A Meta-Analysis of the Effectiveness of Digital Game-Based Language Learning on Second Language Development

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Abstract. Digital game-based language learning (DGBLL) has garnered increasing attention from researchers for its potential to enhance learner engagement, foster collaboration, and facilitate knowledge acquisition. However, the impact of DGBLL on second language development (SLD) remains debated with considerable variability across studies. This meta-analysis aims to assess the effectiveness of DGBLL and identify potential moderating factors that may influence its efficacy in both English and Chinese contexts. A total of 49 quasi-experimental and experimental studies were identified from seven databases, yielding 73 independent samples. Data analysis was conducted using Comprehensive Meta-Analysis V.3 software, with Cohen's d used to calculate effect sizes for both overall effect analysis and moderator analysis. The results show that DGBLL has a large and positive effect on SLD ($d = 1.128$), with its effectiveness influenced by moderators including educational level, language proficiency, game type, learning environment, learning focus and treatment intensity. These findings suggest the need for educators to refine DGBLL strategies and design more personalized instructional programs that address learners' individual needs. Future research could explore the impact of DGBLL across diverse language background and its effects on learners' emotions, motivation, and self-efficacy.

Keywords: Digital game-based language learning, second language development, meta-analysis, effectiveness, moderator

1 Introduction

Digital game-based language learning (DGBLL) refers to "the design and use of a diverse array of digital games for the purpose of learning or teaching a second or foreign language" ([1], p.183). Due to its potential to create immersive learning environments, reduce learning anxiety, overcome emotional barriers, and increase communication in the target language, DGBLL is gaining popularity among educators and attracting attention from researchers in the field of second language development (SLD). Several

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studies have reported significantly positive effects of DGBLL on SLD [2], while others suggest that its impact may be negligible or even negative [3]. As a result, the effectiveness of DGBLL in promoting SLD remains a subject of ongoing debate. Moreover, factors such as learners' educational level, language proficiency, game type, learning environment, learning focus and treatment intensity may influence the outcomes of DGBLL. Although existing studies have explored these variables, their findings are inconsistent regarding the extent to which each factor affects SLD. Therefore, the present study conducts a meta-analysis to quantitatively synthesize 49 quasi-experimental and experimental studies (73 independent samples) from English and Chinese contexts to rigorously quantify DGBLL's overall effect on SLD and identify key moderators, guiding educators, researchers, students, and game developers.

2 Literature Review

DGBLL is supported by several complementary theoretical frameworks. Flow theory [4] and the affective filter hypothesis [7] explain how optimal challenges and reduced performance anxiety facilitate deep immersion and the efficient internalization of linguistic input. Complementing these individual psychological factors, sociocultural and constructivist frameworks position learners as active agents who utilize digital scaffolding to construct knowledge through goal-oriented interactions [5,6]. However, these theoretical affordances are often undermined by cognitive overload, where complex game mechanics divert mental resources away from language processing. Such theoretical tension is reflected in mixed empirical findings, where gains in domains like vocabulary or motivation are often contingent on learner proficiency or game design [2,3]. In summary, DGBLL generally supports motivation, engagement, and proficiency, but outcomes depend on learner traits, game design, and contextual implementation, warranting further moderator analyses for a more nuanced understanding.

2.1 Potential Moderators of DGBLL Effectiveness

Drawing on previous meta-analyses and theoretical considerations, this study examines six key moderators.

2.1.1 Educational Level.

Educational level is a critical moderator of DGBLL effectiveness, spanning kindergarten, primary school, middle school, and university stages [10]. Learners at these levels differ in cognitive abilities, prior knowledge, and motivation, potentially influencing outcomes [11]. Prior meta-analyses have examined this variable with mixed results: Kao [12] found larger effects for primary school learners in EFL contexts compared to secondary and university levels, whereas Nitisakunwut and Hwang [10] reported greater benefits for secondary and university learners in ESL/EFL settings. These inconsistencies may arise from variations in participant characteristics, study time spans, and data sources. Notably, kindergarten has been largely overlooked. The present study addresses these gaps by including educational level as a moderator, with

kindergarten as a subcategory, to provide a more comprehensive evaluation of its role in DGBLL outcomes.

