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SQL Island for SQL Learning in Indonesian Vocational Education: A Quasi-Experimental Study of Learning Outcomes and Motivation

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ABSTRACT

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Game-based learning (GBL) has gained considerable attention as a strategy to enhance student engagement in technical subjects, yet evidence from vocational secondary school contexts in Southeast Asia remains limited. This study examined the effect of SQL Island — a web-based SQL learning game — on the learning outcomes and motivation of Grade XI vocational students (RPL program) at SMK Negeri 2 Karanganyar, Indonesia. A quasi-experimental Pretest-Posttest Control Group Design was employed with 53 students (n=23 experimental, n=30 control) selected through cluster random sampling. Instruments included a 12-item essay test (ICC=0.985) and a 22-item Likert scale motivation questionnaire (Cronbach's α=0.770), both validated using Aiken's content validity formula. Data were analyzed using ANCOVA, Independent Samples t-test, Mann-Whitney U, and N-Gain in Jamovi. Results showed no significant effect of SQL Island on learning outcomes (ANCOVA: F=0.465, p=0.498, η^2p=0.009) or motivation (t=0.030, p=0.976). Post-hoc power analysis revealed the study was substantially underpowered ($1-\beta$=0.07), contextualizing the null result. Critically, a ceiling effect in the experimental class (mean pretest=87.2/100) severely constrained measurable improvement, yielding negative mean N-Gain scores for both groups (experimental: −0.441; control: −0.186). These findings contribute methodological insight on ceiling effect as an underreported confound in quasi-experimental GBL research, and offer practical guidance for future implementations: pre-assessment screening, extended treatment duration (≥4 sessions), and language scaffolding are recommended prior to deploying SQL Island in vocational settings.

Keywords: SQL Island, Game-Based Learning, learning motivation, learning outcomes, SQL, quasi-experimental, vocational education, ceiling effect

1. INTRODUCTION

Information systems and databases play a crucial role in supporting fast and accurate decision-making across various fields (Aulia et al., 2023). Databases serve as a core component in information management by enabling systematic data storage, organization, and access (Sari & Nasution, 2025). For students in Vocational High Schools (SMK) majoring in Software Engineering (RPL), mastery of database competencies—particularly the ability to write Structured Query Language (SQL) syntax—is a core skill aligned with industry needs (Tommy et al., 2025).

Based on observations and interviews with the Database subject teacher at SMK Negeri 2 Karanganyar, student learning motivation was found to be low. Many students were passive during lessons and had not mastered basic SQL syntax (CRUD operations) even though the material had progressed to advanced SQL. According to Self-Determination Theory, learning motivation is sustained when learners experience autonomy, competence, and relatedness in the learning process (Ryan & Deci, 2020). Rahman (2021) further affirms that motivation directly influences learning outcomes and determines competency achievement. This situation was exacerbated by the dominance of conventional teaching methods such as lectures, discussions, and PDF modules, which tend to produce passive and less interactive learning (Zahrah et al., 2025).

Game-Based Learning (GBL) has been proposed as an effective alternative to address these issues. GBL integrates game elements such as challenges, rules, feedback, and narratives to create engaging and interactive learning experiences (Adipat et al., 2021). Research shows that GBL can enhance motivation, self-efficacy, and learning outcomes at various educational levels (Tsai et al., 2023; Wong et al., 2025). In the context of SQL learning, SQL Island—a web-based educational game developed by Schildgen (2014)—presents an adventure scenario in which students practice writing SQL queries to complete missions, with immediate feedback on each response.

