make an important contribution by mapping broad developments in mobile-assisted learning, computer-assisted language learning, technology-enhanced language education, and related agendas (e.g., 21st-century skills, AI innovation, ethics, and equity). However, they do not resolve the specific research problem at the center of the present inquiry. Across the set, SRS is rarely operationalized as a primary analytic variable, digital flashcards are often not isolated as a distinct intervention category, and vocabulary outcomes are frequently treated as secondary to wider educational aims. In addition, methodological choices in some reviews (e.g., mini-review formats or non-PRISMA or non-Kitchenham approaches) can limit reproducibility and comparability when evaluating effectiveness. Consequently, despite their value, the existing evidence

remains fragmented with no clear consensus about when, for whom, and under which conditions SRS-based digital flashcards support L2 vocabulary acquisition and delayed retention. This gap underscores the need for the current systematic literature review.

Metode Penelitian

This systematic literature review adopts the core methodological principles proposed by Kitchenham for conducting evidence-based reviews in the fields of computing and information technology, by applying the three fundamental stages of planning, execution, and reporting to organize the whole process (Kitchenham & Charters, 2007). Within this framework, the review protocol was first specified and refined and then used to guide manual searches of the literature. Thereafter, transparent screening procedures were carried out, followed by systematic data extraction and synthesis. Figure 1 illustrates the three main stages and the internal procedures within each of these stages.

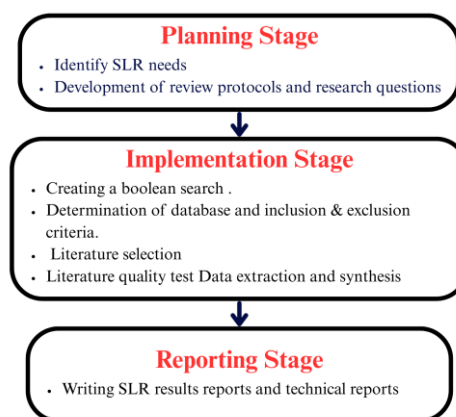


Figure 1: Kitchenham Guidelines Stages.

Planning Stage

The first stage of this review is pivotal because it paves the way for clarifying the importance of the study, its objectives, and the gaps it seeks to address. In this stage, the broader context of vocabulary learning through digital flashcards based on spaced repetition was explored, both theoretically and practically, and it is also necessary at this stage to revisit previous literature reviews in order to identify the questions they have answered and those they have left unresolved, and to delineate the gaps clearly. This process made it possible to specify the research gap with greater precision. On this basis, a set of focused, coherent, and clear research questions was formulated to align fully with the aims of the review and to guide the analysis effectively. At the same time, an appropriate methodological protocol—Kitchenham's protocol—was selected to provide a clear roadmap for the subsequent steps, from identifying and screening studies through to analysing and presenting the findings (Kitchenham & Charters, 2007).

Implementation Stage

The implementation stage in this study comprises a series of interrelated steps, beginning with the selection of six major databases as literature sources, namely: ACM Digital Library, IEEE Xplore, ProQuest, ScienceDirect, Scopus, and Taylor & Francis. The literature search was conducted using

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keywords combined through Boolean operators in order to obtain more accurate and comprehensive results. The primary keywords used in this study are: "Digital Flashcards", "Spaced Repetition Systems (SRS)", "Vocabulary Acquisition", and "L2 Learners". To ensure that the search results are relevant and comprehensive, a table will be prepared that includes a list of the synonyms used for each of these keywords, in accordance with the search mechanism of each database. Table 2 presents the adopted synonyms for each keyword used in the search strategy.

Table 2 : Keywords and Synonyms of Keywords

Keyword	Keyword Synonyms
Digital Flashcards	"Digital Flashcards" OR "Electronic Flashcards" OR "Online Flashcards" OR "Mobile Flashcards" OR "Flashcard Software" OR "Flashcard Application" OR "Computer-Based Flashcards" OR "Anki"
Spaced Repetition Systems (SRS)	"Spaced Repetition" OR "Spaced Repetition System" OR "SRS" OR "Spaced Practice" OR "Spaced Retrieval" OR "Retrieval Practice"
Vocabulary Acquisition	"Vocabulary Acquisition" OR "Vocabulary Learning" OR "Vocabulary Knowledge" OR "Vocabulary Retention" OR "Word Acquisition" OR "Word Learning" OR "Lexical Acquisition" OR "Vocabulary" OR "Retention" OR "Recall" OR "Long-term Memory" OR "Lexis" OR "Lexical"
L2 Learners	"L2 Learners" OR "L2 Learning" OR "Second Language Learners" OR "Second Language Acquisition" OR "SLA" OR "Foreign Language Learners" OR "Language Learning" OR "Language Education" OR "EFL Learners" OR "ESL Learners"

