

Bridging Language and Discipline: The Impact of Digital Game-Based Learning on Technical Vocabulary Acquisition and Motivation

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Abstract

Technical vocabulary instruction in Foreign Language for Specific Purposes (FLSP) contexts poses persistent challenges due to its low frequency in daily communication. Drawing on the Self-Determination Theory (SDT) and informed by the Cognitive Theory of Multimedia Learning (CTML), this quasi-experimental study examined the effectiveness of digital game-based learning (DGBL) on the short- and long-term acquisition of French technical vocabulary, and on both intrinsic and extrinsic motivation, as well as on the predictive relationship between motivation and vocabulary retention. Fifty-nine undergraduates majoring in viticulture and enology participated in a six-week intervention through a WeChat-based mini program specifically designed for professional French vocabulary learning. Quantitative analyses, including a mixed-design ANOVA, non-parametric tests, and hierarchical regression, were conducted to investigate vocabulary performance and motivational influences. Results indicated that the DGBL group achieved significantly greater vocabulary gains and stronger long-term retention than the control group. Students exposed to DGBL also reported higher levels of overall, intrinsic motivation and identified regulation, demonstrating enhanced autonomy and competence as postulated by SDT. Regression analysis further revealed

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that DGBL moderated the relationship between motivation and retention, helping students with lower motivation attain comparable performance levels. Overall, the findings support the value of DGBL in technical vocabulary instruction and in fostering autonomous motivation.

Keywords

intrinsic motivation, extrinsic motivation, digital game-based learning, technical vocabulary acquisition, foreign language for specific purposes

Introduction

Technical vocabulary, also defined as “specialized vocabulary”, “academic vocabulary”, “discipline-specific vocabulary”, or “professional vocabulary” by several researchers (Alharbi, 2023; Ali & Muhammad, 2019; Jia et al., 2025; Kohnke, 2020; Mustaeva et al., 2022), typically refers to lexical items that carry core meaning within a particular discipline and constitute part of the knowledge system of that discipline (Chung & Nation, 2004). Unlike academic vocabulary, which is widely shared across fields, technical terms are highly dependent on disciplinary context and are rarely encountered in general language use, with meanings that are not easily transferable beyond their specific domain (Coxhead, 2017).

Due to these characteristics, technical vocabulary plays a central role in disciplinary language comprehension. Research has shown that learners need to know 95% to 98% of the words in a text to ensure adequate understanding (Coxhead & Demecheleer, 2018). However, technical terms often account for more than 30% of lexical items in specialized discourse, including academic textbooks and professional publications (Drayton & Coxhead, 2023). Thus, technical vocabulary functions as a crucial linguistic bridge to disciplinary knowledge and is essential for effective instruction in Foreign Language for Specific Purposes (FLSP) contexts. In fact, difficulties in acquiring technical vocabulary have been widely observed across a wide range of school subjects, largely due to limited exposure and insufficient opportunities for repeated encounters in daily communication (Wright & Peltier, 2016). However, without sufficient repetition, reinforcement, and opportunities for deeper cognitive processing, newly learned vocabulary tends to fade quickly from memory and becomes difficult to apply in real communication (Seibert Hanson & Brown, 2020).

Digital game-based learning (DGBL) is an innovative instructional approach that combines educational technology with cognitive and motivational theories to foster interactive, engaging and immersive learning experiences (Esteban, 2024). A growing body of empirical research has demonstrated that this approach significantly enhances student engagement, stimulates intrinsic motivation, and facilitates language acquisition (Soyoo et al., 2024). As digital games continue to capture learners’ attention, educators and researchers have become interested in leveraging the motivational appeal of games to support cognitively demanding language learning tasks (Dixon et al., 2022;

Prensky, 2003). Unlike traditional vocabulary instruction, which often relies on mechanical repetition and static presentation, DGBL has the potential to transform vocabulary memorization, typically perceived as monotonous and repetitive, into an intrinsically motivating and cognitively engaging learning experience. Vocabulary acquisition is inherently a gradual process that requires repeated contextual exposure and long-term accumulation (Schmitt & Schmitt, 2020). However, conventional classrooms often fail to provide sufficient input frequency, diverse presentation formats, or timely feedback, which can lead to diminished learner motivation and cognitive investment. Against this backdrop, DGBL, with its integration of natural repetition, high motivational intensity, diversified feedback, authentic task design, and strong interactivity, aligns well with the principles of vocabulary acquisition and effectively promotes sustained learner engagement. As a result, vocabulary learning has become one of the most frequently explored topics in digital game-based language learning (DGBLL) research.

According to Self-Determination Theory (SDT) (Ryan & Deci, 2000), autonomous forms of motivation (such as intrinsic motivation and identified regulation) serve as key drivers of the learning process. However, in the context of FLSP instruction, technical vocabulary often involves highly specialized disciplinary concepts (Coxhead & Demecheleer, 2018). Because learners in non-native settings have limited exposure to authentic professional discourse and often possess restricted language proficiency (Shi et al., 2024), such concepts may initially appear distant and difficult to comprehend (Coxhead, 2017; Drayton & Coxhead, 2023). This cognitive gap makes it challenging to foster intrinsic motivation through conventional teaching approaches. DGBL environments can address these challenges by offering interactive and multimodal experiences that sustain motivation while simultaneously supporting deeper cognitive processing and long-term retention (Camacho-Sánchez et al., 2024; Liu, Alotaibi, & Hashemifardnia, 2025). Drawing on principles from the Cognitive Theory of Multimedia Learning (CTML), such designs engage learners in active processing across verbal and visual channels, thereby facilitating comprehension and memory consolidation (Mayer, 2014). Through this combination of motivational and cognitive affordances, DGBL offers a pedagogically powerful approach to technical instruction.

To address these motivational and cognitive challenges, this study developed and implemented a DGBL platform based on WeChat mini program (WMP), specifically designed to support the acquisition of French technical vocabulary among undergraduate students majoring in viticulture and enology. The platform includes 180 terms organized into 18 learning modules. It integrates game-based task designs such as image matching and happy eliminating, as well as key game elements including instant feedback, points, and leaderboards. By combining pedagogical structure with interactive design, the platform was intended to create an engaging and professionally relevant learning environment that supports both vocabulary acquisition and motivational development. To evaluate its effectiveness, the platform was implemented within a quasi-experimental design that compared learning outcomes and motivational responses between a DGBL group and a control group receiving traditional instruction. In addition to examining the short- and long-term effects of DGBL on vocabulary

acquisition and its impact on different motivational dimensions, this study also explores the predictive relationship between motivation and vocabulary retention, as well as the moderating role of DGBL in this relationship. This analytical perspective extends the theoretical integration of SDT and CTML, offering a deeper understanding of how motivational and cognitive mechanisms jointly shape learning outcomes in the FLSP instruction based on DGBL.

Literature Review

Challenges in Acquiring Technical Vocabulary

The acquisition of technical vocabulary is widely recognized as a significant challenge in foreign language learning. Previous research has identified several representative difficulties that learners commonly encounter when dealing with technical vocabulary acquisition.

High Semantic Abstraction and Limited Accessibility to Prior Knowledge. Technical vocabulary often encodes highly specialized and abstract disciplinary knowledge, making it difficult for learners to associate such terms with familiar linguistic experiences or concrete cognitive representations (Carrier, 2013; Kamaşak et al., 2021). Unlike general vocabulary that frequently appears in routine discourse, the meanings of technical terms typically require discipline-specific background knowledge for accurate comprehension (Chung & Nation, 2004; Tian & Umar, 2026). This semantic opacity considerably increases the difficulty of understanding and reduces the effectiveness of incidental learning. Therefore, mastering such terminology is not merely linguistic but epistemic, involving an understanding of how knowledge is structured and communicated within a field. The educational research based on context indicates that learners must engage with specialized concepts in authentic professional scenarios to construct meaning effectively (Dolfing et al., 2021).