2.1.2 L2 Proficiency.

L2 proficiency, categorized as high, intermediate, or low based on language mastery, may influence DGBLL efficacy by affecting information processing and cognitive load [10]. Cognitive load theory posits that proficiency levels reflect prior knowledge, impacting learning demands [9]. Empirically, higher-proficiency learners have been proven to excel in DGBLL, while lower-proficiency counterparts may face barriers overwhelming cognition [13]. Nevertheless, few prior meta-analyses on DGBLL have examined L2 proficiency as a moderator, limiting insights for practice. This study investigates its moderating role to inform language teaching.

2.1.3 Game Type.

Digital games in DGBLL may fall into drill-and-practice (e.g., repetitive tasks for memory reinforcement) or meaningful/engaging types (narrative-driven exploration for deeper understanding). These differ in cognitive, emotional, and experiential impacts. Debate persists on drill-and-practice efficacy, with critiques of shallow learning. Prior meta-analyses, like [14], overlook drill-and-practice games. This study adopts Kao's [12] classification to examine game type's relationship with outcomes.

2.1.4 Learning Environment.

Learning environment encompasses the contexts and conditions for DGBLL, divided into formal, informal, and blended types [10]. It can affect outcomes positively or negatively based on teacher guidance, learner autonomy, and pressure in implementation [11]. Formal settings provide teacher support to lower cognitive load and boost efficiency. Informal ones encourage self-directed regulation. Blended environments are defined as the integration of both, such as structured classroom pre-teaching followed by autonomous out-of-class gameplay as a required component of the course. Prior meta-analyses on learning environment's moderating role in DGBLL yield mixed results. Some studies noted significant effects on vocabulary through motivation [15], while others found no impact on overall English proficiency [10]. These inconsistencies call for deeper examination.

2.1.5 Learning Focus.

Learning focus denotes the targeted language skills in DGBLL, including vocabulary, grammar, listening, speaking, writing, and overall proficiency. DGBLL's emphasis varies by skill, enhancing rule understanding and application for vocabulary and grammar, providing authentic dialogues and oral opportunities for listening and speaking, and offering structured guidance, assessment, and feedback for writing [16,17]. Outcomes thus differ by focus. Despite its potential influence, existing meta-analyses have underexplored its moderating role. This study therefore examines learning focus

as a moderator to clarify its effects on DGBLL outcomes and inform intervention design and delivery.

2.1.6 Intensity of Treatment.

Treatment intensity refers to the frequency and duration of instructional interventions. It comprises single sessions (one continuous instructional experiment) and multiple sessions (two or more experiments over days, weeks, or months). This variable may substantially affect learners' engagement with DGBLL and learning experiences. Clark [18] observed that extended use of novel media like digital games reduces effectiveness, attributable to waning novelty effects and potential short-term memory overload, risking knowledge loss without reviews, thus favoring single sessions. Conversely, Wouters et al. [8] posited that multiple sessions enhance familiarity with game mechanics, promoting efficient SLA. Despite this debate, no meta-analysis has explored treatment intensity as a moderator. This study therefore incorporates it to elucidate its influence on DGBLL efficacy.

2.2 Previous Meta-Analysis on DGBLL

To the best of our knowledge, four meta-analyses have examined the effects of DGBLL on SLD, all of which focus on English-language studies. Chiu et al. [19] found a moderately positive effect of DGBLL on English learning, suggesting that games designed to be meaningful and engaging were more effective than drill-and-practice games in improving learning outcomes. Kao [12] expanded on this analysis by incorporating additional factors and also found a moderately positive effect of DGBLL on English learning in EFL contexts. Moreover, Kao's study indicated that DGBLL had a stronger impact on elementary school learners, compared to middle and high school students. Despite these valuable findings both studies are somewhat dated and do not account for recent developments in the field of DGBLL. Additionally, they are primarily concerned with the effects of digital games on English language learning and do not explore its potential impact on the acquisition of other second languages.

Dixon et al. [14] addressed some of these limitations by extending the time span of included studies to cover research published between 2014 and 2020. Their findings further reinforced the positive influence of DGBLL on SLD. Interestingly, Dixon et al. found that entertainment-focused games were more effective than those explicitly designed for language acquisition, suggesting that integrating more authentic language interactions into educational games could enhance their efficacy. Despite its valuable contributions, Dixon et al.'s study has limitations. It only included studies that focused on engaging and meaningful games, overlooking drill-and-practice games. This omission limits our understanding of how different types of games might differentially influence DGBLL outcomes. Additionally, the range of moderator variables considered was not sufficiently comprehensive; key factors such as learners' L2 proficiency levels, learning environments, and the intensity of intervention were not included, despite their potential significance in SLA and DGBLL research.