SQL Island was selected for this study based on strong academic support (Xinogalos & Satratzemi, 2022), ease of web-based access without complex configuration, a simple and intuitive interface, comprehensive coverage of basic SQL syntax (SELECT, UPDATE, DELETE, WHERE, GROUP BY, JOIN), and provision of instant feedback. However, existing studies on SQL Island have predominantly been conducted in university settings or outside Indonesia, with little attention to vocational secondary education. Moreover, prior studies have not simultaneously evaluated both learning outcomes and motivation under controlled conditions, leaving a gap in evidence regarding SQL Island's instructional efficacy at the SMK level in Southeast Asia. Existing GBL studies have also rarely examined students' prior ability as a moderating variable, despite its theoretical importance in aptitude-treatment interaction research (Snow, 1991). The present study addresses these gaps by conducting a quasi-experimental evaluation of SQL Island as a primary classroom medium with Grade XI vocational students, explicitly accounting for prior ability through ANCOVA. This study addresses the following research questions:

- RQ1: Does SQL Island significantly affect learning outcomes of Grade XI RPL students compared to conventional instruction?
- RQ2: Does SQL Island significantly affect learning motivation compared to conventional instruction?
- RQ3: How effective is SQL Island based on N-Gain scores?

The contribution of this study is threefold: (1) it provides empirical evidence on GBL efficacy in an Indonesian vocational context; (2) it identifies ceiling effect as a methodological confound in GBL research; and (3) it offers practical recommendations for pre-assessment protocols in GBL implementation

2. LITERATUR REVIEW

2.1. Game-Based Learning: Theory and Evidence

Game-Based Learning (GBL) refers to instructional approaches that embed learning objectives within game environments, leveraging game mechanics such as challenges, immediate feedback, and narrative progression to sustain learner engagement (Adipat et al., 2021). Empirical evidence supports the efficacy of GBL across multiple educational levels and subject areas. Tsai et al. (2023) demonstrated that a programming course utilizing the GAME model significantly improved undergraduate students' self-efficacy and conceptual understanding compared to conventional instruction. Similarly, Wong et al. (2025) reported that Sokoban, a game-based learning tool for programming, enhanced problem-solving skills among Malaysian undergraduates. Despite these promising results, Greipl et al. (2020) caution that GBL effectiveness is highly contingent on implementation conditions, particularly the duration of exposure and students' familiarity with the game interface. Insufficient time for students to adapt to game mechanics can offset the instructional benefits of even well-designed GBL tools.

2.2 SQL-Specific Game-Based Learning Tools

Within the domain of database education, several GBL tools have been developed to address the challenge of teaching SQL syntax in engaging ways. SQL Island (Schildgen, 2014) is among the most widely recognized, presenting an adventure scenario in which learners write SQL queries to complete survival missions on a deserted island. The game provides immediate feedback on each query, allowing students to self-correct iteratively. Sun et al. (2023) emphasize that effective educational games must minimize extraneous cognitive load by ensuring that game interfaces are intuitive and instructions are easily comprehensible — a criterion that becomes particularly salient when the game interface language differs from students' first language.

2.3 Evidence on SQL Island Effectiveness

The most directly relevant prior study is Xinogalos and Satratzemi (2022), who evaluated SQL Island as a supplementary assignment in a web programming course for undergraduate students, reporting a 91% task completion rate and positive student reception. However, their study differs substantially from the present research in three key respects: (1) the participant population was university students with higher cognitive maturity and greater prior SQL exposure; (2) SQL Island was used as a supplementary assignment rather than as the primary instructional medium; and (3) the study did not employ a control group design, limiting causal inference. These differences highlight a significant gap in the literature: no controlled quasi-experimental study has evaluated SQL Island as a primary instructional medium with vocational high school students in an Indonesian context.

3. RESEARCH METHOD

This study used a quantitative approach with a quasi-experimental Pretest-Posttest Control Group Design. This study was approved by the Institutional Review Board of Universitas Sebelas Maret (No. 702/UN27.02/PK.03.08/2026). Informed consent was obtained from all participants and their guardians. Participation was voluntary and data were anonymized. The study was conducted at SMK Negeri 2 Karanganyar, Karanganyar Regency, Central Java, which offers an RPL program and is equipped with computer laboratories with internet access. Data collection was carried out in January 2026.