Furthermore, the search included reviewing some leading journals in the fields of language education and Human-Computer Interaction, with the aim of expanding the scope of relevant studies. The SCImago Journal Rank (SJR) was used to identify the highest-ranked and most influential journals in these two fields, which ensures the credibility of the sources consulted and their valuable scholarly contribution within the scope of this study. Subsequently, the search was conducted across various databases using the keywords previously mentioned in Table 2, focusing on each article's title, keywords, and abstract. The retrieved articles were then organized, managed, and screened using Mendeley Reference Manager to support a rigorous filtering and analysis process for the sources that passed the initial screening stage. The article selection process was carried out carefully, based on the inclusion and exclusion criteria in Table 3.

Table 3 : Keywords and Synonyms of Keywords

Stage	Inclusion Criteria	Exclusion Criteria
Stage 1: Initiation	1) Topic: SRS + digital flashcards + vocabulary + L2 learners. 2) English + journal/conference paper + published 2015–2025.	1) Not aligned with SRS/flashcards/vocabulary/L2. 2) Not in English, not a journal/conference paper, or published before 2015.
Stage 2: Title & abstract	1) Title and abstract match research aims and questions. 2) Discusses digital flashcards and SRS in L2 learning.	1) Duplicate or review paper. 2) SRS discussed outside language learning.
Stage 3: Full-text selection	1) Addresses the research questions. 2) Describes SRS-related technologies/features and their challenges/impact on vocabulary.	1) Does not address research questions or relevant technologies/features. 2) Does not report challenges or impact on vocabulary.

In order to ensure recency and scientific relevance, while at the same time ensuring broad and in-depth scholarly coverage of the research topic, the scope of the literature search was limited to publications from the last ten years, specifically from 2015 to 2025. The articles were selected through four successive stages; the first stage began with searching for potential studies across multiple databases. After that came an initial screening stage based on the articles' titles and abstracts to verify their relevance to the study topic. Next, in the third stage, the articles that passed the preliminary screening were read in full and evaluated according to predetermined criteria. In the final stage, a systematic quality assessment was conducted on the selected articles. This selection process is visualized in Figure 2.

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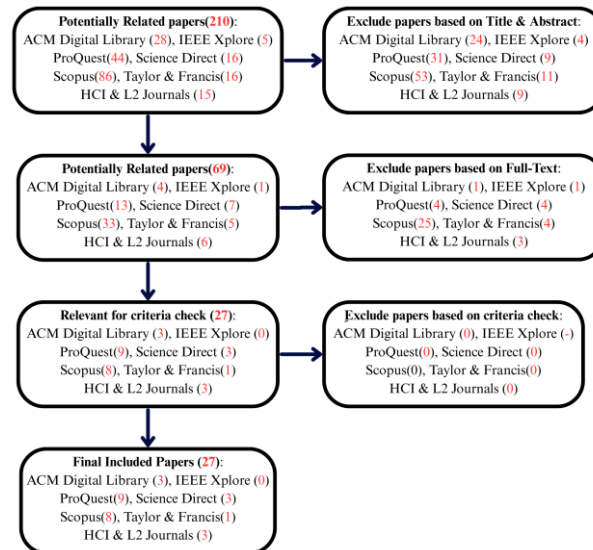


Figure 3: Visualization of Final Paper Selection

Figure 3 illustrates the study screening workflow across four successive stages; first, 210 potentially relevant studies were collected from the selected databases and journals, after which some studies were excluded based on title and abstract screening, leaving 69 studies. Subsequently, full-text screening was conducted to reduce the set to 27 studies, and then relevance and quality criteria were applied to determine the final sample (27 studies).