Low Frequency of Exposure and Limited Opportunities for Repetition. Technical terms rarely occur in general language input, restricting incidental encounters through routine reading or listening activities (Bancroft-Billings, 2020). In classroom settings, time and resource limitations often restrict contextual reinforcement of these terms. Without spaced review and repeated practice, newly acquired vocabulary tends to decay, undermining long-term retention and transferability (Miroshnychenko, 2024; Zhang et al., 2022).

Affective Burden and Motivational Barriers. Beyond linguistic and cognitive challenges, learners' emotional attitudes and motivational states critically shape vocabulary acquisition (Reynolds et al., 2021). Technical terms are often perceived as tedious, difficult, and irrelevant, particularly when instruction lacks meaningful context or personal relevance. This can trigger negative emotional responses such as anxiety, frustration, or disengagement (Wright & Peltier, 2016). As Alamer (2022) notes,

vocabulary instruction that lacks interactivity or intrinsic interest is likely to weaken learners' motivation and reduce their investment in the learning process. Evidence from higher education further indicates that students are most invested when instructional content is perceived as relevant, practical, and connected to real-world professional identity (O'Neill & Short, 2025). When such relevance is absent, learning is experienced as externally imposed and emotionally disengaging, which depresses motivation and, in turn, undermines retention.

Integrating Motivational and Cognitive Perspectives in DGBLL

As discussed in the previous section, learning technical vocabulary in Foreign Language for Specific Purposes (FLSP) contexts involves both affective and cognitive challenges that can hinder persistence and learning efficiency. Although technical terminology connects with students' disciplinary identity, its limited use in everyday communication often makes it feel abstract and distant. This dual nature highlights the need to examine how motivation and cognition interact in technical vocabulary learning.

Self-Determination Theory (SDT) provides a foundation for understanding how motivation influences learning in second language acquisition and educational technology research. SDT proposes that the satisfaction of three psychological needs (autonomy, competence, and relatedness) leads to more self-determined forms of motivation, such as intrinsic motivation and identified regulation, which promote sustained engagement and deeper processing (Al-Hoorie & Albijadi, 2024; Ryan & Deci, 2020). Empirical research has shown that when these needs are fulfilled, learners normally achieve better outcomes in vocabulary, reading, and writing (Chiu et al., 2024; Darvin & Norton, 2023). For example, Liu, Wang, and Wang (2025) found that satisfying these needs significantly reduced the experience of boredom and enhanced learners' behavioral engagement, while some studies identified that autonomous motivation was a strong predictor of language achievement (Alamer & Lee, 2019; Chowdhury et al., 2024). However, this predictive link may vary depending on the instructional design and contextual supports.

While SDT explains why learners engage and persist, the Cognitive Theory of Multimedia Learning (CTML) describes how learning occurs through multimodal information processing. Recent reviews (e.g., Al-Khresheh, 2025; Vnucko & Klimova, 2023; Zhou et al., 2024) have highlighted that effective vocabulary learning in technology-assisted environments depends on multimodal presentation, management of cognitive load, and learner engagement. CTML suggests that learning improves when verbal and visual inputs are coordinated, cognitive load remains manageable, and learners actively select, organize, and integrate information. In vocabulary learning, multimodal design helps students build stronger connections between form, meaning, and context. For technical vocabulary, this design turns abstract concepts into concrete representations and creates multiple retrieval paths that enhance both immediate learning and long-term retention. Yang et al. (2025) reported that combining multimodal resources with self-regulated learning strategies in a digital game-based

environment improved vocabulary development and reduced cognitive load. [Teng and Zhang \(2024\)](#) found that integrating multimedia input with productive tasks promoted dual-channel processing and deeper lexical integration, which resulted in better retention.

Despite extensive evidence that DGBL enhances both engagement and learning outcomes, few studies have examined how motivational and cognitive mechanisms interact within game-based environments, particularly in the acquisition of highly abstract technical vocabulary. Within the framework of SDT, motivation determines the depth and persistence of engagement ([Ryan & Deci, 2020](#)), whereas CTML emphasizes that multimodal input and interactive practice promote active processing and reduce cognitive load ([Mayer & Fiorella, 2022](#)). Integrating these perspectives suggests that DGBL may both enhance motivation and mitigate the cognitive difficulty of abstract technical terms through multimodal association, contextualized repetition, and retrieval-based learning ([Calvo-Ferrer, 2021](#); [Jia et al., 2025](#)). Moreover, these rich presentations of feedback and the adaptive nature of DGBL provide cognitive and affective scaffolding that compensates for lower initial motivation, thereby moderating the influence of motivation on achievement ([Mayer & Fiorella, 2022](#); [Shen et al., 2024](#)). Therefore, this study draws on SDT and CTML as complementary theoretical frameworks to explain how motivational and cognitive processes jointly shape learning in the DGBL environment.

The Role of DGBL in Technical Vocabulary Acquisition

In the context of increasing emphasis on individualized and digitalized approaches to language learning, digital game-based language learning (DGBLL) has emerged as an innovative instructional strategy that integrates foreign language education, educational technology, as well as motivational theory ([Dixon et al., 2022](#)). It has increasingly attracted attention in the field of vocabulary instruction and research. DGBLL environments often incorporate game-based elements and mechanics, which could enhance learners' engagement and interactivity, and support vocabulary comprehension, memorization, as well as retention through multimodal input and structured repetition ([Chen & Chang, 2024](#); [Dixon et al., 2022](#); [Govender & Arnedo-Moreno, 2021](#)).

Numerous studies have confirmed the effectiveness of DGBL in promoting vocabulary learning performance. From a cognitive perspective, multimodal input that integrates text, images, and audio facilitates the creation of richer lexical representations and promotes long-term retention ([Calvo-Ferrer, 2021](#); [Hwang et al., 2023](#)). [Yang et al. \(2020\)](#) further demonstrated that audiovisual input in game contexts reduced cognitive load and enhanced the retrieval of newly learned vocabulary. Moreover, spaced repetition and interleaved testing techniques with interactive feedback embedded in game tasks increase the frequency of lexical encounters and support long-term retention ([Maie et al., 2025](#); [Zhang et al., 2023](#); [Çakmak et al., 2021](#)). These findings suggest that multimodal design encourages coordinated information processing and meaningful learning. Further evidence from [Jia, Zhang, Pack, Guan, and Zou \(2024a, 2024b\)](#) showed that DGBL supports both receptive and productive vocabulary growth,

confirming its potential for strengthening learning outcomes across multiple dimensions of lexical competence.

At the same time, DGBL has shown considerable potential in fostering learner motivation (Camacho-Sánchez et al., 2024). By providing an emotionally supportive and autonomy-enhancing learning environment, DGBL can help reduce anxiety, strengthen learners' sense of control and engagement, and improve their acceptance and retention of vocabulary (Ahmed et al., 2022; Kazu & Kuvvetli, 2023; Othman, 2024). Learners experience competence through goal completion, immediate feedback, and visible progress, which sustain self-determined motivation. Yang et al. (2024) reported that students using a mobile DGBL application demonstrated significant improvements in both vocabulary performance and learning confidence. Similarly, studies have proven that game-based features such as adaptive challenges and reward mechanisms encourage intrinsic interest and long-term engagement (e.g., Duisenova & Zhorabekova, 2024; Sun et al., 2024). These results indicate that DGBL satisfies the psychological needs for autonomy, competence, and relatedness, contributing to more stable and self-regulated forms of motivation (Rachels & Rockinson-Szapkiw, 2018; Syifa et al., 2024). These findings collectively indicate that DGBL offers pedagogical potential for technical vocabulary learning, which provides the foundation for the present study.