The study population comprised all Grade XI RPL students of SMK Negeri 2 Karanganyar for the 2025/2026 academic year, totaling 108 students. Through cluster random sampling, Class XI RPL A was selected as the experimental group and XI RPL C as the control group. After excluding incomplete data from students absent during the pretest or posttest due to illness, school activities, or other reasons, 23 students in the experimental class and 30 in the control class were analyzed.

The experimental group received instruction using SQL Island as a game-based learning medium across three sessions of 90 minutes each (total: 270 minutes), while the control group received equivalent-duration instruction using the direct instruction method with PDF modules and teacher-led Q&A. The treatment was structured as follows:

Table 1. Treatment Procedure per Session

Session	Duration	Topic	Experimental Class Activity	Control Class Activity
1	90 minutes	SELECT & WHERE	Introduction to SQL Island interface; completing missions involving SELECT and WHERE clauses with immediate game feedback	Teacher explanation; structured exercises on SELECT and WHERE using PDF module
2	90 minutes	JOIN & GROUP BY	SQL Island missions involving JOIN operations and GROUP BY clauses; peer discussion on failed queries	Teacher-led demonstration; individual practice on JOIN and GROUP BY
3	90 minutes	AGGREGATE FUNCTIONS	SQL Island missions involving COUNT, SUM, AVG, MAX, MIN; reflection on overall SQL Island experience	Teacher explanation and guided practice on aggregate functions; Q&A session

The experimental class was taught by the researcher, while the control class was taught by the regular Database subject teacher at SMK Negeri 2 Karanganyar. This difference in instructor constitutes a limitation of the study, as instructor variability could not be fully controlled; however, both instructors followed the same curriculum scope and sequence to ensure topical equivalence across groups. Both groups completed a pretest before and a posttest after the treatment.

Table 2. Design Method

Group	Pretest	Treatment	Posttest
Experimental	O_1	X (SQL Island)	O_2
Control	O_1	direct instruction	O_2

Learning outcomes were measured using a pretest-posttest essay instrument covering DML Clause commands (SELECT, JOIN, WHERE, GROUP BY, AGGREGATE FUNCTIONS). Learning motivation was measured using a 5-point Likert scale questionnaire with 22 items covering five dimensions: perseverance, tenacity in facing difficulties, interest and attentiveness, achievement orientation, and independent learning (Pintrich, 2003; Yang & Li, 2025).

Both instruments were validated using Aiken's content validity formula by two expert validators—a lecturer in educational evaluation and a Database teacher. All items obtained $V \geq 0.4$, with mean V values of 0.862 for learning outcome test and 0.921 for motivation questionnaire. Test reliability was confirmed through inter-rater reliability using the Intraclass Correlation Coefficient (ICC = 0.985), which exceeded the minimum acceptable threshold of 0.75, indicating excellent agreement between raters. Questionnaire reliability was assessed using Cronbach's Alpha ($\alpha = 0.770$), which was higher than the acceptable reliability threshold of 0.60, indicating that the questionnaire was reliable.

Data analysis was performed using Jamovi software. Normality was tested with Shapiro-Wilk and homogeneity with Levene's test. For learning outcomes, since the pretest data were non-normally distributed, Mann-Whitney U was used for pretest comparison, and Analysis of Covariance (ANCOVA, with pretest as covariate) for posttest comparison after verifying assumptions of homogeneity of regression slopes and residual normality. For learning motivation, which met normality and homogeneity assumptions, an Independent Samples t-test was used. Effectiveness was evaluated using N-Gain scores, with non-parametric Mann-Whitney U to compare N-Gain distributions between groups.

4. RESULT

4.1. Descriptive Statistics

Descriptive statistics of learning outcomes and motivation are presented in Tables 3 and 4.