The subsequent stage of the research involves assessing the quality of the literature to ensure its relevance and that it meets criteria supporting the study's validity. The assessment covers the alignment of study objectives with the research topic, the depth and breadth of prior literature reviews, the suitability of methodologies, the validity of results, the strength of conclusions, and the reputation of the publication venue, which is measured using the SCImago database. The evaluation is conducted quantitatively on a 0–1 scale, where 0 indicates non-compliance and 1 indicates high compliance(Hidayat et al., 2025). For a study to be included in the final sample, it must achieve a minimum of 5 points out of an eight-criterion checklist. Details of the questions used in this quality control process are provided in Table 4.

Table 4: Literature Quality Test Questions

Checklist	Question Checklist
C1	Does the article clearly describe its aims and research questions?
C2	Does the article include a literature review, background, and research context?
C3	Does the article present previous research to demonstrate the main contributions of the research?
C4	Does the article clearly describe the methodology used?
C5	Does the article have research results that answer the research question?
C6	Does the article present relevant conclusions to the objectives and research questions?
C7	Does the article suggest future improvements?
C8	Scopus indexed (Q1/Q2/Q3/Q4) or Conference Paper?

After completing the final screening stage based on full-text review, the resulting 27 papers underwent a quality assessment. All of these papers achieved scores above 6 points, which confirms that they surpassed the established minimum threshold of 5 points. This indicates that they meet the required quality standards and are therefore eligible to be included in the final list of studies.

Reporting Stage

At the reporting stage, this study adopts a narrative approach to present the findings of the systematic review and to synthesize the evidence related to the topic: the impact of digital flashcards based on spaced repetition systems (SRS) on vocabulary acquisition and retention among L2 learners. The results are then organized systematically into five sub-sections to answer the research questions. RQ1 addresses recent research trends in the use of SRS-based digital flashcards for L2 vocabulary acquisition and retention, whereas RQ2 presents the reported benefits of using these flashcards for vocabulary learning. RQ3 reviews the challenges encountered in implementing digital SRS for vocabulary learning, and RQ4 identifies the key factors influencing the effectiveness of digital SRS. Finally, RQ5 provides practical recommendations derived from the literature to support effective SRS implementation.

Results and Discussion

Addressing RQ1. What are the recent research trends in the use of SRS-based digital flashcards for L2 vocabulary acquisition and retention?

The research trends in the field of Human–Computer Interaction (HCI) related to language learning based on digital flashcards and spaced repetition systems (SRS) will be analyzed through four main visualizations. This includes tracking publication trends by year to monitor the development of research interest and examining the distribution by article type (journal article/conference paper) to reflect prevailing academic orientations. In addition, the distribution of studies by database will be presented as the primary retrieval sources. The research contexts will also be displayed by country to highlight the geographical spread of the literature and to identify potential gaps that may guide future studies. Figure 3 below illustrates the distribution of papers by year.

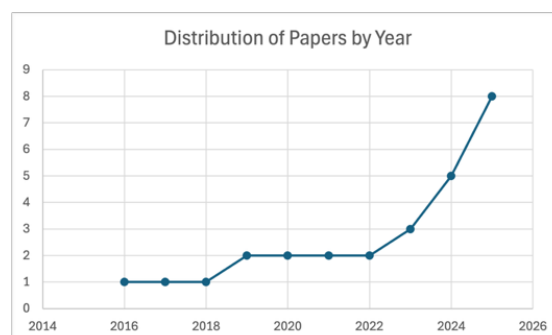


Figure 4: Distribution of Papers by Year

The temporal distribution of publications shows a relative stability in the number of studies during the period 2020–2022, which may be attributed to the impacts of the COVID-19 pandemic on the course of research and scientific publishing. After that, a clear increase in the number of articles is recorded during 2023–2025, which reflects a rising research interest in the topic and its transformation into notable research (Trend) in recent years. Figure 4 below illustrates the distribution of papers by Country.

The shift to online learning might seem to favor digital tools, but the lack of progress is due to how the pandemic was handled, which is often called "Emergency Remote Teaching" (ERT). Unlike planned

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e-learning, ERT was more about short-term survival (like getting connected and using an LMS) than about making specific teaching tools like flashcards work better. Moreover, executing stringent experimental research proved challenging; researchers forfeited control over the learning environment, where extraneous variables—such as technical discrepancies, domestic distractions, and pandemic-induced anxiety—could undermine the validity of data concerning vocabulary retention.