A more recent meta-analysis by Nitisakunwut and Hwang [10] synthesized 43 primary studies and reported moderate effect sizes ($g = 0.432$ for fixed-effect models and $g = 0.501$ for random-effect models). Their findings further confirmed the positive impact of DGBLL on SLA and expanded the scope by exploring additional moderating variables, such as intervention duration and game type. This allowed for a more nuanced understanding of the factors influencing DGBLL effectiveness. However, several issues remain unresolved. First, the data sources were limited to two databases, excluding unpublished doctoral dissertations, which could exacerbate publication bias and reduce the representativeness of the findings. Second, the time span of the included studies was confined to 2000-2019, overlooking more recent studies published after 2019. As a result, the study may not fully capture the latest developments in the field of DGBLL.

Building on prior meta-analytic studies, this study seeks to address existing gaps by expanding in the following aspects: (1) searching literature across more authoritative databases to enrich the dataset; (2) incorporating the most recent empirical studies on DGBLL in both English and Chinese to enhance the comprehensiveness of data sources; and (3) examining underexplored moderators that may influence DGBLL efficacy (e.g., L2 proficiency, learning focus, game type, and the intensity of treatment). Through these efforts, the study aims not only to shed light on the overall impact of DGBLL on SLD but also to provide a more nuanced understanding of how various factors moderate its effectiveness.

3 Method

3.1 Research Questions

1. What is the overall effectiveness of DGBLL on SLD?
2. To what extent do the following moderator variables influence DGBLL efficacy: L2 proficiency, game type and learning environment?

3.2 Literature Search

The present study retrieved literature in both Chinese and English, including peer-reviewed journals and unpublished doctoral dissertations. English-language sources were primarily obtained from Web of Science, Scopus, the Education Resource Information Center (ERIC), Linguistic and Language Behavior Abstracts (LLBA), and ProQuest Dissertations and Theses. Chinese-language sources were mainly retrieved from the China National Knowledge Infrastructure (CNKI) and the Wanfang database. The search keywords were categorized into three groups: (1) digital games-related terms, including “gamification learning”, “gamified learning”, and “game-based learning”; (2) language acquisition-related terms, such as “language learning”, “language acquisition”, “learning outcomes”, and “learning achievement”; and (3) intervention-related terms, such as “experimental study”. After the initial search, previous meta-analyses on

DGBLL were investigated for potential primary studies. Reference tracking and citation screening were employed to ensure comprehensive coverage of relevant literature while systematically excluding irrelevant or duplicate studies.

The databases employed in this study adhere to stringent screening criteria and comprehensive review mechanisms, ensuring the inclusion of high-quality, up-to-date literature on DGBLL. This meticulous selection process enhances the authority and reliability of the data sources. While this study is limited to Chinese and English literature due to language constraints, this restriction may introduce potential publication bias, as studies published in other languages could be overlooked. However, the search results show that English and Chinese publications account for 98.8% of the total, with literature in other languages making up less than 1% (as of January 2021). While this may introduce a slight bias, we argue that its impact on the overall findings is negligible. Furthermore, with the increasing globalization of educational technology, DGBLL has seen widespread application worldwide. Much research has been conducted across Asia, particularly in China and other Chinese-speaking regions. As such, the inclusion of Chinese-language literature not only improves the representativeness of the data but also provides a more comprehensive understanding of DGBLL research in Asia, especially in China.

3.3 Inclusion Criteria

To be included in the dataset, a study:

1. was published before January 2021 (the completion date of the literature search).
2. investigated the impact of DGBLL on SLD, rather than the effects of DGBLL on learning motivation, styles, and beliefs.
3. provided clear descriptions of the chosen digital games, aligning with the definition of DGBLL in the present study.
4. utilized digital games for second language or foreign language learning.
5. was conducted with typical second language learners, not learners with autism (ASD) or other learning disabilities.
6. employed experimental or quasi-experimental designs.
7. reported sufficient data, such as sample size (N), mean (M), and standard deviation (SD), to calculate effect sizes.

