Development of water rescue competence through a project-based approach enriched with game elements

El desarrollo de la competencia en rescate acuático a través de un enfoque basado en proyectos enriquecido con elementos de juego

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Abstract

Introduction: Water rescue competence is an important component of aquatic education. Project-Based Learning (PjBL) supported by selected game-based elements may enhance engagement and competence development; however, its application in water rescue education remains limited. Objective: To examine the effectiveness of a Project-Based Learning (PjBL) approach supported by selected game-based elements in improving water rescue competence among university students and to analyze the moderating roles of gender and initial swimming ability.
Methodology: A quasi-experimental pretest–posttest non-equivalent control group design was conducted with 120 university students assigned to experimental and control groups based on intact class membership. Water rescue competence was assessed across cognitive, affective, and psychomotor domains using a performance-based instrument. Data were analyzed using mixed-design ANOVA.
Results: Significant improvements in water rescue competence were observed over time, with a significant time effect, $F(1,112) = 122.02$, $p < .001$, $\eta^2_p = .521$, and a significant time × group interaction, $F(1,112) = 16.12$, $p < .001$, $\eta^2_p = .126$, indicating greater gains in the experimental group. A significant time × ability interaction, $F(1,112) = 23.28$, $p < .001$, $\eta^2_p = .172$, indicated greater relative improvement among participants with lower initial ability, whereas gender did not significantly moderate competence improvement.
Discussion: These findings suggest that PjBL supported by selected game-based elements can facilitate competence development in aquatic education.
Conclusions: PjBL supported by selected game-based elements appears effective in improving water rescue competence among university students.

Keywords

Project-based learning; water rescue competence; aquatic education; water safety; higher education.

Resumen

Introdução: A competência em salvamento aquático é uma componente importante da educação aquática. A Aprendizagem Baseada em Projetos (ABP) apoiada por elementos selecionados dos jogos pode aumentar o envolvimento e o desenvolvimento da competência; no entanto, a sua aplicação na educação em salvamento aquático é ainda limitada. Objectivo: Examinar a eficácia de uma abordagem de Aprendizagem Baseada em Projectos (ABP) apoiada por elementos seleccionados de jogos na melhoria da competência em salvamento aquático entre estudantes universitários e analisar o papel moderador do género e da capacidade inicial de natação.
Metodologia: Um estudo quase-experimental com pré-teste e pós-teste, com um grupo de controlo não equivalente, foi conduzido com 120 estudantes universitários, alocados a grupos experimental e de controlo com base na turma em que estavam inscritos. A competência em salvamento aquático foi avaliada nos domínios cognitivo, afetivo e psicomotor, através de um instrumento baseado no desempenho. Os dados foram analisados através de ANOVA de medidas repetidas. Resultados: Foram observadas melhorias significativas na competência em resgate aquático ao longo do tempo, com um efeito significativo do tempo, $F(1,112) = 122{,}02$, $p < 0{,}001$, $\eta^2_p = 0{,}521$, e uma interação significativa entre o tempo e o grupo, $F(1,112) = 16{,}12$, $p < 0{,}001$, $\eta^2_p = 0{,}126$, indicando maiores ganhos no grupo experimental. Uma interação significativa entre o tempo e a capacidade, $F(1,112) = 23{,}28$, $p < 0{,}001$, $\eta^2_p = 0{,}172$, indicou uma maior melhoria relativa entre os participantes com menor capacidade inicial, enquanto o género não moderou significativamente a melhoria da competência.
Discussão: Estes resultados sugerem que a Aprendizagem Baseada em Projectos (ABP) apoiada por elementos seleccionados dos jogos pode facilitar o desenvolvimento de competências na educação aquática.
Conclusões: A ABP apoiada por elementos selecionados de jogos parece eficaz na melhoria da competência em resgate aquático entre estudantes universitários.

Palabras clave

Aprendizaje basado en proyectos; competencia en rescate acuático; educación acuática; seguridad acuática; educación superior.

Introduction

Drowning remains one of the leading causes of unintentional death worldwide, affecting individuals across all age groups in both open and confined water environments (Beale, 2012; Ramos et al., 2021; Zaara et al., 2022; Varner & Liu, 2022; Schwebel & Johnston, 2025). In response to this issue, the role of physical education and sport pedagogy in promoting water safety and rescue education has become increasingly important. Water safety is now recognized as an essential component of physical literacy and lifelong movement competence. This perspective aligns with contemporary approaches in physical education that emphasize the integration of safety competence, environmental awareness (Mekkaoui et al., 2025), and lifelong aquatic skills within holistic physical literacy development (Invernizzi et al., 2021).

