FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

GAMIFIED SPACED REPETITION FOR TECHNICAL VOCABULARY LEARNING IN VOCATIONAL ENGINEERING EDUCATION: A QUASI-EXPERIMENTAL STUDY

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ABSTRACT

This research aims to analyze the effectiveness of gamification-based spaced repetition in improving the mastery and retention of civil engineering vocabulary among students of Politeknik Dewantara Palopo. The research method employed is a quasi-experimental design with experimental and control groups. The instruments used include a civil engineering vocabulary test and a motivation questionnaire. The results show a significant improvement in vocabulary mastery in the experimental group using gamified spaced repetition media. This research contributes to the application of technology-based learning methods to enhance the quality of vocational education. Furthermore, it suggests that the integration of gamification with spaced repetition provides a more engaging and effective learning environment, promoting better retention and long-term recall of technical vocabulary. The study also highlights the importance of incorporating modern educational technologies in vocational education to address the challenges of traditional learning methods. This study provides empirical evidence of the potential benefits of using gamification-based spaced repetition techniques in improving vocabulary acquisition in technical fields such as civil engineering, contributing to the advancement of educational practices in vocational training settings. As such, it has significant implications for curriculum development and the enhancement of teaching methodologies in technical education.

Keywords: Gamification, Spaced Repetition, Vocational Education, Vocabulary Mastery,

INTRODUCTION

Vocational education plays a strategic role in preparing students to meet industry demands, particularly in technical fields such as civil engineering. As an applied educational pathway, vocational education emphasizes competence-based training, industry relevance, and employability-oriented outcomes, requiring learners to master not only practical skills but also technical communication for professional contexts (Bai et al., 2020). Within civil engineering education, mastery of technical vocabulary is fundamental for interpreting construction drawings, understanding technical specifications and standards, documenting project workflows, and collaborating in multidisciplinary teams. Vocabulary knowledge is widely recognized as a strong predictor of academic achievement and communicative competence, particularly in English for Specific Purposes (ESP) contexts (Subhash & Cudney,

FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

2018). In technical disciplines, vocabulary mastery involves form–meaning mapping, contextualized use, and accurate retrieval under authentic task demands (Toda et al., 2017). When vocabulary competence is inadequate, students may experience difficulties in comprehending domain texts and performing professional communication tasks required in workplace settings (Zainuddin et al., 2020).

Despite its importance, vocabulary instruction in many vocational settings still relies on conventional memorization and teacher-centered explanation, which may generate short-term gains but often fails to ensure durable retention. Learning science has long demonstrated that memory decays systematically when newly learned information is not reinforced over time, as described in the classical forgetting function (Huang et al., 2020). Furthermore, a substantial body of research shows that distributed practice yields more robust long-term retention than massed practice, indicating that vocabulary learning benefits from structured review schedules rather than cramming (Kang, 2016). The spacing effect—where retention improves when repetitions are spread over time—has been repeatedly validated in experimental and applied learning studies (Küpper-Tetzel, 2014).

Spaced repetition has therefore gained strong attention as an evidence-based learning strategy for vocabulary mastery. By scheduling reviews at increasing intervals aligned with memory consolidation principles, spaced repetition can improve retrieval strength and reduce forgetting rates (Carpenter et al., 2012). Practical implementations of spaced repetition through spaced repetition systems (SRS) have been associated with improved vocabulary acquisition efficiency and sustained retention in language learning settings (Lo, 2024). In addition, meta-analytic evidence indicates that distributed practice produces meaningful learning benefits across materials and learner populations, supporting its relevance for technical vocabulary learning in vocational education (Nakata & Webb, 2016). However, although spaced repetition is cognitively effective, it does not automatically resolve motivational barriers—particularly in vocational classrooms where learners often prefer interactive, task-based, and contextually authentic instruction (Webb & Nation, 2017). Research in second language vocabulary learning also emphasizes that deliberate vocabulary study requires sustained engagement and repeated encounters, which can be challenging to maintain without motivational support (Schmitt & Schmitt, 2020).