3.4 Coding

Upon completing the literature search and selecting studies that met the inclusion criteria for this meta-analysis, it is essential to systematically code the relevant information from these studies for subsequent statistical analysis and computation. The coding scheme is as follows.

(1) Literature information: Author(s), title, year of publication, type of literature (journal article, book chapter, and doctoral thesis).

(2) Participant characteristics: Native language, second language, country or region, age, educational level (kindergarten, primary school, middle school, and university), L2 proficiency level (low, intermediate, and high), and L2 proficiency measure tools.

(3) Treatment features: Game type (drill and practice games, meaningful and engaging games), learning environment (formal, informal, and blended), intensity of treatment (one shot vs. over multiple sessions), assessment type (receptive, productive, and mixed), learning focus (vocabulary, grammar, listening, speaking, writing, and overall proficiency).

(4) Study quality: Research design (between-group, within-group, mixed), pretest (yes or no), delayed post-test (yes or no), timing of delayed post-test, control group (yes or no), type of control group (maturational control group, which receives no treatment, and true experimental group, which receives treatment), intervention length of the control group, instrument reliability, and inter-rater reliability of outcome measures;

(5) Data information: Overall sample size, sample size of the treatment group, sample size of the control group, mean and standard deviation of the included studies.

3.5 Data Analysis

Outliers were identified via CMA V.3, excluding those with standardized residuals outside -2.5 to 2.5. Publication bias was assessed using funnel plots (Figure 1), trim-and-fill, and fail-safe N. Trim-and-fill indicated 15 missing studies, reducing effect size by 24% under random-effects, suggesting some bias. Fail-safe N (3,181 > threshold 375) implies minimal impact, ensuring reliability.

Effect size measures intervention magnitude, revealing effectiveness beyond p-value limitations. Data were analyzed using CMA V.3 software with Cohen's d for DGBLL's impact on second language learning. It calculated between- and within-group effects from study data. Random- or fixed-effects models computed sample effects for DGBLL on SLA. I^2 and Q tests assessed heterogeneity across studies.

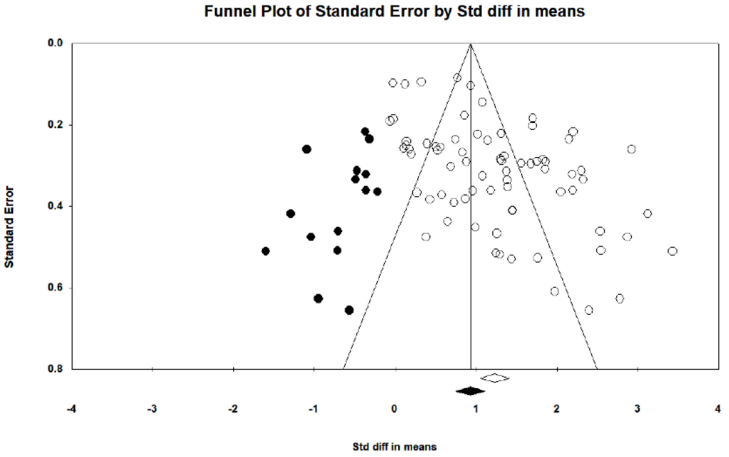

Fig. 1. Funnel plot

4 Results and Discussion

4.1 Descriptive Statistics about the Dataset

After a thorough screening and exclusion of outliers, a total of 49 studies, comprising 73 independent samples, were included in the analysis. These studies span the period from 2003 to January 2021.

Regarding participant characteristics, 32% were native Chinese speakers, 9% spoke English, 4% spoke Persian and Arabic (each), and 23% spoke other languages. The most common target language was English (62%), followed by Portuguese, Chinese, and Dutch (2% each), with 5% for other languages. The largest group of participants came from China (31%), while 10% were from the United States, 7% from Sweden, and 25% from other countries. Educationally, the majority had attained university-level education (34%), followed by primary school (23%), secondary school (11%), and kindergarten (4%). Approximately 10% of participants were aged 14 – 18, 28% were under 14, and 35% were over 18. As for L2 proficiency, 16% were at a low level, 11% at a medium level, and 5% at a high level.