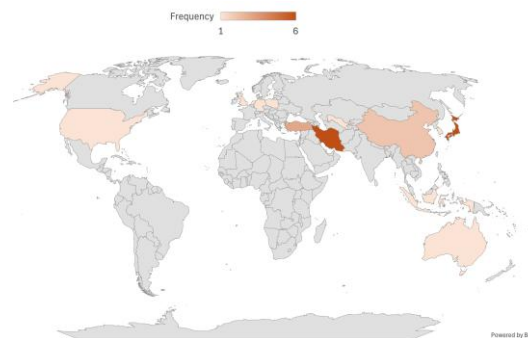


Figure 5: Number of Papers per Country

Figure 4 indicates the analysis of the geographical distribution shows that Iran and Japan are the top contributors to this field, with six publications each. If you look more closely at the authors' affiliations, you'll see that these articles were not written by people from only one school in either country. For instance, the Iranian studies are distributed across distinct universities, such as Kharazmi University and Islamic Azad University, while the Japanese studies stem from various institutions like Okayama University, Waseda University, and Osaka Metropolitan University. Rather than being the product of a singular regional research group, the fact that these studies come from a variety of academic institutions indicates a robust national interest in CALL within these settings.

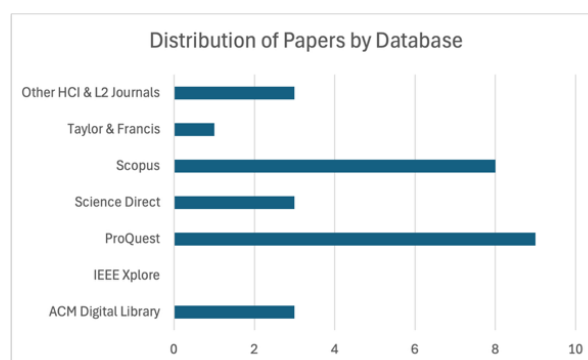


Figure 6: Distribution of Papers by Database

The figure shows the distribution of research papers according to the databases used in retrieval, which reflects variation in the contribution of each database to compiling the relevant literature. It is evident that ProQuest and Scopus accounted for the largest share of papers, followed by databases such as ScienceDirect and ACM Digital Library and other specialized sources, while limited representation appears for both Taylor & Francis and IEEE Xplore. These results indicate a notable reliance on certain databases as main sources of publications. Figure 6 below illustrates the distribution of papers by Article Type.

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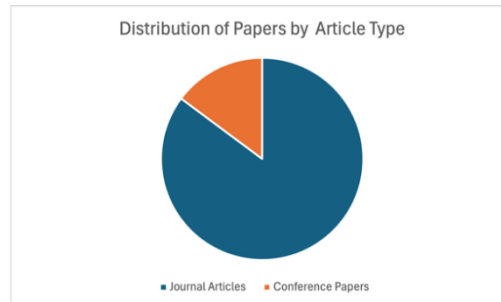


Figure 7: Distribution of Papers by Article Type.

The figure shows the distribution of research papers by publication type, as the proportional chart indicates a clear dominance of articles published in scientific journals compared with conference papers. It also suggests that most scholarly output in this field prefers peer reviewed publication channels with more detailed theoretical and methodological review, while the contribution of conferences represents a relatively smaller share. It may further reflect researchers' tendency to document findings as completed studies published in specialized journals rather than presenting them initially at conferences. Finally, Figure 8 illustrates the distribution of the reviewed papers categorized by the target languages.



Figure 8: Distribution of Reviewed Papers by Target Language.

Figure 8 illustrates the distribution of the reviewed papers categorized by the target language. These articles were written by authors from different schools in many countries targeting ESL, which is why most of the studies (n=20) were chosen. There are two studies on Spanish, while there is only one study (n=1) on each of the other languages: Swahili, Hindi, French, Japanese, and Esperanto. The distribution indicates that most current research concentrates on the acquisition of English vocabulary. However, a wide range of language situations can effectively utilize digital flashcards and SRS.

Addressing RQ2. What are the reported benefits of using digital SRS-based flashcards for vocabulary learning?