In this regard, gamification emerges as a complementary pedagogical innovation. Gamification is commonly defined as the use of game design elements in non-game contexts to enhance engagement and user experience in goal-directed activities (Plonsky & Oswald, 2014). In education, gamification typically operationalizes elements such as points, levels, badges, progress indicators, challenges, and immediate feedback to support learners' persistence and participation (Mayer, 2024). Theoretically, gamification is often linked to motivational frameworks such as self-determination theory, which posits that autonomy, competence, and relatedness are key determinants of high-quality motivation and sustained learning behaviors (Ryan & Deci, 2020). Empirical reviews have reported that gamification can positively influence engagement and learning outcomes, although effects depend on design quality, context, and alignment with learning objectives (Dichev & Dicheva, 2017).

Although previous studies have demonstrated the benefits of spaced repetition for retention and gamification for engagement, a clear research gap remains regarding their

FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

integrated application for discipline-specific vocabulary mastery in vocational civil engineering education. Existing evidence on gamified vocabulary learning frequently focuses on general language vocabulary rather than specialized technical lexicons; moreover, the vocational higher-education context where industry alignment, technical literacy, and applied competence are central remains underrepresented in the literature (Sailer & Homner, 2020). Additionally, research has noted that gamification can generate unintended negative effects (e.g., overemphasis on extrinsic rewards or competitiveness) if not carefully designed, underscoring the need for empirically validated, context-adaptive frameworks (Lyster & Saito, 2010).

Therefore, empirical investigation is needed to determine whether integrating gamification with spaced repetition can simultaneously strengthen memory consolidation and sustain learner engagement for technical vocabulary learning outcomes. The novelty of this study lies in the systematic integration of gamification design principles with an algorithmically structured spaced repetition model specifically tailored to discipline-specific vocabulary learning in civil engineering within a vocational higher education context, and in evaluating both immediate mastery and longer-term retention as outcome measures (Pass et al., 2003). Accordingly, this study aims to examine the effectiveness of gamification-based spaced repetition in improving the mastery and long-term retention of civil engineering vocabulary among students of Politeknik Dewantara Palopo, contributing evidence to technology-enhanced pedagogy and curriculum development in vocational technical education (UNESCO, 2021).

METHODS

Research Design

This study employed a quasi-experimental design using a non-equivalent control group structure with pre-test, post-test, and delayed post-test measures. The design was selected to examine the causal effect of gamification-based spaced repetition on vocabulary mastery and long-term retention while maintaining ecological validity within a natural classroom setting.

Two intact classes of civil engineering students at Politeknik Dewantara Palopo were assigned as the experimental group and the control group. Both groups completed a pre-test to establish baseline equivalence. Following the intervention period, a post-test was administered to measure immediate vocabulary mastery. A delayed post-test was conducted four weeks after the intervention to assess retention stability.

The independent variable was the instructional model (gamification-based spaced repetition vs. conventional vocabulary instruction). The dependent variables were (1) vocabulary mastery (post-test scores) and (2) long-term retention (delayed post-test scores). Learning motivation was measured as a secondary outcome variable and potential predictor.

Participants

The participants consisted of undergraduate civil engineering students enrolled in a technical English course. A purposive sampling technique was used to select two comparable

FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

classes with similar academic backgrounds. The total sample size ranged between 50 and 70 students (approximately 25–35 students per group), which met the minimum requirement for parametric statistical testing.

Before the intervention, a homogeneity test was conducted using pre-test scores to ensure baseline equivalence between groups.

Instructional Treatment

Experimental Group

The experimental group received vocabulary instruction through a gamified spaced repetition system (SRS) that incorporated distributed review intervals based on recall performance, provided immediate corrective feedback, and included gamification features such as points, progress bars, levels, badges, and leaderboard rankings, along with weekly cumulative vocabulary challenges. Vocabulary items were selected from civil engineering terminology commonly used in construction documentation and technical communication. Students engaged with the system for 20–30 minutes per session, three times per week, over a six-week intervention period.

Control Group

The control group received conventional vocabulary instruction, which included teacher-led explanations, word lists, and translation exercises, in-class memorization activities, and paper-based practice tasks. The instructional duration and vocabulary content were aligned with the experimental group to ensure equivalent content exposure.