In terms of treatment features, studies utilizing meaningful and engaging games were more common (53%) than those centered on drill-and-practice games (34%). Custom-designed games were the most frequently used (56%), with software-based games accounting for 38%, and web-based games making up just 5%. Formal settings were the primary environment of the dataset (81%), while informal environments constituted 18%, and blended settings represented only 1% of the studies. A larger proportion of studies adopted multiple interventions (60%) compared to those implementing a single intervention (40%). Receptive and mixed assessments were the most widely used (40% each), with productive testing employed in 12% of studies. Vocabulary learning was the dominant area of focus, comprising 62% of the studies, whereas overall language proficiency (22%), grammar (11%), writing (3%), and listening and speaking (1% each) received less attention.

With respect to experimental design, the majority of studies employed within-group designs (56%), surpassing those that used between-group designs (40%) and mixed designs (4%). Additionally, most studies incorporated pre-testing (81%), while a smaller proportion conducted delayed post-testing (29%), and 71% of studies did not include any delayed posttest.

4.2 Overall Effects of DGBLL

As shown in Table 1, the heterogeneity test in CMA V.3 revealed an I^2 value over 75% and a significant Q statistic, signaling high heterogeneity among studies. This warrants a random-effects model. Based on Plonsky and Oswald's [20] criteria for SLA effect sizes, DGBLL positively impacts second language learning ($d = 1.228$, $p < 0.05$). This aligns with prior meta-analyses showing DGBLL benefits for language development. Results also fit flow theory and sociocultural and constructivist views. Overall, findings affirm DGBLL's role in boosting second language outcomes and academic performance.

Table 1. Overall effects of DGBLL

Model	N	K	Effect size	95% CIs		p	Heterogeneity			
				Lower limit	Upper limit		Q	df	p	I^2
Random	49	73	1.228	1.048	1.407	0.000	727.918	72	0.000	90.109

4.3 Moderator Analyses

The results of the moderator analyses are presented in Table 2.

Table 2. Moderator analyses

Moderator	Subgroup	N	K	Effect size	95% CIs		p
					Lower limit	Upper limit	
Education level	kindergarten	3	4	0.801	0.517	1.085	0.000
	primary school	14	22	1.244	0.914	1.573	0.000
	middle school	8	12	0.757	0.453	1.060	0.000
	university	24	34	1.440	1.122	1.759	0.000
L2 proficiency	low	11	16	1.220	0.729	1.711	0.000
	intermediate	8	11	1.103	0.682	1.524	0.000
	high	4	5	1.567	1.165	1.969	0.000
Game type	drill-and-practice	17	25	1.235	0.891	1.579	0.000
	meaningful and engaging	27	39	1.335	1.087	1.583	0.000
Learning environment	formal	40	59	1.291	1.082	1.501	0.000
	informal	9	13	1.009	0.673	1.345	0.000
	blended	1	1	0.136	-0.356	0.627	0.589
Learning focus	vocabulary	29	45	1.194	0.956	1.432	0.000
	grammar	4	8	1.607	1.047	2.168	0.000
	listening	1	1	0.741	0.279	1.203	0.002
	speaking	1	1	2.049	1.335	2.763	0.000
	writing	1	2	0.973	0.432	1.514	0.000
	overall	13	16	1.148	0.798	1.497	0.000
Intensity of treatment	single intervention	16	29	1.414	1.036	1.793	0.000
	multiple intervention	33	44	1.097	0.911	1.282	0.000

Concerning educational level, DGBLL shows higher effectiveness among university learners (d = 1.440) and primary school students (d = 1.244), but weaker impact in kindergarten (d = 0.801) and secondary school settings (d = 0.757). University students benefit due to well-defined goals, intrinsic motivation, and advanced cognition, facilitating efficient SLD [19]. Primary school students, in a key language development stage, respond well to games' engaging nature, boosting SLD motivation. In contrast, secondary students face exam pressure and view games recreationally, limiting DGBLL

engagement. Kindergarten learners, with limited cognition, focus on superficial aspects, yielding minimal SLD gains. Educators should foster intrinsic motivation, sustained interest, and goal-aligned activities to optimize DGBLL. At kindergarten, balance game mechanics with educational content to guide attention toward meaningful SLD. These findings inform effective DGBLL program design, enhancing SLD across age groups.