To answer the second research question (RQ2), this study summarizes the pedagogical benefits of using mobile digital flashcards in vocabulary learning, as reported in recent literature. Accordingly, the results are presented in Table (5), which consolidates the key benefit themes along with the supporting references for each theme, to facilitate comparison and inference, following a unified classification derived from the studies.

Table 5: Reported Benefits of Digital Flashcards for Vocabulary Learning

No	Benefit	No. of Studies
1	Enhancing Long-term Vocabulary Retention	25
2	Personalization and Adaptive Learning	24
3	Improving Receptive Vocabulary Knowledge	20
4	Superiority over Traditional Methods (Paper/Lists)	19
5	Enablement of Microlearning (Learning On-the-Go)	18
6	Facilitation of Multimodal Learning (Dual Coding)	17
7	Increased Motivation and Engagement (Gamification)	17
8	Provision of Immediate Feedback	17
9	Promotion of Learner Autonomy	17
10	Improvement of Learning Efficiency	17
11	Enhancement of Academic/Technical Vocabulary Acquisition	12
12	Benefits of User-Generated Content	10
13	Sustainability of Learning Practices	10
14	Push Effect via Notifications	6
15	Creation of Low-Anxiety Learning Environment	2

Most literature indicates that integrating spaced repetition algorithms (SRS) into digital flashcards represents a fundamental shift in vocabulary acquisition strategies, as these systems schedule reviews at carefully calculated time intervals to resist forgetting, which leads to strengthening long-term retention of vocabulary with effectiveness that statistically surpasses traditional methods such as lists and paper flashcards (Janebi Enayat et al., 2025; Najafi Karimi & Kheradmandi Amiri, 2025; Seibert Hanson & Brown, 2020). The effectiveness of these tools stands out particularly in improving receptive vocabulary knowledge, where recognizing words precedes the ability to produce them in the early stages of learning (Iravi & Malmir, 2023; Mohammadi et al., 2024). Moreover, these applications support multimodal learning theories (Multimodal Learning), as combining texts with images and audio clips leads to activating dual coding theory, which creates deeper cognitive links and reduces cognitive load compared to text-only inputs (Hicks et al., 2025; Huang et al., 2025). This technological integration not only accelerates the acquisition process, but it also proves high efficiency in learning complex academic and technical vocabulary that requires rich contexts for understanding (Koleini et al., 2024).

The benefit of digital flashcards goes beyond the cognitive aspects to include enhancing affective aspects and learner autonomy through adaptive and personalized learning environments. These systems allow learners to control the pace of study, especially when they engage in creating their own content (User-Generated Content), which stimulates deeper mental processing compared to using ready-made flashcards (Koh & Kim, 2025; Pan et al., 2022; Zarrati et al., 2024). These applications also support the “microlearning” pattern (Microlearning) and the use of in-between times, which ensures continuity of exposure to the language outside classrooms through mobile devices (Dingler et al., 2017; Zakian et al., 2022). On the other hand, gamification elements (Gamification) and smart notifications (Push Effect) play a pivotal role in raising levels of motivation and engagement, while adaptive algorithms provide immediate feedback and personalized learning paths that suit each student’s level (Barghamadi et al., 2022; Kose & Mede, 2018; Xiang et al., 2025). This individual interaction contributes to reducing language anxiety and providing a safe environment for trial and error, which enhances self-confidence and the sustainability of self-learning habits (Çakmak et al., 2021).

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Addressing RQ3. What are the reported challenges encountered in implementing digital SRS for vocabulary learning?

To answer the third research question (RQ3), this study summarizes the reported challenges facing the use of digital flashcards in vocabulary learning, as stated in the recent literature. Accordingly, the results were presented in Table (6), which integrates the main challenge themes with the supporting references for each theme, in order to facilitate the process of comparison and inference, following a unified classification derived from previous studies.