Purposes of This Study

This study aims to evaluate the effectiveness of DGBL in enhancing both technical vocabulary acquisition and motivation within a non-English, domain-specific context through a quasi-experimental comparison between DGBL and traditional teaching methods. A review of existing literature reveals several key gaps that the present study seeks to address. First of all, in terms of research scope, most empirical studies on DGBL have focused on the acquisition of general vocabulary among learners of English as a foreign language, while a small but growing body of research has also examined its use in English for Specific Purposes and English for Academic Purposes contexts (e.g., Tan et al., 2022; Wu et al., 2020). However, such studies remain scarce and fragmented, with relatively limited attention paid to other target languages such as French and German (Hwang et al., 2023; Tian & Naufal Umar, 2025; Xu et al., 2020). Second, at the theoretical level, although numerous studies have investigated either motivational or cognitive effects of DGBLL separately, few have systematically explored how these two dimensions interact or have adopted integrated frameworks linking both mechanisms (Zou et al., 2021). Finally, at the empirical level, previous studies have primarily focused on immediate test performance, whereas long-term retention has received insufficient attention (Jia et al., 2025). In particular, very few studies have employed inferential models such as regression analysis to examine whether learners' motivation predicts retention outcomes or whether the DGBL environment moderates this relationship (Al-Khresheh, 2025).

To address these research gaps, the present study examines how DGBL, compared with traditional instruction, supports both motivation and technical vocabulary

acquisition in a non-English language context. Beyond examining the main effects of DGBL on vocabulary performance and motivation, this study also investigates the predictive relationship between students' motivation and vocabulary retention, as well as whether DGBL moderates this relationship. Based on these aims, the following research questions are proposed.

RQ1: To what extent does DGBL improve students' short-term recall and long-term retention of technical vocabulary in a FLSP context compared to traditional instruction?

RQ2: To what extent does DGBL foster higher levels of intrinsic and extrinsic motivation than traditional instruction in the context of technical vocabulary acquisition?

RQ3: Does the motivation of students predict their vocabulary retention across instructional conditions?

RQ4: Does the learning method (DGBL vs. traditional instruction) moderate the relationship between students' motivation and vocabulary retention?

Methods

Research Design and Participants

This study employed a non-randomized quasi-experimental design to investigate the effects of DGBL on the acquisition, retention, and motivation of technical vocabulary in a French course for students majoring in viticulture and enology. A total of 59 third-year undergraduates from this program voluntarily participated. Due to instructional scheduling, cluster sampling was applied, and two intact classes from the same program were designated as the experimental group ($n = 29$) and the control group ($n = 30$). The experimental group received a six-week intervention through a DGBL platform developed within the WeChat mini program (WMP), while the control group received traditional classroom instruction. Although random assignment was not possible, the two groups were comparable in academic background, demographic characteristics, and pre-test vocabulary performance, which helped to minimize potential selection bias. To ensure instructional equivalence, both groups studied the same 180 technical vocabulary items and completed their learning modules within the same time frame.

Participants were between 20 and 22 years old and had completed one year of formal French study at the A2 proficiency level according to the Common European Framework of Reference for Languages (CEFR). Before data collection began, the researcher explained the purpose and procedures of the study to all participants, emphasizing anonymity and voluntary participation. Written informed consent was obtained, and the research was approved by the university's ethics committee.

The total sample size ($n = 59$) was determined by the actual enrollment of the two intact classes. To evaluate the adequacy of this sample for detecting effects, a post hoc

sensitivity analysis was conducted using G*Power 3.1. The analysis was set for a mixed-design ANOVA with Cohen’s $f = 0.25$ (medium effect size), $\alpha = 0.05$, and two groups. The results indicated an estimated statistical power of 0.64 for detecting a medium effect, which is below the conventional benchmark of 0.80, suggesting limited sensitivity to medium-sized effects. This limitation in statistical power is acknowledged. However, the study design prioritized ecological validity within an authentic classroom context. To address this limitation and provide richer information, effect sizes and their 95% confidence intervals were reported along with p -values to facilitate a clearer interpretation of the magnitude and precision of the observed effects.

Design of the Educational Game Based on WeChat Mini Program

To enhance students’ acquisition of French technical vocabulary and the internalization of their motivation, a digital game-based vocabulary learning game titled “*Wine French Vocabulary*” was designed and developed within the WeChat mini program (WMP). The platform followed the instructional design and development model proposed by Alessi and Trollip (2001), and integrated motivational mechanisms from SDT with cognitive processing principles from CTML. Its goal was to achieve an integration of instructional design, cognitive processing, and motivational support.

The learning content was derived from the multilingual dictionary of vine and wine, published by the International Organization of Vine and Wine (OIV) in 2013 (Li, 2013), which covers eight languages, including French, English, and Chinese. A total of 180 technical terms were selected and structured into 18 modules, with each module containing 10 targeted vocabulary items. The game, built on the WMP technology, enabled students to engage in mobile-based autonomous learning. Game elements such as points, chances, feedback, and badges were incorporated to increase engagement and sustain learning motivation (Liu, Alotaibi, & Hashemifardnia, 2025).

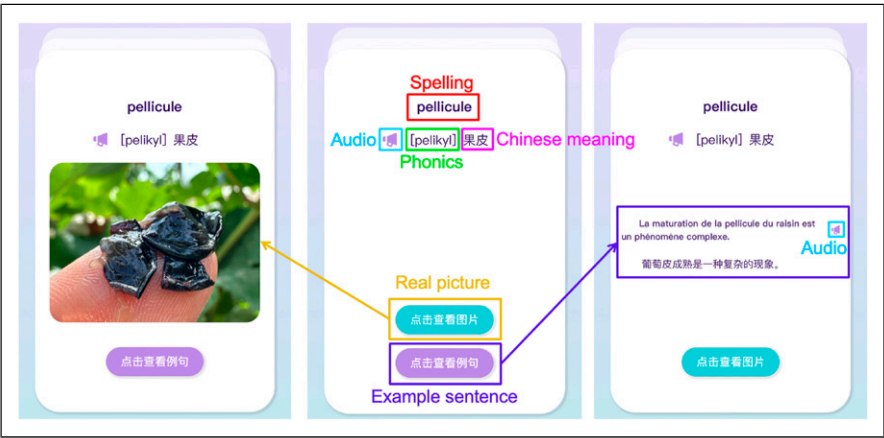


Figure 1. Presentation interface for technical vocabulary learning

Each learning module consisted of two stages: the multimodal input representation and an interactive practice stage. In the multimodal input stage (see Figure 1), the system presented vocabulary through various formats, including orthographic forms, phonetic spelling, Chinese definitions, images, and example sentences. These multimodal representations supported both visual and auditory processing, promoting deeper encoding of meaning (Zhou et al., 2024). In the interactive practice stage (see Figure 2), students consolidated vocabulary processing and memory through game tasks. The games included Happy Eliminating (matching-removal), audio-image pairing, text-image pairing, and contextual application of terms in professional discourse. For example, in the Happy Eliminating game, students were required to match the correct Chinese-French vocabulary “grapes” within a limited time to complete the elimination. Correct matches generated points, and instant feedback (color change and sound effects), reinforcing accurate responses and fostering a sense of accomplishment (Lin et al., 2025). Unlike the control group, which relied on static pictures, example sentences, and fixed exercises, learners in the DGBL group engaged in active meaning construction through interactive tasks. During matching, pairing, and elimination activities, they dynamically activated visual and linguistic representations and reorganized abstract technical terms within authentic contexts. This process transformed passive memorization into active construction (Dong, 2025), allowing vocabulary meanings to be internalized through experience. The system also permitted students to replay each module multiple times until they reached the desired level of accuracy. It automatically tracked their progress and displayed unlocked modules on the main interface. Moreover, each time students re-entered a module, the game automatically reorganized task content, providing varied practice opportunities that encouraged repeated retrieval and deeper semantic processing of the target vocabulary.