Table 3. Descriptive Statistics of Learning Outcomes

Statistic	Group	Pretest	Posttest
N	Experimental	23	23
	Control	30	30
Mean	Experimental	87.2	89.2
	Control	75.9	88.2
Standard deviation	Experimental	10.7	8.41
	Control	18.8	8.21
Minimum	Experimental	56	67
	Control	38	67
Maximum	Experimental	100	98
	Control	100	100

Table 4. Descriptive Statistics of Learning Motivation

Statistic	Group	Pretest	Posttest
N	Experimental	23	23
	Control	30	30
Mean	Experimental	80.5	87.8
	Control	81.2	87.7
Standard deviation	Experimental	10.4	9.22
	Control	14.2	10.3
Minimum	Experimental	63	62
	Control	41	69
Maximum	Experimental	100	107
	Control	108	110

The experimental class had a higher mean pretest score (87.2, SD=10.7) than the control class (75.9, SD=18.8), indicating a significant imbalance in initial ability. The wider standard deviation in the control class also suggests greater heterogeneity in prior knowledge. Both classes showed posttest improvements: the experimental class from 87.2 (SD=10.7) to 89.2 (SD=8.41), and the control class from 75.9 (SD=18.8) to 88.2 (SD=8.21). The narrowing of standard deviations in both groups at posttest suggests convergence in performance after the treatment period. For learning motivation, both classes started at similar levels (experimental: 80.5, SD=10.4; control: 81.2, SD=14.2) and reached nearly identical final scores (experimental: 87.8, SD=9.22; control: 87.7, SD=10.3), indicating equivalent motivational improvement across groups.

4.2. Prerequisite Tests

Normality and homogenity test results are presented in Table 5 and 6.

Table 5. Shapiro-Wilk Normality Test Results

Variable	Group	Statistic W	Sig. (p)
Learning outcome pretest	Experimental	0.908	0.036
	Control	0.918	0.024
Learning outcome posttest	Experimental	0.833	0.001
	Control	0.948	0.150
Learning motivation pretest	Experimental	0.969	0.671
	Control	0.948	0.148
Learning motivation posttest	Experimental	0.961	0.487
	Control	0.964	0.389

Table 6. Levene's Homogenity Test Results

Variable	F	Df1	Df2	Sig. (p)
Learning outcome pretest	7.372	1	51	0.009
Learning outcome posttest	0.247	1	51	0.622
Learning motivation pretest	0.758	1	51	0.388
Learning motivation posttest	0.379	1	51	0.541

The Shapiro-Wilk normality test showed that pretest and posttest learning outcome data for the experimental class were non-normally distributed ($p<0.05$), necessitating non-parametric analysis. In contrast, motivation data for both groups met normality assumptions ($p>0.05$). Levene's test indicated homogeneous variances for the posttest learning outcomes and all motivation data ($p>0.05$), but non-homogeneous variances for the pretest learning outcomes ($p<0.05$), confirming the need for ANCOVA with pretest as a covariate in the learning outcome analysis.

4.3. Hypothesis Testing of Learning Outcomes

The Mann-Whitney U pretest analysis yielded $U=226$, $p=0.033$ (<0.05), confirming a significant difference in initial ability between the two groups and requiring ANCOVA for posttest analysis. ANCOVA assumptions were verified: homogeneity of regression slopes ($F=2.60$, $p=0.113>0.05$) and residual normality (confirmed via Q-Q Plot). ANCOVA results are presented in Table 7.

Table 7. ANCOVA Test Result

Source	SS	df	MS	F	p	η^2p
Group	26.8	1	26.8	0.465	0.498	0.009
Pretest (covariate)	627.2	1	627.2	10.880	0.002	0.179
Residual	2882.1	50	57.6	-	-	-

ANCOVA results showed no significant effect of SQL Island on learning outcomes after controlling for prior ability ($F=0.465$, $p=0.498>0.05$, $\eta^2p=0.009$). The effect size ($\eta^2p=0.009$) falls in the small category based on Cohen (1988) criteria. However, the pretest covariate was highly significant ($p=0.002$), indicating that initial student ability is the dominant predictor of posttest scores. These results must be interpreted cautiously given the ceiling effect: the experimental class's mean pretest of 87.2 out of a maximum of 100 left very limited room for improvement (max 12.8 points), while the control class, starting from 75.9, had substantially more room to improve.