In many drowning incidents, lay rescuers individuals who attempt rescues despite having limited training or preparation are frequently involved. In some cases, lay rescuers also become victims themselves, a phenomenon commonly referred to as double drowning (Turgut, 2011; Brander et al., 2019). This condition highlights that water rescue competence is important not only for professional personnel such as lifeguards or pool attendants (Osmond, 2016), but also for non-professional individuals such as school and university students who may potentially serve as first responders in aquatic environments.

Therefore, water rescue learning should be designed as a pedagogical process that prepares students to respond to aquatic emergencies through contextual, reflective, and meaningful learning experiences. Such learning should emphasize not only technical rescue procedures but also situational judgment, risk perception, and safe decision-making skills in emergency situations (Poser & Dransch, 2010; Ahmed et al., 2020; Wang et al., 2020; Nasar et al., 2023).

Previous studies have demonstrated that learner-centered and activity-based water safety education can improve safety-related knowledge, skills, and attitudes (Petrass & Blitvich, 2014; Bánfai et al., 2018; Calle-Molina & Sanz-Arribas, 2024). In line with the growing emphasis on authentic and student-centered learning in physical education, Project-Based Learning (PjBL) has emerged as a promising instructional approach for promoting meaningful learning experiences, collaboration, active participation, and problem-solving skills among students (Simonton et al., 2021).

PjBL is a student-centered instructional model that engages learners in collaborative inquiry processes to solve authentic real-world problems (Krajcik & Czerniak, 2018; Fernandes et al., 2021; Rohm et al., 2021; Wibowo et al., 2025). PjBL is commonly implemented through structured phases including problem identification, planning, execution, product development, and presentation (Sánchez-García & Reyes-de-Cózar, 2025). A defining characteristic of PjBL is the development of tangible products that represent students' understanding and are presented to others for evaluation. Through this process, students actively construct knowledge, develop problem-solving abilities, and engage in meaningful collaboration.

In addition to the instructional strengths of PjBL, researchers have increasingly explored complementary strategies to enhance student engagement and participation during project activities. One such strategy involves the incorporation of selected game-based elements such as points, badges, challenge activities, feedback systems, and collaborative tasks. These elements have been increasingly used in educational settings to support learner motivation, participation, and engagement. Rather than functioning as a comprehensive gamification system, these elements may serve as complementary pedagogical supports that enhance students' learning experiences within broader student-centered learning environments (Subhash & Cudney, 2018; Junior et al., 2019; Huang et al., 2023).

The use of selected game-based elements within PjBL environments has been reported across various educational contexts. These include incorporating game-based elements into the structural design of PjBL (Isabelle, 2020), embedding them within project content (Warin et al., 2016; Hernandez Gandara & Cañabate Ortiz, 2020), employing digital games during the initial stages of PjBL to develop foundational knowledge and skills (Y. H. Wang, 2020; Gabriele et al., 2017; Alden & Tramonti, 2020; Fuster-Guilló et al., 2019), utilizing game-based elements to facilitate project management (Punia et al., 2020), and using educational games as the primary context for project implementation (Callaghan, 2016; Ke et al., 2019; Díaz-Lauzurica & Moreno-Salinas, 2019; Hewett et al., 2020). In addition, game creation has been employed as both a final product and a visible learning outcome within PjBL, in both digital (Engström et al., 2019; Osman & Lay, 2022) and non-digital formats (Arnab et al., 2019; Baran et al., 2018). Collectively, these studies suggest that game-based elements can serve as complementary pedagogical supports within Project-Based Learning environments by enhancing learner engagement, participation, collaboration, and motivation throughout project activities (Huang et al., 2023).

This approach may be particularly relevant in water rescue education, where learners must develop not only technical rescue skills but also situational analysis, decision-making abilities, and collaborative problem-solving abilities (Poser & Dransch, 2010; Ahmed et al., 2020; Wang et al., 2020; Nasar et al., 2023). However, despite growing interest in student-centered instructional approaches supported by game-based elements, their application in aquatic safety and water rescue education remains limited. Most existing studies primarily focus on swimming competence or basic water safety awareness (Petrass & Blitvich, 2014; Petrass et al., 2021; Reichmuth et al., 2021; Fone & Lyngstad, 2025), with insufficient attention given to instructional approaches that simultaneously address cognitive, affective, and psychomotor domains of water rescue competence. Furthermore, little empirical evidence is available regarding the effectiveness of Project-Based Learning supported by selected game-based elements for improving comprehensive water rescue competence among university students.