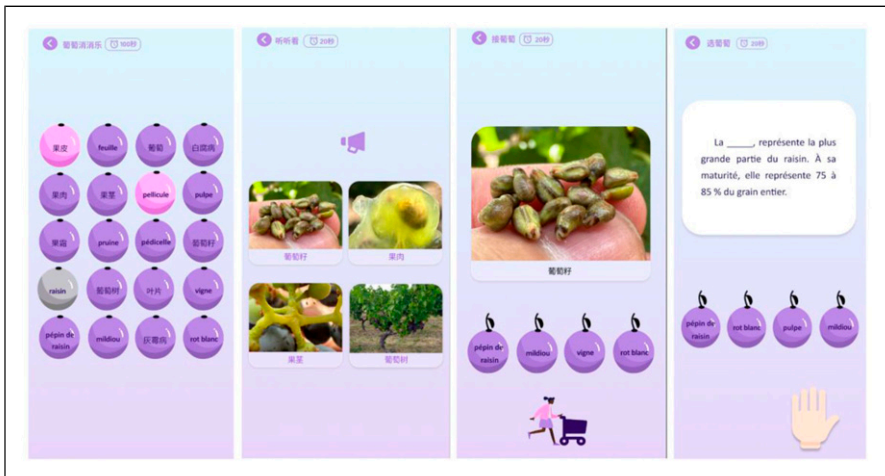


Figure 2. Exercise interface for technical vocabulary practice

To promote continuous participation and engagement, the platform also incorporated a point and badge reward system. Completing a new module granted up to 100 points, which were displayed on a real-time leaderboard to encourage mild competition. Two types of badges were awarded (see [Figure 3](#)), one for achieving over 80 points (out of 100) within a single new module, and another for maintaining daily learning across seven consecutive days. These design features corresponded to the three basic psychological needs in SDT: autonomy (self-paced learning) ([Hsu et al., 2023](#)), competence (instant feedback and points system) ([Taskiran et al., 2024](#)), and relatedness (peer connection and professional relevance) ([Li, Hew, & Du, 2024](#)). Together, they created a learning environment that combined cognitive processing with motivational support for technical vocabulary development.

All content and interface designs were jointly reviewed and revised by two experts in French language education and two subject specialists in viticulture and enology. Before the formal implementation, a beta test was conducted with five students who had

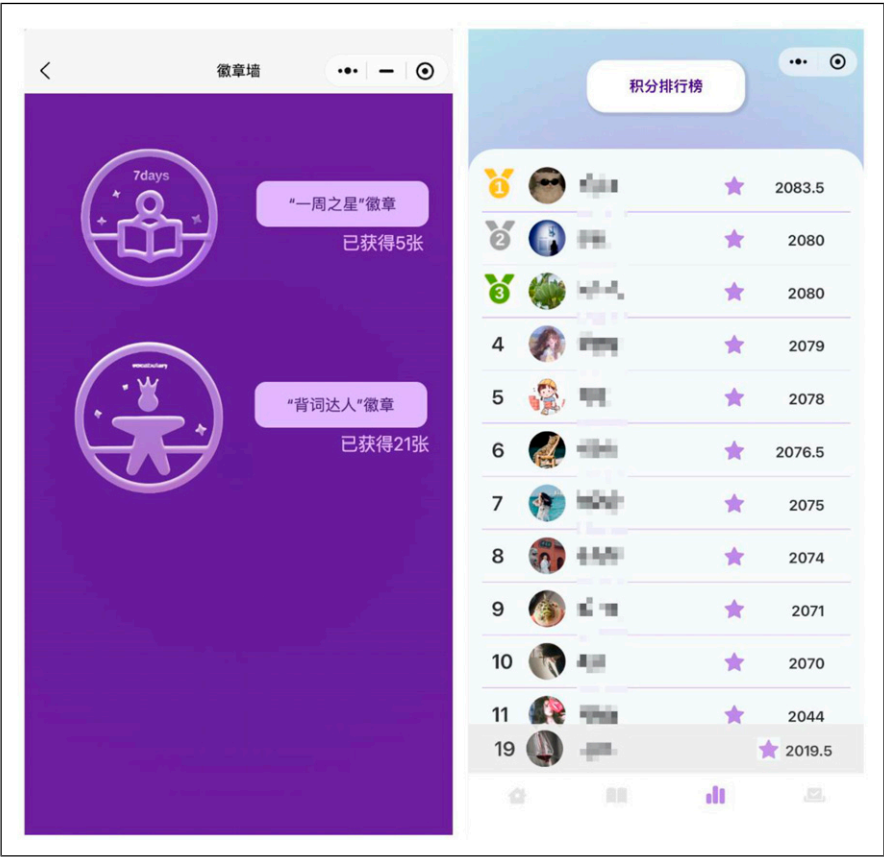


Figure 3. Interface of badges, leaderboards, and points

similar academic backgrounds to the target participants. They confirmed that the game design was helpful for learning technical vocabulary and provided practical suggestions. Based on their feedback, several adjustments were made.

Research Instruments

Vocabulary Tests. To evaluate students' acquisition and retention of French technical vocabulary, three vocabulary tests were administered at three time points: pre-test, immediate recall post, and delayed retention tests. Each test contained 40 items divided into three sections that consistently measured different aspects of lexical knowledge. The first section included 10 picture-word matching items designed to assess students' basic recognition of domain-specific terminology. The second section comprised 20 multiple-choice questions that evaluated students' understanding of vocabulary use in real contexts. The third section featured 10 cloze test items adapted from authentic French materials related to viticulture and enology, aiming to examine students' ability to identify and apply technical terms in professional discourse. All tests were identical in structure and scoring, with each item worth 2.5 points out of 100 and the time limit of 60 minutes.