4.4. Hypothesis Testing of Learning Motivation

Table 8. Independent Samples t-test Results

Variable	Statistic	Df	Sig. (p)
Pretest	-0.213	51	0.832
Posttest	0.030	51	0.976

The Independent Samples t-test showed no significant difference in learning motivation between the two groups, neither at pretest (t=-0.213, df=51, p=0.832>0.05) nor posttest (t=0.030, df=51, p=0.976>0.05). Both classes showed equivalent motivation improvement during the treatment period. This can partly be explained by the fact that instruction in the control class was not entirely passive; the teacher applied an interactive approach with questions and exercises that maintained student motivation at a comparable level.

4.5. Effectiveness Analysis (N-Gain)

Table 9. N-Gain Score Results

Statistic	Group	N-Gain Score
Mean	Experimental	-0.441
	Control	0.186
Shapiro-Wilk p	Experimental	<0.001
	Control	<0.001

Table 10. Mann-Whitney U test Results on N-Gain Scores

Statistic	Sig. (p)	Effect Size
199	0.113	-0.144

N-Gain scores were calculated individually for each student. The mean N-Gain for the experimental class was -0.441 and for the control class -0.186. Based on Hake's (1999) criteria as cited in Wahab et al. (2021), both values fall in the Failing category ($g \leq 0$). The Mann-Whitney U test on N-Gain scores showed no significant difference between groups (U=199, p=0.113>0.05, Cohen's d=-0.144). Negative N-Gain values are primarily a mathematical consequence of the ceiling effect: students with very high pretest scores (e.g., 95/100) who experience small fluctuations in the posttest yield large negative N-Gain values, even though they have already demonstrated high competence.

4.6. Post-hoc Power Analysis

A post-hoc power analysis was conducted using G*Power 3.1 to evaluate the statistical adequacy of the study's sample size. For the primary analysis (ANCOVA on learning outcomes), with an observed effect size of $\eta^2p = 0.009$ ($f = 0.095$), $\alpha = .05$, total sample $N = 53$ ($n = 23$ experimental, $n = 30$ control), and one covariate, the achieved statistical power was $1 - \beta = 0.07$. This value falls substantially below the conventional threshold of 0.80 (Cohen, 1988), indicating that the study was underpowered to detect an effect of the observed magnitude.

To achieve power of 0.80 with the same effect size and $\alpha = .05$, a minimum total sample of approximately $N = 880$ would be required. Conversely, to detect a medium effect ($f = 0.25$) with the current sample ($N = 53$) at $\alpha = .05$, power would reach 0.56 — still below the recommended threshold.

These findings do not invalidate the null result; rather, they contextualize it: the absence of a significant effect may reflect either a genuine lack of treatment efficacy or insufficient power to detect a small true effect. Future studies should conduct an a priori power analysis prior to data collection to ensure adequate sample size, particularly given the small effect sizes commonly reported in quasi-experimental GBL research.

5. DISCUSSION

The non-significant results in this study do not necessarily reflect the ineffectiveness of SQL Island as a learning medium. Several methodological and contextual factors warrant consideration.

Ceiling Effect as Primary Constraint. The most critical factor limiting this study's statistical sensitivity was the ceiling effect in the experimental class. With a mean pretest of 87.2/100, students had very limited mathematical room for improvement (maximum 12.8 points), making statistical detection of gains nearly impossible regardless of treatment quality. This aligns with Zulkarnain's (2020) finding that initial ability is a strong predictor of learning achievement, reinforcing the critical role of prior knowledge as a moderating variable in instructional intervention research. This finding underscores the importance of conducting pre-assessment screening prior to GBL implementation to ensure students enter the treatment with intermediate, not near-maximum, prior ability. Future studies should set an explicit inclusion criterion — for example, excluding students with pretest scores above 80 — to avoid this confound.

Treatment Duration and Game Familiarization. A treatment duration of only three sessions was likely insufficient for students unfamiliar with the game interface to adapt and fully benefit from the GBL experience. Greipl et al. (2020) state that GBL implementation requires careful planning and adequate time for students to become familiar with game mechanics before learning can be optimized. A minimum of 4–6 sessions is recommended for future replications.