Instruments

Civil Engineering Vocabulary Test

The vocabulary test consisted of 40 multiple-choice and contextual usage items, covering technical terminology relevant to civil engineering. The test assessed word recognition, contextual meaning, and applied usage in technical sentences. Content validity was ensured through expert judgment by two lecturers, one in civil engineering and one in English for Specific Purposes (ESP). Reliability was assessed using Cronbach's Alpha, with a value of $\alpha \geq 0.70$ considered acceptable. The same test format was used for the pre-test, post-test, and delayed post-test, with item reordering applied to minimize testing effects.

Learning Motivation Questionnaire

Student motivation was measured using a Likert-scale questionnaire adapted from validated motivational constructs based on self-determination theory. The questionnaire assessed intrinsic motivation, perceived competence, engagement, and persistence. Construct validity was tested using exploratory factor analysis (EFA), while reliability was evaluated using Cronbach's Alpha.

FOSTER JELT
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Data Analysis

Data were analyzed using SPSS (or equivalent statistical software). The analysis procedure included:

Descriptive Statistics

Descriptive statistics were used to summarize the data, including the calculation of the mean and standard deviation. Normality testing was conducted using the Shapiro-Wilk test to assess the distribution of the data.

Baseline Equivalence Testing

An independent samples t-test was performed on the pre-test scores to test for baseline equivalence between the experimental and control groups, ensuring that there were no significant differences between the groups before the intervention.

Effectiveness Testing

Effectiveness was assessed using independent samples t-tests to compare post-test scores between the experimental and control groups. A similar t-test was applied to the delayed post-test scores to evaluate retention. Additionally, gain score analysis was conducted to measure the improvement from pre-test to post-test.

Effect Size Calculation

Cohen's d was calculated to determine the practical significance of the results, with values of 0.20, 0.50, and 0.80 indicating small, medium, and large effects, respectively.

Regression Analysis

Multiple regression analysis was used to examine whether motivation significantly predicted vocabulary mastery and retention outcomes, allowing for an understanding of the relationship between motivation and vocabulary learning.

RESULTS

Preliminary Analysis

Before hypothesis testing, descriptive statistics and assumption checks were conducted. The pre-test scores indicated no statistically significant difference between the experimental group (M = 56.42, SD = 8.31) and the control group (M = 55.87, SD = 7.94), $t(58) = 0.27$, $p = .79$. This result confirmed baseline equivalence between groups before the intervention.

The Shapiro–Wilk test indicated that all test score distributions were normally distributed ($p > .05$). Levene's test confirmed homogeneity of variance for post-test and delayed post-test scores ($p > .05$). The homogeneity of regression slopes assumption for ANCOVA was also satisfied, as the interaction between group and pre-test scores was not significant ($p > .05$).

FOSTER JELT
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***e*-ISSN: 2723-4126**
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Table 1. Descriptive Statistics of Vocabulary Scores

Group	Pre-test (M ± SD)	Post-test (M ± SD)	Delayed Post-test (M ± SD)
Experimental	56.42 ± 8.31	78.65 ± 7.24	75.38 ± 7.96
Control	55.87 ± 7.94	69.13 ± 8.02	63.41 ± 8.75

Effect of Gamification-Based Spaced Repetition on Vocabulary Mastery

After the six-week intervention, the experimental group demonstrated higher post-test scores (M = 78.65, SD = 7.24) compared to the control group (M = 69.13, SD = 8.02).

An ANCOVA was conducted with post-test scores as the dependent variable, group as the fixed factor, and pre-test scores as the covariate. After controlling for baseline performance, a statistically significant effect of instructional model was found:

$f(1,57) = 18.47$, $p < .001$, $\eta p^2 = .245$.

The adjusted mean post-test score for the experimental group (M_adj = 78.12) remained significantly higher than the control group (M_adj = 69.48). The partial eta squared value ($\eta p^2 = .245$) indicates a large effect size, suggesting that approximately 24.5% of the variance in post-test scores was explained by the instructional treatment.