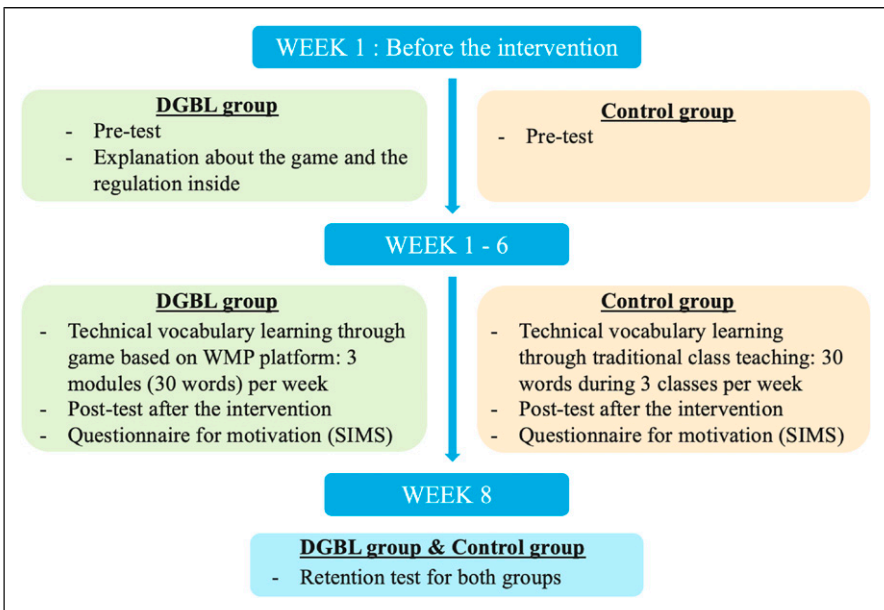
The design of the tests was informed by previous studies on technical vocabulary assessment in specialized domains (e.g., [Wanpen et al., 2013](#); [Yüksel et al., 2022](#)), and all items were reviewed by two French language instructors with experience in FLSP and two disciplinary experts in viticulture and enology to ensure linguistic accuracy and content validity. A pilot test involving 15 students was conducted before the main experiment to verify the clarity and difficulty balance of the items. Based on the pilot results, minor wording adjustments were made to improve comprehensibility.

The reliability of the pre-test and retention test was assessed using the Kuder-Richardson Formula 20 (KR-20), which is suitable for dichotomously scored tests ([Webb & Nation, 2017](#)). The KR-20 coefficients were 0.86 for the pre-test and 0.88 for the retention test, indicating good internal consistency ([Webb et al., 2017](#)).

Motivational Scale. Students' motivation was assessed after the six-week intervention through the Situational Motivation Scale (SIMS), originally developed by [Guay et al. \(2000\)](#) and grounded in SDT. The SIMS measures four dimensions of motivation, including intrinsic motivation, identified regulation, external regulation, and amotivation, across 16 items rated on a 7-point Likert scale ranging from 1 (corresponds not at all) to 7 (corresponds exactly). In this study, minor adaptations were made to the SIMS to align with the instructional conditions of each group. For the experimental group, which engaged in DGBL, the original item "I think that this activity is interesting" was revised as "I think that learning wine-related technical vocabulary through a game-based learning approach is interesting". For the control group, which received traditional instruction, the same item was adapted as "I think that learning wine-related technical vocabulary is interesting". The revised version was reviewed by two experts in educational psychology to ensure linguistic clarity and contextual validity. Cronbach's alpha coefficients obtained from the pilot data indicated satisfactory to high

reliability across all subscales: intrinsic motivation ($\alpha = 0.945$), identified regulation ($\alpha = 0.788$), external regulation ($\alpha = 0.732$), and amotivation ($\alpha = 0.849$).

Experimental Procedure and Data Collection. The overall experimental timeline is illustrated in Figure 4. In week 1, before the intervention, both groups completed a vocabulary pre-test to establish baseline equivalence in technical vocabulary knowledge. From weeks 1 to 6, participants in the two groups engaged in different instructional modalities but followed an identical learning schedule and vocabulary sequence (30 new words per week, totaling 180 terms). The control group received conventional instruction delivered by the teacher through approximately three 15-min sessions per week, each introducing 10 new technical terms. Each session included the vocabulary presentation and practice. The experimental group, by contrast, learned the same 180 vocabulary items through the DGBL platform. Students completed three modules per week, each corresponding to 10 words, matching the control group's learning schedule and content. Each module took approximately 15 minutes to complete and featured interactive tasks. In week 6, both groups completed the immediate recall test and the SIMS to measure vocabulary learning outcomes and motivation levels after the intervention. Two weeks later, in week 8, all participants took the delayed retention test to evaluate long-term vocabulary retention. The entire data collection process was supervised by the same researcher to maintain procedural consistency across both instructional conditions.



Data Analysis. Quantitative data were analyzed using SPSS for macOS (version 29) to examine learners' performance in technical vocabulary acquisition and motivation. A mixed-design ANOVA was conducted to analyze changes in vocabulary test scores across three time points (pre-test, immediate post-test, and delayed retention test), with Group (DGBL vs. control) as the between-subjects factor and Time as the within-subjects factor. Before analysis, data were screened for extreme outliers, and statistical assumptions were examined using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variance. Effect sizes (partial η^2) were calculated and interpreted following Cohen's (2013) guidelines, and 95% confidence intervals were reported to provide estimates of precision.

To compare post-intervention motivational levels between groups, the Mann-Whitney U test was applied to the four subdimensions of the SIMS scale: intrinsic motivation, identified regulation, external regulation, and amotivation. Given that the SIMS used a 7-point Likert scale, this nonparametric test was considered appropriate for ordinal data and moderate sample sizes ($n = 29$ and $n = 30$). As the four SIMS subscales represent theoretically distinct motivational constructs within the SDT framework, they were analyzed separately. Therefore, no formal multiple-comparison correction was applied in order to avoid unnecessary loss of statistical power given the moderate sample size.

In addition, a hierarchical multiple regression analysis was performed to examine the predictive role of motivation on vocabulary retention and to test whether the learning method (DGBL vs. traditional instruction) moderated this relationship. Three models were constructed: Model 1 included pre-test scores as a control variable, Model 2 added motivation and group, and Model 3 introduced the interaction term (motivation $\times$ group). Standardized regression coefficients (β), p-values, and 95% confidence intervals were reported for all predictors. All statistical tests were conducted at a significance level of $p < 0.05$, and both effect sizes and confidence intervals were reported to enhance the interpretability and transparency of results.

Findings

Effects of DGBL on Technical Vocabulary Acquisition

Before conducting the analysis, data were screened to ensure the assumptions of ANOVA, including independence, approximate normality, absence of extreme outliers, and homogeneity of variance. Tests of normality (Shapiro-Wilk) and homogeneity of variance (Levene's test) indicated no severe violations, and no extreme outliers were identified. However, Mauchly's test indicated a violation of sphericity ($W = .829$, $\chi^2 = 10.512$, $df = 2$, $p = 0.005$). Therefore, the Greenhouse-Geisser correction was applied to ensure the validity of subsequent analyses.

Table 1 presents the descriptive statistics of students' technical vocabulary scores across the three test points for both the DGBL and control groups. Table 2 summarizes the results of the mixed-design ANOVA. The analysis revealed a significant main effect of time, $F(1.71, 97.34) = 373.37$, $p < 0.001$, $\eta^2_p = 0.868$, indicating an exceptionally

Table 1. Descriptive Statistics of Vocabulary Acquisition by Group and Time

Test time	DGBL (n = 29)		Control (n = 30)	
	M	SD	M	SD
Pre-test	39.31	14.55	43.42	12.65
Recall test	88.71	8.09	75.33	8.73
Retention test	81.81	12.10	66.67	9.36

large effect size (Cohen, 2013) and substantial improvements across the three time points. There was also a significant main effect of group, $F(1, 57) = 12.98, p < 0.001, \eta^2_p = 0.185$, indicating a large effect size, with the DGBL group consistently outperforming the control group. Moreover, the interaction between time and group was also significant, $F(1.71, 97.34) = 22.69, p < 0.001, \eta^2_p = 0.285$, representing a large effect size and demonstrating that the DGBL group showed steeper improvement and better long-term retention. Figure 5 further illustrates the interaction effect, showing that the DGBL group maintained a higher level of vocabulary retention. The error bars in the figure represent the 95% confidence intervals of the means. At the pre-test stage, the wide overlap between the two intervals confirmed the absence of any significant initial difference between the groups. In contrast, the non-overlapping confidence intervals at the recall and retention tests indicated statistically significant and robust group differences.