Another important aspect that warrants further examination is the role of individual learner characteristics in water rescue education. Previous studies have reported that gender differences may influence learning outcomes and motivation in aquatic learning contexts. Some studies have reported greater learning gains among male participants, whereas female participants may require more gradual and supportive approaches when introduced to aquatic environments (Kiss et al., 2024). Other studies suggest that females tend to assess their swimming competence more accurately, whereas males often demonstrate higher levels of self-confidence even in hazardous swimming situations (Rejman et al., 2020; Sakamoto et al., 2020). These differences may influence risk perception and rescue-related decision-making (Znajmiecka-Sikora & Sałagacka, 2022). Understanding gender-related behavioral tendencies is therefore important for developing inclusive and adaptive pedagogical strategies in aquatic education (Marmeleira et al., 2020; Laxdal & Giske, 2020; Frikha et al., 2024; Salvatori & Cherubini, 2024).

Another equally important factor requiring further investigation is basic swimming ability. Previous studies indicate that water rescues are often performed in high-risk situations in which lay rescuers and even professionals frequently prioritize direct-contact rescue techniques. Although such approaches may occasionally be necessary in emergency situations, they are generally considered a last resort because of their associated risks (Michniewicz et al., 2008; Moran et al., 2012; Stallman et al., 2014; Petrass & Blitvich, 2018). These findings suggest that extensive water experience and strong swimming ability do not automatically guarantee safe rescue decisions. Therefore, water rescue education should emphasize not only technical mastery but also decision-making, risk awareness, and the selection of appropriate rescue strategies. This reinforces the importance of instructional approaches that integrate cognitive understanding, behavioral awareness, and practical rescue skills in aquatic education (Willcox-Pidgeon et al., 2020; Koon et al., 2021; Cook et al., 2024; Luo & Mei, 2025).

Based on these considerations, this study aimed to examine the effectiveness of a Project-Based Learning (PjBL) approach supported by selected game-based elements in improving water rescue competence among university students. The instructional approach incorporated selected game-based elements, such as points, badges, feedback, and challenge activities, as complementary supports to enhance engagement throughout structured PjBL phases involving collaborative problem solving, development of rescue-related products, and project presentation activities. The study also examined the roles of gender and initial swimming ability in influencing learning outcomes among students as potential lay rescuers, with the aim of contributing to the development of evidence-based instructional strategies in aquatic education and sport pedagogy.

Method

This study employed a quantitative approach using a quasi-experimental design with a *pretest–posttest non-equivalent control group design*. This design was selected to examine the effectiveness of a Project-Based Learning (PjBL) intervention supported by selected game-based elements in improving students' water rescue competence while accounting for naturally existing class groupings.

Participants

The participants were 120 undergraduate students enrolled in a Physical Education or Sport Science program, drawn from four intact classes (approximately 30 students per class). In accordance with the quasi-experimental design, classes were assigned without individual randomization, with two classes (n = 60) allocated to the experimental group (PjBL supported by selected game-based elements) and two classes (n = 60) to the control group (conventional instruction).

The participants had a mean age of 20.3 ± 1.2 years, with an average height of 168.4 ± 7.6 cm and body weight of 63.1 ± 9.2 kg. Participants were selected using a purposive sampling technique, with inclusion criteria including being physically fit to participate in aquatic activities and having basic swimming experience. Participation in the study was voluntary, and all participants agreed to take part in the research prior to data collection.

To ensure balanced representation and to strengthen the examination of gender as a moderating variable, the sample was deliberately composed of equal proportions of male and female students, consisting of 60 males (50%) and 60 females (50%). This quota-based allocation was applied across the experimental and control groups, resulting in an equal gender distribution within each group (experimental group: 30 males and 30 females; control group: 30 males and 30 females).

Although intact classes were used, class selection was conducted by considering their gender composition to achieve balanced representation across groups without reassigning individual participants, thereby preserving the ecological validity of the quasi-experimental design.

This controlled gender composition was implemented to reduce potential confounding effects and to enhance the statistical power in detecting interaction effects involving gender within the quasi-experimental framework. Demographic characteristics, including gender and initial swimming ability (classified as low and high based on pretest performance), were recorded and treated as moderating variables in the analysis.