Cognitive Load from Language Barrier. SQL Island's English-language interface added extraneous cognitive load for students who had to translate instructions before addressing SQL challenges, potentially diverting cognitive resources from core learning content. Sun et al. (2023) assert that well-designed educational games must minimize extraneous cognitive load by ensuring instructions are easily comprehensible — a criterion that becomes particularly salient when the game interface language differs from students' first language. Providing a bilingual guide or Indonesian-language orientation sheet prior to gameplay may mitigate this effect.

Attrition and Selection Bias. The higher attrition rate in the experimental class (36.1% vs. 16.7% in the control class) potentially introduced selection bias, as students with different ability profiles may have been disproportionately excluded from analysis. This asymmetry should be addressed in future studies through stricter attendance protocols or intention-to-treat analysis.

Comparison with Prior Literature. Compared to Xinogalos and Satratzemi (2022), who reported a 91% completion rate using SQL Island as a supplementary assignment for web programming undergraduates, this study's context differs substantially along three dimensions: participant population (vocational vs. university), usage model (primary medium vs. supplementary assignment), and prior ability level. These differences likely explain the divergent outcomes and highlight the difficulty of generalizing SQL Island's effectiveness across educational contexts.

Motivational Equivalence. Despite statistically non-significant results on learning outcomes, SQL Island successfully maintained student motivation at a level equivalent to conventional instruction. Both classes showed nearly identical posttest motivation scores (87.8 vs. 87.7), consistent with findings on the motivational equivalence of GBL approaches (Putri et al., 2025; Adipat et al., 2021). This finding suggests that SQL Island has meaningful pedagogical value when implemented under more optimal conditions — including appropriate student prior ability, adequate treatment duration, and structured pedagogical scaffolding.

6. CONCLUSION

This study examined the effect of SQL Island as a game-based learning medium on the learning outcomes and motivation of Grade XI RPL students at SMK Negeri 2 Karanganyar. Three main conclusions can be drawn:

First, SQL Island had no significant effect on learning outcomes compared to conventional instruction (ANCOVA, $F=0.465$, $p=0.498>0.05$, $\eta^2p=0.009$). Prior ability proved to be the dominant predictor of posttest scores, and the ceiling effect in the experimental class (mean pretest=87.2) severely limited detectable improvement.

Second, SQL Island had no significant effect on learning motivation compared to the control class (t-test, $p=0.976>0.05$). However, both classes showed equivalent and meaningful motivation improvement, indicating that SQL Island is at least as effective as conventional instruction in supporting motivational development.

Third, N-Gain analysis categorized both classes as Failing (experimental: -0.441; control: -0.186), primarily due to the ceiling effect rather than actual competence decline. Future research is advised to ensure initial group equivalence, use samples with intermediate prior ability to avoid ceiling effects, extend treatment duration to at least 4–6 sessions, and consider language scaffolding for SQL Island's English interface.

This study makes three contributions to the literature on game-based learning in vocational education. Theoretically, it provides one of the first controlled quasi-experimental evaluations of SQL Island as a primary instructional medium — rather than a supplementary tool — with vocational secondary school students in an Indonesian context, extending prior work by Xinogalos and Satratzemi (2022) to a substantially different population and implementation model. Methodologically, it demonstrates that ceiling effect is a critical and underreported confound in quasi-experimental GBL research: when students enter treatment with near-maximum prior ability, both N-Gain scores and ANCOVA effect sizes become mathematically constrained regardless of treatment quality. This finding has implications for how future GBL studies design their sampling criteria and interpret null results. Practically, this study offers concrete implementation guidelines for educators considering SQL Island in vocational settings: conduct pre-assessment screening to ensure intermediate prior ability, plan for a minimum of 4–6 sessions to allow game familiarization, and provide language scaffolding to reduce cognitive load from SQL Island's English-language interface.

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