Effects of DGBL on Motivation

As shown in Table 3, significant group differences emerged for overall motivation ($U = 61.5, Z = -5.667, p < 0.001$), intrinsic motivation ($U = 2.0, Z = -6.622, p < 0.001$), and identified regulation ($U = 117.5, Z = -4.880, p < 0.001$), with the DGBL group consistently outperforming the control group. A marginally significant difference was observed in external regulation ($U = 568.5, Z = 2.034, p = 0.042$), where the control group showed slightly higher scores. No significant difference was found for amotivation ($U = 421.0, Z = -0.216, p = 0.829$), while effect size (r) and their 95% confidence intervals were also calculated to indicate the precision of these group differences.

Table 2. Results of the Mixed-Design ANOVA on Vocabulary Acquisition

Effects	df	F	η^2_p	p
Time	1.71, 97.34	373.37	0.868	<0.001
Group	1, 57	12.98	0.185	<0.001
Time $\times$ group	1.71, 97.34	22.69	0.285	<0.001

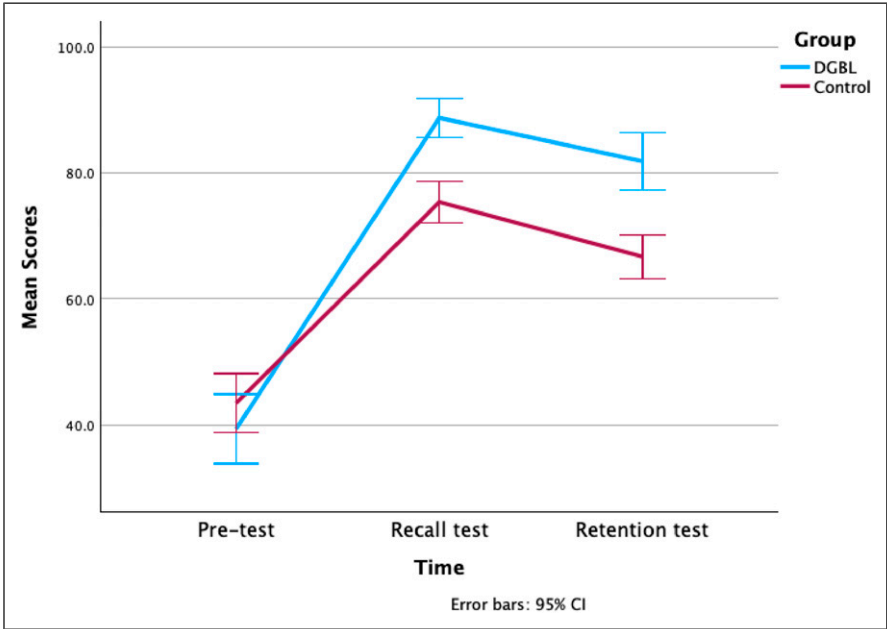


Figure 5. Estimated marginal means of vocabulary scores across time and group

Predictive Role of Motivation and Moderating Effects of Learning Method on Vocabulary Retention

To address RQ3 and RQ 4, hierarchical regression analyses were conducted to examine the predictive and moderating effects of motivation and learning method on vocabulary retention. Preliminary analyses confirmed that motivation ($r = 0.67, p < 0.001$) and

Table 3. Mann-Whitney U Test and Descriptive Statistics of Motivation Dimensions by Group

Motivation dimension	Groups	M (SD)	U	Z	p
Overall motivation	DGBL	100.83 (6.20)	61.5	-5.67	<0.001
	Control	84.43 (8.47)			
Intrinsic motivation	DGBL	26.48 (1.55)	2.0	-6.62	<0.001
	Control	11.70 (3.82)			
Identified regulation	DGBL	26.79 (1.32)	117.5	-4.88	<0.001
	Control	24.00 (2.10)			
External regulation	DGBL	22.21 (3.21)	568.5	2.03	0.042
	Control	23.93 (3.36)			
Amotivation	DGBL	25.34 (2.36)	421.0	-0.22	0.829
	Control	24.80 (3.48)			

learning method ($r = 0.58, p < 0.001$) were both significantly and positively correlated with retention. The tolerance (≥ 0.26) and VIF (≤ 3.79) values demonstrated no multicollinearity issues, and assumption tests showed acceptable normality, homoscedasticity, and independence of residuals.

As presented in Table 4, after controlling for pre-test scores in Model 1 ($\beta = 0.21, p = 0.108$), Model 2 further revealed that motivation was a significant positive predictor of vocabulary retention ($\beta = 0.43, p = 0.006$). The group variable showed a positive effect but reached only marginal significance ($\beta = 0.30, p = 0.055, 95\% \text{ CI } [-0.18, 15.55]$), indicating that students in the DGBL group may have outperformed those in the control group. This result may be influenced by the limited sample size, which reduced the statistical power and prevented the effect from reaching the conventional level of significance ($p < 0.05$). Nevertheless, Model 2 accounted for a substantially greater proportion of variance ($\Delta R^2 = 0.46, F = 25.42, p < 0.001$), confirming that the inclusion of motivation and learning method jointly enhanced the model's predictive power for vocabulary retention, with motivation demonstrating a stronger and statistically significant effect. The regression coefficients and their 95% confidence intervals were also examined to ensure the precision and reliability of the parameter estimates.

Model 3 added the interaction term (motivation $\times$ group) based on Model 2. The interaction was significant ($\beta = -0.46, p = 0.004, 95\% \text{ CI } [-1.68, -0.33]$), contributing additional explained variance to the model ($\Delta R^2 = 0.07, F = 8.83, p = 0.004$). In this model. Both the main effect of motivation ($\beta = 0.73, p < 0.001$) and that of learning method ($\beta = 0.38, p = 0.010$) were significant. The negative interaction indicates that the

Table 4. Hierarchical Regression Predicting Vocabulary Retention From Motivation and Learning Mode

Predictor	B	SE	β	t	p (β)	95% CI
Model 1						
Pre-test	0.20	0.13	0.21	1.63	0.108	[-0.05, 0.45]
Model 2						
Pre-test	0.21	0.10	0.22	2.20	0.032	[0.02, 0.41]
Motivation (C)	0.51	0.18	0.43	2.87	0.006	[0.15, 0.86]
Group	7.69	3.92	0.30	1.96	0.055	[-0.18, 15.55]
Model 3						
Pre-test	0.18	0.09	0.19	1.96	0.055	[-0.004, 0.36]
Motivation (C)	0.87	0.21	0.73	4.23	<0.001	[0.46, 1.28]
Group	9.99	3.75	0.38	2.66	0.010	[2.47, 17.51]
Motivation $\times$ group	-1.00	0.34	-0.46	-2.97	0.004	[-1.68, -0.33]

Notes: B = unstandardized coefficient; SE = standard error; β = standardized coefficient; CI = confidence interval. Dependent variable = Retention test score; Motivation (C) = centered motivation score; group was coded as 0 = Control group, 1 = DGBL group.

Model 1: $R^2 = 0.045, F(1, 57) = 2.66, p = 0.108$.

Model 2: $\Delta R^2 = 0.459, F(3, 55) = 25.42, p < 0.001$.

Model 3: $\Delta R^2 = 0.070, F(1, 54) = 8.83, p = 0.004$.

positive predictive effect of motivation on vocabulary retention was attenuated under the DGBL condition compared to the control group, as illustrated in Figure 6.