Table 6: Reported Challenges of Digital Flashcards for Vocabulary Learning

No	Challenge	No. of Studies
1	Lack of Guidance and Digital Literacy Barriers	12
2	Decontextualization of Vocabulary	9
3	Limited Development of Productive Skills	8
4	Boredom and Resistance to Repetition	8
5	Metacognitive Overconfidence (Illusion of Competence)	3
6	Technical Issues and Battery Drain	3
7	Disruption and Timing of Notifications	2
8	Context-Dependency (Cue Dependence)	2

To answer the third research question (RQ3), Table (6) summarizes the essential challenges facing the integration of digital spaced repetition systems in vocabulary learning. The literature highlights the presence of an educational gap, as these tools significantly enhance receptive skills while the development of productive skills remains limited, which hinders learners' ability to use words in actual communication (Janebi Enayat et al., 2025; Mohammadi et al., 2024). Related to this is the challenge of "Decontextualization," where vocabulary is learned in an isolated manner, which makes it difficult to transfer it to real discursive contexts (Koh & Kim, 2025; Zarrati et al., 2024). From a cognitive perspective, learners face the risk of excessive reliance on visual cues (Context-Dependency), which leads to retrieval failure when images are absent, in addition to the phenomenon of "Metacognitive Overconfidence," where students overestimate the extent of their learning when supportive media are present (Huang et al., 2025a; Pan, Zung. Inez, et al., 2023; van den Broek et al., 2021). On the psychological and technical level, continuous repetitions lead to boredom and resistance to review, while technical problems, battery drain, and the inappropriate timing of notifications cause disruption to the course of the educational process and distraction of attention (Dingler et al., 2017; Janebi Enayat et al., 2025; Seibert Hanson & Brown, 2020). Finally, the lack of pedagogical guidance and weak digital skills constitute additional barriers to the effective use of these applications (Çakmak et al., 2021).

Addressing RQ4. What are the key factors influencing the effectiveness of digital SRS?

To answer the fourth research question (RQ4) about the main factors affecting the effectiveness of digital spaced repetition systems (Digital SRS), modern literature indicates that these factors can be classified into two basic components: scheduling dynamics and algorithms, and the design characteristics of the flashcard.

Precise timing and the mechanism of content repetition constitute the backbone of the effectiveness of

SRS systems. Effectiveness is not limited to merely spacing the intervals but extends to include the “number of learning rounds” (Learning Rounds) and the learner’s efficiency in responding to these rounds. Studies have shown that increasing the number of retrieval rounds (for example, from 3 to 4 rounds) noticeably enhances the “retrieval practice effect” (Retrieval Practice Effect), as the additional repetition leads to consolidating the mental representations of vocabulary and resisting forgetting more effectively. Moreover, the results indicate that “learning efficiency” (Learning Efficiency)—that is, the number of attempts the learner needs to reach a mastery criterion—is a stronger indicator than “language aptitude” (Language Aptitude) in predicting long-term vocabulary retention, which means that algorithms that adapt to the learner’s response speed (such as SuperMemo 2 or Constant Coefficient algorithms) play a decisive role in improving outcomes,. Studies have also proven the presence of a statistically significant relationship between the total number of repetitions carried out through the system and score gains in standardized proficiency tests such as (TOEIC), which confirms that the intensity of interaction with the algorithm is a determining factor for success.

The second component relates to how content is presented and its source, as design plays a dual role in enhancing memory or hindering it. On the positive side, the literature strongly supports the use of “multimodal” (Multimodal) cards that integrate text, audio, and image, as they have proven statistically superior to text-only (Monomodal) cards in enhancing retrieval accuracy, in line with dual coding theory that creates multiple cognitive pathways to access meaning. In addition, “user-generated content” (User-Generated Content) is an essential factor in effectiveness; students who formulate their cards themselves (through paraphrasing or mindful copying) achieve better performance in memory and application tests compared to those who use ready-made cards (Premade), due to the cognitive effort exerted during creation. However, researchers warn against design that turns images into “crutches” that reveal the answer during the retrieval attempt, which reduces the required mental effort and leads to weak performance in subsequent tests that lack images. Therefore, it is recommended that images appear as “feedback” after the attempt, not as “hints” (Hints) during it. Finally, integrating varied and mixed tasks (Interleaved Practice) which cover aspects of meaning, form, and use—enhances the depth of the acquired knowledge compared to focusing on only one aspect.

Addressing RQ5. What practical recommendations can be derived from the literature for SRS implementation?

To answer the fifth research question (RQ5), this study offers a set of practical recommendations derived from the literature, which can be categorized into three main themes: content design strategies, algorithmic structuring of repetition, and pedagogical and motivational support.