Ethical Considerations

Ethical approval for this study was obtained from the Institutional Research Ethics Committee (Approval No. 01/07.091056/II/2026). The approved protocol covered the quasi-experimental design, including both the experimental and control groups, and all 120 participants involved in the study. Written informed consent was obtained from all participants prior to data collection. All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Instruments

Data were collected using performance-based assessments.

Water Rescue Competence Test

Water rescue competence was assessed using a researcher-developed performance-based instrument grounded in established frameworks (Moran et al., 2012; Stallman et al., 2014; Royal Life Saving Society, 2014), encompassing cognitive, affective, and psychomotor domains. The instrument comprised 30 indicators, with each domain represented by 10 items. The cognitive domain assessed conceptual knowledge of water rescue principles, the affective domain evaluated students' attitudes and behavioral responses during rescue situations, and the psychomotor domain measured practical skills in executing rescue techniques and team-based simulations. All items were rated using a 5-point Likert scale ranging from 1 (very poor) to 5 (excellent performance).

Prior to the main study, the instrument was pilot-tested on 50 undergraduate students enrolled in a sport science program who had successfully completed a swimming course. Content validity was evaluated using Aiken's V coefficient based on ratings from three experts, including two professionals from the National Search and Rescue Agency and one academic specializing in aquatic education. The results demonstrated that all items achieved acceptable to very high levels of content validity, with Aiken's V coefficients ranging from 0.75 to 0.98. The affective domain demonstrated the highest content validity, followed by the cognitive and psychomotor domains. A summary of Aiken's V coefficients is presented in Table 1.

Table 1. Summary of Aiken's V coefficients

Domain	Min V	Max V	Mean V	Interpretation
Cognitive	0.78	0.93	0.86	High
Affective	0.92	0.98	0.95	Very High
Psychomotor	0.75	0.93	0.85	High

To further ensure measurement consistency, reliability analysis was conducted using two complementary procedures: test–retest reliability and inter-rater reliability, both analyzed using the Intraclass Correlation Coefficient (ICC). Test–retest reliability was evaluated using a two-way mixed-effects model with consistency agreement to examine the temporal stability of the instrument across repeated measurements. The results indicated good to excellent stability across domains, with ICC values ranging from 0.790 to 0.900. The cognitive domain demonstrated the highest temporal stability (ICC = 0.900), followed by the total score (ICC = 0.883), affective domain (ICC = 0.876), and psychomotor domain (ICC = 0.790).

Inter-rater reliability was subsequently assessed using a two-way random-effects model with absolute agreement to determine the consistency of scoring among independent raters. The findings revealed excellent agreement across all domains, with ICC values ranging from 0.896 to 0.946. The total score demonstrated the highest inter-rater agreement (ICC = 0.946), followed by the psychomotor domain (ICC = 0.940), cognitive domain (ICC = 0.927), and affective domain (ICC = 0.896). A summary of reliability coefficients is presented in Table 2.

Table 2. Summary of reliability coefficients (ICC)

Domain	Test–Retest ICC	Interpretation	Inter-Rater ICC	Interpretation
Psychomotor	0.790	Good	0.940	Excellent
Affective	0.876	Good	0.896	Good–Excellent
Cognitive	0.900	Excellent	0.927	Excellent
Total	0.883	Good	0.946	Excellent

Overall, the findings indicate that the instrument possesses strong evidence of content validity, temporal stability, and inter-rater consistency. These results support the suitability of the instrument for assessing water rescue competence among higher education students in aquatic education contexts.

Swimming Ability Test

Initial swimming ability was assessed prior to the intervention using the Swimming Competence Assessment Scale (SCAS), which evaluates coherent movement and postural stability. The instrument has demonstrated strong construct validity (average variance extracted [AVE] > 0.75) and good internal consistency (Cronbach's α > 0.80) (Zhao et al., 2024). Based on the assessment results, participants were classified into low and high swimming ability groups.

Procedure

The study was conducted during regular physical education classes between February and May 2026. Pretest assessments were conducted in February 2026, followed by a 10-week instructional intervention implemented from February to April 2026. Posttest assessments were completed in May 2026. At baseline, all participants completed a pretest consisting of the Water Rescue Competence Test and the Swimming Competence Assessment Scale (SCAS). The pretest assessed competence across cognitive, affective, and psychomotor domains and was used to classify participants into low and high swimming ability groups.