Cohen's *d* for the between-group post-test comparison was calculated as d = 1.25, indicating a large practical effect. These findings support H1, demonstrating that gamification-based spaced repetition significantly improved vocabulary mastery compared to conventional instruction.

Table 2. ANCOVA Results for Vocabulary Mastery (Post-test)

Source	F	p-value	Partial η^2
Group	18.47	< .001	.245
Covariate (Pre-test)	12.83	.001	.184

Note: Dependent variable = Post-test score; Covariate = Pre-test score.

Effect on Long-Term Retention

Four weeks after the intervention, delayed post-test scores revealed that the experimental group maintained higher retention (M = 75.38, SD = 7.96) compared to the control group (M = 63.41, SD = 8.75).

ANCOVA analysis controlling for pre-test scores showed a significant group effect:

$f(1,57) = 26.93$, $p < .001$, $\eta p^2 = .321$.

The adjusted retention mean for the experimental group (M_adj = 74.89) was significantly higher than that of the control group (M_adj = 63.88). The effect size ($\eta p^2 = .321$) indicates a large effect, with 32.1% of variance in retention scores attributable to the instructional model.

FOSTER JELT
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Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

Cohen's *d* for retention comparison was d = 1.41, also indicating a large effect. These findings support H2, confirming that gamification-based spaced repetition significantly enhanced long-term vocabulary retention.

Table 3. ANCOVA Results for Long-Term Retention (Delayed Post-test)

Source	F	p-value	Partial η^2
Group	26.93	< .001	.321
Covariate (Pre-test)	14.75	< .001	.206

Note: Dependent variable = Delayed post-test score; Covariate = Pre-test score.

Gain Score Analysis

Gain scores (Post-test − Pre-test) were calculated to measure learning improvement. The experimental group showed a mean gain of 22.23 points, whereas the control group showed a mean gain of 13.26 points. An independent samples t-test revealed a significant difference:

$t(58) = 4.12, p < .001.$

This further confirms the superiority of the intervention in improving vocabulary performance.

Motivation Analysis

The motivation questionnaire results indicated that the experimental group reported higher overall motivation (M = 4.12, SD = 0.46) compared to the control group (M = 3.54, SD = 0.52).

An independent samples t-test showed a statistically significant difference:

$t(58) = 4.63, p < .001, d = 1.19.$

These findings support H3, indicating that gamification-based spaced repetition significantly increased student motivation.

Table 4. Motivation and Regression Analysis

Group	Mean Motivation Score	SD	t	p	Cohen's d
Experimental	4.12	0.46	4.63	< .001	1.19
Control	3.54	0.52			

Regression Analysis

A multiple regression analysis was conducted to examine whether motivation significantly predicted vocabulary mastery and retention outcomes.
Results indicated that motivation significantly predicted post-test scores:

$\beta = .42, t = 3.68, p < .001,$

$R^2 = .28.$

FOSTER JELT
Journal of English Language Teaching

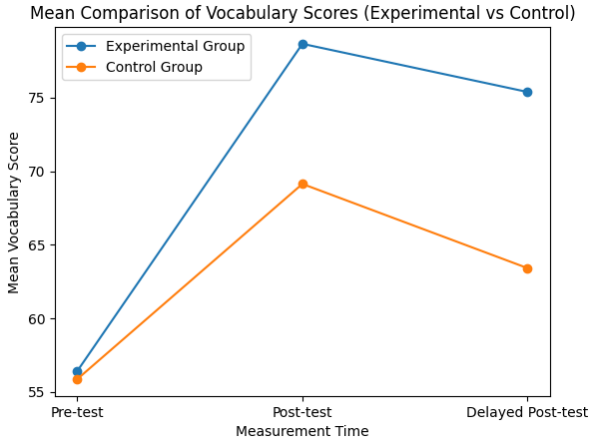
Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

Similarly, motivation significantly predicted delayed post-test scores:

$\beta = .48$, $t = 4.12$, $p < .001$,

$R^2 = .34$.

This suggests that motivation explained 28% of the variance in mastery scores and 34% of the variance in retention scores, supporting H4.