Discussion

Interpreting the Learning Gains in Technical Vocabulary through DGBL

The finding confirmed that DGBL significantly improved students’ acquisition and retention of technical vocabulary compared with traditional instruction. Although both groups showed statistically significant progress, the DGBL group achieved greater immediate gains and maintained higher performance over time, demonstrating the dual benefits of this approach for both short-term learning and long-term retention. This finding supports the effectiveness of DGBL in facilitating technical vocabulary acquisition within the FLSP context and aligns with previous studies on general vocabulary learning, which have consistently emphasized the advantage of DGBL in promoting deeper processing and more durable retention (Al-Hoorie & Albijadi, 2024; Vnucko & Klimova, 2023). For example, the empirical study of Yang et al. (2025) emphasized that both audio and visual stimuli in DGBL environments effectively facilitate learners’ processing and internalization of instructional content, thereby enhancing both their confidence and vocabulary acquisition. From a cognitive

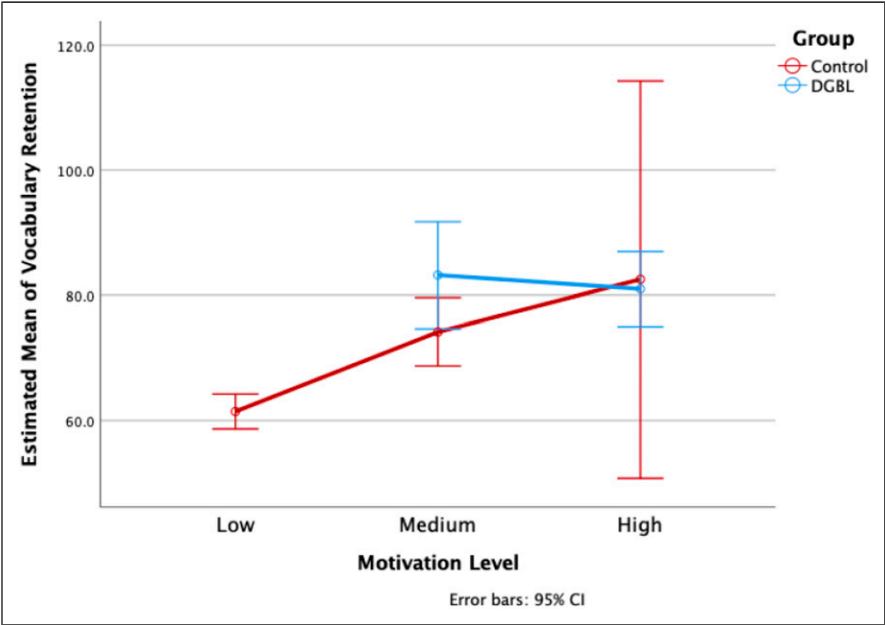


Figure 6. Interaction between motivation and learning method in predicting vocabulary retention

perspective, these results are consistent with the CTML, suggesting that multimodal vocabulary input, such as visual and auditory representation combined with contextualized example sentences, may enhance information organization and encoding (Mayer & Fiorella, 2022). This process reduces the abstractness and cognitive load of technical terms, allowing learners to build richer semantic representations (Jia et al., 2025).

In addition, the effectiveness of DGBL appears closely linked to its diverse and meaningful repetition. Previous studies have highlighted that, compared with rote memorization or drill-based methods, the incorporation of varied vocabulary tasks within gamified environments helps maintain learners' interest and motivation, ultimately improving learning persistence and outcomes (Calvo-Ferrer, 2021; Jia, 2024). Such mechanisms also help to compensate for the limited exposure frequency of technical vocabulary in non-native language learning contexts (Wu et al., 2020).

Nevertheless, it is worth noting that both groups presented a decline in performance from the recall to the retention test, suggesting that forgetting over time is an inevitable phenomenon. However, the DGBL group demonstrated a significantly smaller decline than the control group. This result may be attributed to its interactive repetition mechanism, which differs from passive repetition in conventional instruction. In this design, students are required to actively retrieve, verify, and reconstruct word meanings within dynamic task contexts, thereby engaging in generative processing and memory reconsolidation. Previous research has confirmed that such retrieval-based learning effectively strengthens memory traces and enhances long-term retention (Kazu & Kuvvetli, 2023). Moreover, the instant feedback embedded in the game tasks further reinforced successful recall, creating a cyclical loop of retrieval and reinforcement (Zhang et al., 2023).

Overall, these features constitute a cognitively enriched learning environment that sustains student engagement while slowing the rate of forgetting over time. Theoretically, this finding reinforces the role of generative processing and retrieval practice in promoting durable memory retention, and practically, it provides robust empirical support for the pedagogical value of DGBL in technical vocabulary education.

Examining the Motivational Shifts Induced by DGBL

The motivational results indicated that DGBL had a significant positive impact on students' overall motivation, particularly in the two autonomous dimensions of intrinsic motivation and identified regulation. These findings are consistent with recent studies highlighting the capacity of DGBL to promote more internalized and self-determined motivational orientations among foreign language learners (e.g., Ahmed et al., 2022; Esteban, 2024). From the perspective of SDT, such improvement can be interpreted as a result of greater satisfaction of the three basic psychological needs: autonomy, competence, and relatedness (Deci et al., 1991; Ryan & Deci, 2020).

In this study, first of all, the modular task design of the DGBL platform allowed students to flexibly schedule their own learning time and pace, thereby enhancing their sense of control and fulfilling the need for autonomy (Hsu et al., 2023). To further

support autonomous learning, the integrated points system provided immediate numerical feedback for every completed task and dynamically visualized learners' cumulative progress. This mechanism enabled students to self-monitor their advancement and make independent adjustments to their study pace, reinforcing their perception of autonomy and self-regulation (Govender & Arnedo-Moreno, 2021). Prior evidence suggests that when points function as informational rather than controlling feedback, they strengthen both competence and intrinsic motivation (Kashefian-Naeeni et al., 2024). Second, the instant feedback mechanism enabled students to monitor their progress, identify weaknesses, and consolidate achievements, which strengthened their sense of competence (Taskiran et al., 2024). The badge system complemented this by offering symbolic recognition for high scores or continuous participation, providing students with clear markers of accomplishment. Such visible milestones helped transform performance feedback into a sustained sense of mastery and self-efficacy. To avoid social pressure, badges were visible only to individual students, consistent with the finding of Kyewski and Krämer (2018) that private reinforcement elicits more positive evaluations than public comparisons. Third, the need for relatedness was addressed on both social and academic levels. Socially, the integrated leaderboard and ranking system allowed students to compare their progress with peers in a low-pressure context, fostering a sense of social presence and shared participation (Pi et al., 2024). Academically, the content design was tightly aligned with the students' professional background and incorporated multimodal resources (including text, images, and audio) to facilitate semantic understanding. This contextually rich and professionally relevant input helped them establish meaningful connections between the learning materials and their academic identity (Dolfing et al., 2021; O'Neill & Short, 2025). The joint fulfillment of these three needs provides a reasonable explanation for the significantly higher scores of the DGBL group in autonomous motivation compared with the control group.

Furthermore, the highly interactive and engaging game design also played a crucial role in sustaining students' motivation (Lin et al., 2025). Previous research has indicated that learners tend to exhibit greater motivation and reduced anxiety when facing game tasks that are both interesting and challenging, thereby sustaining continuous learning interest (Dai & Wang, 2024). Similarly, in the present study, each module integrated audio-visual stimuli and varied game tasks that stimulated students' curiosity toward vocabulary learning and enhanced their intrinsic drive to explore. This emotional involvement through game-based experiences aligns with the emphasis of SDT on the enhancement of autonomy and competence, further explaining how DGBL fosters autonomous motivation.