In terms of L2 proficiency, DGBLL shows the strongest effects for advanced learners ($d = 1.567$). Cognitive load theory explains that task complexity interacts with prior knowledge to determine intrinsic load [9]. Advanced learners, with a strong foundation, face lower load, allowing better skill acquisition and SLD. This highlights the need to tailor strategies and designs to proficiency levels. Specifically, DGBLL content and tasks should be calibrated to balance challenge and cognitive load, avoiding excessive demands while enhancing language skills. In practice, careful selection and sequencing of tasks are crucial to maintain moderate difficulty, promoting meaningful engagement and effective outcomes.

For game type, meaningful and engaging games ($d = 1.335$) outperform drill-and-practice ones ($d = 1.235$), aligning with [13] and [19]. The former integrate gameplay and learning via immersive storylines, promoting negotiation, interaction, participation, and motivation. On the contrary, drill games may cause fatigue through repetition. Thus, choosing suitable types could optimize engagement and outcomes.

On learning environment, DGBLL impacts are greater in formal ($d = 1.291$) and informal ($d = 1.009$) settings, whereas the effect size for blended environments is notably lower and non-significant ($d = 0.136$, $p = 0.589$). This discrepancy may stem from the limitation of a small sample size ($k = 1$). Beyond this statistical constraint, the findings may reflect the inherent friction often found in blended designs. Unlike the structured scaffolding of formal classrooms or the high autonomy of informal play, blended environments can suffer from a misalignment between rigid curriculum goals and open-ended game mechanics. This mismatch often increases extraneous cognitive load as learners struggle to reconcile different task demands, potentially diluting the pedagogical impact.

With respect to learning focus, DGBLL was more effective for vocabulary ($d = 1.194$), grammar ($d = 1.607$), speaking ($d = 2.049$), and overall proficiency ($d = 1.148$) than for writing ($d = 0.973$) and listening ($d = 0.741$). This pattern may reflect gamified environments' emphasis on concise expressions, vocabulary acquisition, and oral communication. DGBLL's substantial grammar effect likely derives from contextualized instruction and immediate feedback. For writing, however, which demands critical thinking and organization, DGBLL may insufficiently substitute targeted practice. Listening's moderate effect may stem from limitations in replicating real-life inputs, including intonation, speed, and pronunciation variability. Overall, DGBLL positively influences most domains. Its strengths in vocabulary, grammar, speaking, and proficiency can be leveraged, with supplementary strategies integrated for listening and writing to foster holistic SLD.

Regarding treatment intensity, single interventions ($d = 1.414$) yielded larger effects than multiple ($d = 1.097$). Novel games in single sessions capture curiosity, enhance engagement, and promote immersion, facilitating short-term retention consolidable via

reviews. Multiple interventions, conversely, may erode initial interest, inducing fatigue, boredom, and memory decay [18]. Intervention frequency and duration thus warrant adjustment based on goals and learner needs to sustain motivation, with regular reviews incorporated to reinforce memory and optimize long-term benefits.

5 Conclusion

This meta-analysis synthesized 73 effect sizes from 49 quasi-experimental and experimental studies in English and Chinese, revealing a significantly positive, large effect of DGBLL on SLD (d = 1.128). Moderator analyses indicated influences from language proficiency, learning focus, game type, learning environment, and treatment intensity. These findings underscore DGBLL's potential to enhance SLD in English and Chinese contexts, providing evidence-based guidance for optimizing its application.

The findings of this meta-analysis offer insights for DGBLL design and implementation, with implications for educators and researchers. By incorporating underrepresented Chinese-language sources, the study provides a comprehensive perspective applicable to both English- and Chinese-language contexts. The overall effect size supports DGBLL's efficacy, suggesting its potential integration into language curricula. The nonsignificant moderators indicate DGBLL's robustness across participant characteristics, treatment features, and experimental designs. For instance, the absence of moderation by game type implies consistent effects on second language development, affording educators flexibility in game selection. Thus, instructional focus can prioritize alignment between game content and learning objectives.

Limitations include incomplete data on variables like L2 proficiency and learning focus in primary studies, potentially contributing to nonsignificant subgroup results. Future research requires detailed methodological and statistical reporting to bolster rigor. Research imbalances persist, with disproportionate emphasis on vocabulary (k = 45) versus grammar (k = 4), listening (k = 1), and speaking (k = 1), limiting holistic insights into SLD. Broader investigations are needed to address these gaps. Although this study focused on SLD impacts, it overlooked emotional and motivational factors, such as learners' emotions, motivation, and self-efficacy. Future inquiries should examine these psychological dimensions to elucidate their contributions to outcomes.

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