Picture 1. Mean Comparison of Vocabulary Scores (Experimental vs Control)

DISCUSSION

The findings of this study provide empirical support for the theoretical integration of cognitive reinforcement and motivational design in vocational technical vocabulary instruction. Consistent with distributed practice theory, students exposed to gamification-based spaced repetition demonstrated significantly higher vocabulary mastery and long-term retention compared to those receiving conventional instruction. The large effect sizes observed in both post-test and delayed post-test analyses suggest that structured spaced retrieval significantly strengthened memory consolidation processes.

The retention findings are particularly important in vocational education contexts, where technical terminology must be maintained for future academic and workplace application. The experimental group showed only a slight decline from post-test to delayed post-test, whereas the control group exhibited a more substantial decrease. This pattern aligns with spacing effect research, which emphasizes that distributed review enhances the durability of learning.

In addition to cognitive reinforcement, the motivational dimension played a critical role. The significant difference in motivation scores and the regression results indicate that engagement contributed meaningfully to vocabulary performance. This supports self-determination theory, suggesting that gamification elements such as progress indicators, rewards, and feedback enhance perceived competence and persistence, thereby indirectly strengthening learning outcomes.

FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

Importantly, this study addresses a gap in the literature concerning the integrated application of gamification and spaced repetition in discipline-specific vocabulary learning within vocational civil engineering education. While prior research has examined these approaches separately, the present findings demonstrate that their combination yields synergistic effects. The intervention not only improved immediate mastery but also sustained retention, indicating both cognitive and motivational benefits.

From a practical standpoint, the results suggest that vocational educators should consider integrating algorithmically structured spaced repetition with gamified learning environments to enhance technical vocabulary acquisition. Such integration may improve workplace readiness by ensuring that essential terminology is retained over time.

CONCLUSION

This study provides robust empirical evidence that the integration of gamification-based spaced repetition significantly enhances both vocabulary mastery and long-term retention among civil engineering students in vocational higher education. After controlling for baseline performance through ANCOVA, the experimental group demonstrated substantially higher post-test and delayed post-test scores compared to the control group, with large effect sizes observed across analyses. These findings confirm that combining distributed practice principles with motivational game-design elements produces synergistic cognitive and affective benefits.

The results further indicate that motivation plays a meaningful predictive role in vocabulary learning outcomes. The significant regression coefficients suggest that gamification not only increases engagement but also indirectly strengthens mastery and retention by fostering perceived competence and sustained effort. This aligns with cognitive reinforcement theory and self-determination theory, reinforcing the theoretical rationale for integrating structured retrieval practice with motivational design.

From a pedagogical perspective, the findings highlight the importance of adopting technology-enhanced instructional strategies in vocational education contexts, particularly for discipline-specific vocabulary acquisition. Given that technical terminology is essential for professional communication and workplace readiness in civil engineering, ensuring durable retention represents a critical instructional objective. The present study contributes to the literature by demonstrating that algorithmically structured spaced repetition, when embedded within a gamified learning environment, offers a viable and effective model for improving technical vocabulary learning outcomes in vocational higher education.

Future research may explore broader implementation across different technical disciplines, examine longitudinal impacts beyond four weeks, and investigate potential mediating mechanisms (e.g., engagement trajectories, cognitive load regulation, or self-regulated learning behaviors).

ACKNOWLEDGMENT

The author would like to express sincere gratitude to Politeknik Dewantara Palopo for providing institutional support and facilitating the implementation of this study within the

Vol.6, No. 4, October 2025
***e*-ISSN: 2723-4126**
***p*-ISSN: 2776-8880**

civil engineering program. Appreciation is also extended to the participating students for their active engagement and cooperation throughout the intervention period.

Special thanks are conveyed to colleagues and expert validators in Civil Engineering and English for Specific Purposes (ESP) who contributed to the content validation of the research instruments and provided valuable academic feedback. Their professional insights greatly enhanced the rigor and quality of this research.

The author also acknowledges the constructive input from peer reviewers whose comments and suggestions contributed to the refinement of this manuscript.

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FOSTER JELT
Journal of English Language Teaching

Vol.6, No. 4, October 2025
***e*-ISSN**: **2723-4126**
***p*-ISSN**: **2776-8880**

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