First: Enhancing "Content Generation" and Multimedia The literature strongly recommends transforming learners from passive consumers into active producers of educational content. Students should be encouraged to create their own digital cards (User-Generated Flashcards) instead of relying entirely on ready-made cards, as studies have proven that paraphrasing and searching for definitions during creation enhance the depth of mental processing and consolidate memory (Pan, Zung, et al., 2023). Furthermore, card design must go beyond written text to include multimodal inputs that integrate images, audio clips, and text, in line with Dual Coding Theory, to enhance retrieval paths (Hicks et al., 2025). It is also advised to include rich contexts such as sentences and examples instead of isolated words to link vocabulary to its real-world usage and avoid superficial learning (Koh & Kim, 2025; Zarrati et al., 2024).

Second: Optimizing Repetition Scheduling and Task Interleaving It is essential to improve revision mechanisms by increasing "Learning Rounds" and applying interleaved practice strategies. Results

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indicate that increasing the number of retrievals attempts within a single session enhances the "retrieval practice effect," thereby solidifying mental representations of vocabulary and resisting forgetting more effectively (Huang et al., 2025; Nakata et al., 2025). Additionally, it is recommended to adopt an "Interleaved Spaced Repetition" approach, which is not limited to repeating meaning only, but integrates diverse tasks covering different aspects of lexical knowledge (such as form, meaning, and use) simultaneously. This variety prevents boredom and promotes deep processing, leading to a balanced acquisition of receptive and productive skills (Lafleur & Kanazawa, 2024).

Third: Technical Training and Motivation via Gamification To ensure the sustainable use of SRS applications, technical training and motivational elements must be integrated into the curriculum. It should not be assumed that students possess the necessary skills to use these tools effectively; therefore, explicit guidance must be provided on how to manage repetition intervals and customize settings (Çakmak et al., 2021). To boost motivation and counter the monotony of repetition, it is advisable to select applications that include gamification elements such as leaderboards, points, and rewards, as these elements have proven their ability to raise engagement levels and reduce language anxiety (Enayat et al., 2025). Finally, these tools should be integrated as a core part of the assessment system or semester projects (Project-Based Learning) to ensure continuity and transform them into a sustainable study habit (Koh & Kim, 2025).

Conclusion

This systematic literature review (SLR) presented a synthesis and critical analysis of 27 pioneering empirical studies spanning from 2015 to 2025, aimed at bridging the knowledge gap regarding the effectiveness of digital flashcards based on Spaced Repetition Systems (SRS) in learning second language vocabulary. The study concluded with decisive results confirming that integrating time-scheduled algorithms with multimodal inputs outperforms traditional intensive memorization methods both statistically and pedagogically, particularly in enhancing long-term retention and developing receptive vocabulary. However, the analysis revealed that technology in itself is not a "magic wand"; maximum effectiveness depends on design factors and active usage. It was found that passive reliance on ready-made cards may lead to superficial learning, while user-generated content contributes to deepening mental processing and consolidating information. Despite the proven benefits in personalization and microlearning, the review highlighted fundamental challenges represented by the limited impact of these tools on productive skills (speaking and writing) and the potential for learners to rely excessively on visual cues as memory crutches rather than comprehending meaning in context. Accordingly, SRS applications should not be viewed as a complete substitute for language practice, but rather as a powerful complementary tool that must be integrated within a broader educational framework that supports interleaved practice and increases "retrieval rounds" to enhance efficiency. In conclusion, the study recommends the necessity for educational institutions and learners to shift towards "gamification" strategies and technical training to overcome the boredom of repetition and ensure the sustainability of self-learning, opening future horizons for research on how to transform this digital lexical inventory into real and effective communicative skills in second language environments.

Future Work

Based on the research gaps identified by this review, we propose applying the practical

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recommendations derived from the literature in real-world educational settings in the future; specifically, designing empirical studies that examine the impact of integrating "User-Generated Content" and "Interleaved Practice" strategies instead of the traditional reliance on premade cards and intensive cramming. We also recommend directing research efforts toward measuring the effectiveness of these tools in developing productive skills (speaking and writing), which still suffer from a scarcity of studies compared to receptive skills, in addition to exploring technical solutions for the challenge of "excessive reliance on visual cues" (Cue Dependence). These proposed pathways aim to verify in the field the ability of pedagogically enhanced spaced repetition algorithms to transform the digital lexical inventory into sustainable communicative competence.

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