Notably, although there were significant increases in autonomous motivation, the external regulation and amotivation did not show statistically significant differences between the two groups. The control group scored slightly higher in external regulation, whereas amotivation levels were similar across groups. This suggests that the DGBL platform did not rely on external incentives or normative control to enhance motivation. Instead, it strengthened students' internalized value recognition of the learning content through an immersive, enjoyable, and professionally relevant environment,

encouraging greater voluntary engagement (Chen & Chang, 2024). The studies by Camacho-Sánchez et al. (2024) and Li, Chen, and Deng (2024) also confirmed that this motivation transformation mechanism, which focuses on enhancing intrinsic regulation, further underscores the educational potential of DGBL in supporting the development of a high level of motivation. More importantly, improvements in intrinsic motivation and identified regulation reflect not only a qualitative enhancement of motivation but also closer associations with academic performance, persistence, and cognitive engagement (Ryan & Deci, 2020).

Predictive Role of Motivation and Moderating Effect of Learning Method

The regression analysis further clarified the predictive role of motivation in technical vocabulary retention and how this relationship differs across instructional conditions (DGBL vs. traditional instruction). Motivation significantly and positively predicted the retention outcomes, indicating that higher motivational levels were associated with better performance on the retention test. This result aligns with SDT, which posits that autonomous forms of motivation foster deeper processing and sustained engagement, thereby supporting longer-term learning outcomes (Alamer & Lee, 2019; Chiu et al., 2024; Ryan & Deci, 2020).

A more interesting finding was the significant negative interaction between motivation and group, demonstrating that the predictive strength of motivation for retention was weaker under DGBL than under traditional instruction. Although this finding may appear, at first glance, to contradict the central role of motivation, it in fact highlights the unique value of DGBL. The DGBL environment not only directly enhanced vocabulary retention (as evidenced by the significant main effect of learning method in Model 3) but also provided compensatory benefits through its cognitive and emotional support mechanisms for students with varying initial motivation levels. This result echoes the findings of Li, Chen, and Deng (2024), who reported that digital learning environments could moderate the relationship between motivation and academic performance, offering particular support for students with lower motivation.

From a theoretical perspective, this motivational-environmental interaction supports the complementary relationship between SDT and CTML. DGBL environments stimulate motivation through external design features (e.g., challenges, feedback, and rewards) while simultaneously promoting cognitive processing and consolidation through multimodal inputs and repeated retrieval practice (Yang et al., 2020; Zhou et al., 2024). For highly motivated students, DGBL facilitates the transfer of motivation into effective vocabulary retention (Chowdhury et al., 2024). For students with lower motivation, it provides powerful external stimulation that compensates for motivational deficits and supports continuous progress (Al-Khresheh, 2025). This compensatory function highlights the inclusive value of DGBL, as it creates a more equitable and effective learning environment for students with diverse motivational profiles (Zhang et al., 2023).

In summary, the regression findings confirm the control role of motivation in learning outcomes and also demonstrate the unique moderating function of DGBL. Beyond enhancing students' overall motivation, DGBL design elements can buffer

individual motivational differences and promote more stable retention. These results provide new theoretical evidence for understanding how motivational and environmental factors jointly shape vocabulary acquisition within technology-enhanced language instruction.

Conclusion

This study investigated the effects of DGBL on technical vocabulary acquisition and learning motivation in the context of FLSP. Based on a six-week intervention, the results showed that DGBL significantly enhanced students' vocabulary acquisition, with both recall and retention test scores outperforming those of the traditional group. The DGBL environment also significantly improved students' intrinsic motivation and identified regulation, fostering more autonomous learning orientations. The regression analysis further revealed that motivation positively predicted vocabulary retention, while this relationship was partially weakened under the DGBL condition. This finding suggests that the DGBL environment provided built-in cognitive and affective support that compensated for individual motivational differences, thereby promoting more stable learning outcomes.

At the theoretical level, the study deepens the integration of SDT and CTML within DGBL contexts. The findings indicate that DGBL environments not only satisfy students' basic psychological needs for autonomy, competence, and relatedness but also facilitate deeper lexical processing and long-term memory consolidation through dual-channel processing and interactive repetition. The moderating effect of DGBL further reveals that interactivity and feedback mechanisms can play a compensatory role in situations with low motivation by providing cognitive and emotional scaffolding, thus leading to more equitable learning outcomes across learners with different motivational levels.

From a pedagogical perspective, the findings offer practical implications for vocabulary instruction in FLSP contexts. First, in terms of task design, teachers implementing DGBL should focus on combining a variety of multimodal game tasks rather than simply providing multiple sensory inputs. The effectiveness of vocabulary learning depends on the frequency of repetition and on the diversity of task formats, which encourages students to repeatedly retrieve and reorganize word meanings across different perceptual channels and achieve deeper processing through interaction. Second, the design of this study, embedding language learning into the professional context of viticulture and enology, demonstrates that technical vocabulary instruction should move from isolated memorization toward semantic contextualization. For teachers in other FLSP disciplines, designing vocabulary tasks that reflect authentic disciplinary activities can help students naturally understand the usage and collocations of technical terms and transfer language knowledge to academic or professional contexts. Overall, the findings suggest that, within the context of FLSP education, a DGBL approach that integrates game mechanics with multimodal design can simultaneously enhance students' motivation and deepen cognitive processing in technical vocabulary acquisition, providing transferable design insights for the innovation of specialized vocabulary instruction.

Limitations and Future Research Directions

Despite the positive empirical support this study provides for technical vocabulary instruction, several limitations should be acknowledged and addressed in future research. First, in terms of sample characteristics and research design, the participants were Chinese undergraduates majoring in viticulture and enology, whose disciplinary and linguistic backgrounds were relatively homogeneous. Therefore, the generalizability of the findings to other academic fields, language proficiencies, or cultural contexts remains to be tested. Then, as the present study adopted a quasi-experimental design without random assignment, potential influences of students' prior learning experiences, strategies, or external factors cannot be completely ruled out. Future studies may employ stricter experimental control or mixed methods designs to strengthen the validity of the results. Furthermore, the relatively limited sample size may have reduced the statistical power to detect medium-sized effects. Future research could recruit larger and more diverse samples or extend the intervention duration to improve statistical sensitivity and strengthen the robustness of the findings.

Second, regarding measurement and assessment, the study primarily relied on vocabulary tests to assess learning outcomes. While these tests effectively captured participants' knowledge acquisition, they offered limited insight into their ability to apply vocabulary in authentic language contexts. Future research is encouraged to incorporate productive language tasks, such as academic writing, oral presentations, or professional communication, to more comprehensively evaluate the impact of DGBL on technical language proficiency.

Finally, in relation to motivational variables and data sources, this study focused on overall motivational changes but did not examine in depth how specific motivational dimensions function differently. Future work could adopt multidimensional motivational modeling to further explore how intrinsic motivation, identified regulation, and external regulation distinctly contribute to learning processes and outcomes, thereby clarifying the motivational pathways supported by DGBL. Moreover, as motivation in this study was measured primarily through self-report questionnaires, subjective bias may exist. Future studies could integrate behavioral indicators from learning logs or platform analytics, employing learning analytics or educational data mining techniques to provide more objective evidence of motivation and engagement.

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Ethical Approval

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Data Availability Statement

Data will be made available on request.

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