Participants were assigned to experimental and control groups based on intact class membership. The experimental group received a Project-Based Learning intervention supported by selected game-based elements, whereas the control group received conventional instruction consisting of teacher-led explanation, demonstration, and repetitive skill practice. The control group did not engage in structured project development or game-based learning supports. The intervention was delivered over a 10-week period, consistent with durations reported in previous aquatic education interventions (Petrass et al., 2021). Instructional content included contextual problem scenarios, structured practice, and rescue simulations based on the *reach–throw–row–go–tow* framework (Stallman et al., 2014; Royal Life Saving Society, 2014). In the experimental group, learning was organized as a long-term project, where the project functioned as the central driver of the learning process rather than a supplementary activity. Selected game-based elements, including points, badges, challenge-based activities, and continuous feedback, were incorporated as complementary pedagogical supports throughout the project activities to enhance student engagement and participation. The instructional design followed five PjBL phases, with selected game-based elements incorporated as complementary engagement supports within each phase.

Table 3. Project-Based Learning Intervention Supported by Selected Game-Based Elements

PjBL Phase	Learning Activities	Game-Based Elements	Outputs
Problem Identification	Students analyze authentic water rescue scenarios and define project problems	Initial points, entry level, scenario-based challenges	Problem formulation
Planning and Design	Students collaboratively design rescue strategies and project plans	Progress badges, milestone tracking	Project proposal
Project Implementation	Students conduct rescue simulations and practical activities	Leaderboards, scoring system, continuous feedback	Initial solution implementation
Product Development	Students develop tangible outputs (e.g., rescue protocols, simulation models, instructional media)	Level progression, achievement rewards	Final project product
Presentation and Evaluation	Students presented their final products to peers and an authentic audience (e.g., other students or practitioners)	Final badges, achievement levels	Public presentation and evaluation

The control group received comparable instructional content, including basic rescue techniques, safety procedures, and swimming practice, but without project-based learning or the incorporation of game-based elements. At the end of the intervention, all participants completed a posttest using the same instruments administered at baseline to assess changes in water rescue competence. To ensure measurement consistency, all assessments were conducted using standardized scoring procedures by trained evaluators, with inter-rater agreement maintained throughout the evaluation process. The Swimming Ability Test was assessed by three lecturers specializing in swimming instruction. The Water Rescue Competence Test, as a researcher-developed instrument, was evaluated by a panel of three trained raters comprising one professional from the Indonesian National Search and Rescue Agency (BASARNAS), one certified lifeguard, and one university lecturer with expertise in swimming instruction. All evaluators underwent prior training to ensure scoring consistency and alignment with the assessment criteria. Implementation fidelity was ensured through the use of standardized lesson plans and teaching logs maintained throughout the intervention to document the delivery of each instructional session.

Data Analysis

Data tabulation and coding were conducted using Microsoft Excel 2021 (Microsoft Corporation, Redmond, WA, USA). Statistical analyses and data screening procedures were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA).

Data were analyzed using inferential statistics with the assistance of SPSS software. Descriptive statistics were reported as means and standard deviations. Prior to the main analysis, data screening procedures were conducted, including checks for missing values and outliers. The assumptions of normality were assessed using the Shapiro–Wilk test ($p > 0.05$), and homogeneity of variances was examined using Levene's test ($p > 0.05$). The ANOVA assumptions were considered sufficiently satisfied, as F-statistics are robust to moderate non-normality in balanced designs with adequate sample sizes (Field, 2018; Hair et al., 2019)

Baseline equivalence between the experimental and control groups was examined using independent samples t-tests on pretest scores. The primary analysis focused on examining the effectiveness of the Project-Based Learning intervention supported by selected game-based elements. A mixed-design ANOVA was employed, with time (pretest vs. posttest) as the within-subject factor and group, gender, and initial swimming ability as between-subject factors.

The analysis followed a 2 (time) × 2 (group) × 2 (gender) × 2 (initial swimming ability) mixed factorial design. Where significant interaction effects were identified, post hoc comparisons were conducted using the Bonferroni adjustment. Effect sizes were reported using partial eta squared (η^2p). The sample size was considered adequate to detect medium effect sizes in factorial ANOVA designs based on established methodological recommendations. All statistical tests were conducted at a significance level of $\alpha = 0.05$.

Results

Descriptive Statistical

As shown in Table 1, water rescue competence increased from pretest to posttest in both groups, with substantially greater gains observed in the experimental group. The total score in the experimental group improved from $M = 2.82$ ($SD = 0.54$) to $M = 3.48$ ($SD = 0.44$) ($\Delta = +0.66$), whereas the control group showed a smaller increase from $M = 2.86$ ($SD = 0.59$) to $M = 3.17$ ($SD = 0.49$) ($\Delta = +0.31$), indicating a stronger learning effect associated with the intervention. At the domain level, the largest improvement was observed in the psychomotor domain ($\Delta = +0.90$ in the experimental group vs. +0.51 in the control group), followed by the affective domain ($\Delta = +0.69$ vs. +0.32). In contrast, the cognitive domain showed more modest gains ($\Delta = +0.39$ vs. +0.10), suggesting a relatively slower development of conceptual understanding. A general reduction in standard deviations at posttest indicates increased consistency in performance, particularly in the experimental group. Overall, these descriptive findings suggest that the PjBL intervention supported by selected game-based elements was associated with greater and more consistent improvements in water rescue competence.

Table 4. Descriptive Statistics of Water Rescue Competence

Variable	Group	Pretest M (SD)	Posttest M (SD)	Mean Difference
Total Score	Experimental	2.82 (0.54)	3.48 (0.44)	+0.66
	Control	2.86 (0.59)	3.17 (0.49)	+0.31
Psychomotor	Experimental	2.82 (0.55)	3.72 (0.52)	+0.90
	Control	2.85 (0.59)	3.36 (0.54)	+0.51
Affective	Experimental	2.81 (0.55)	3.50 (0.46)	+0.69
	Control	2.85 (0.59)	3.17 (0.50)	+0.32
Cognitive	Experimental	2.82 (0.54)	3.21 (0.40)	+0.39
	Control	2.87 (0.59)	2.97 (0.47)	+0.10

Data Screening and Assumption Testing

Prior to hypothesis testing, data screening procedures were conducted to evaluate the assumptions underlying parametric analyses. Normality was assessed using the Shapiro–Wilk test, which is considered appropriate for sample sizes below 200. The results indicated that most variables were normally distributed ($p > .05$), including all pretest variables across both groups. However, two posttest variables in the experimental group showed significant deviations from normality, namely the total posttest score ($W = 0.918$, $p = .001$) and the affective posttest score ($W = 0.919$, $p = .001$). Despite these deviations, parametric analyses were retained because mixed-design ANOVA is generally robust to moderate violations of normality, particularly under balanced sample conditions and equal group sizes.

Homogeneity of variances was examined using Levene's test on pretest scores. The results demonstrated that all variables met the assumption of homogeneity, including total pretest scores ($F = 0.888$, $p = .348$), psychomotor pretest scores ($F = 0.864$, $p = .354$), affective pretest scores ($F = 0.759$, $p = .385$), and cognitive pretest scores ($F = 0.915$, $p = .341$). These findings indicate that the variances between the experimental and control groups were statistically equivalent at baseline.

To further establish baseline equivalence, one-way ANOVA tests were conducted for all pretest variables. The analyses revealed no statistically significant differences between the experimental and control groups for total competence scores ($F = 0.166$, $p = .684$), psychomotor competence ($F = 0.142$, $p = .706$), affective competence ($F = 0.172$, $p = .679$), and cognitive competence ($F = 0.180$, $p = .672$). These findings confirm that both groups were comparable prior to the intervention.

Overall, the assumption testing results support the appropriateness of proceeding with parametric analyses. Although minor deviations from normality were identified in two posttest variables, the balanced study design and robustness of ANOVA procedures reduce the likelihood that these violations substantially affected the validity of the results.

Table 5. Tests of Normality (Shapiro–Wilk)

Variable	Group	W	p-value	Interpretation
Total Pretest	Experimental	0.966	0.093	Normal
Total Posttest	Experimental	0.918	0.001	Not normal
Psychomotor Pretest	Experimental	0.961	0.052	Normal
Psychomotor Posttest	Experimental	0.964	0.070	Normal
Affective Pretest	Experimental	0.973	0.194	Normal
Affective Posttest	Experimental	0.919	0.001	Not normal
Cognitive Pretest	Experimental	0.966	0.089	Normal
Cognitive Posttest	Experimental	0.971	0.162	Normal
Total Pretest	Control	0.963	0.064	Normal
Total Posttest	Control	0.967	0.099	Normal
Psychomotor Pretest	Control	0.963	0.062	Normal
Psychomotor Posttest	Control	0.986	0.715	Normal
Affective Pretest	Control	0.964	0.070	Normal
Affective Posttest	Control	0.974	0.228	Normal
Cognitive Pretest	Control	0.965	0.086	Normal
Cognitive Posttest	Control	0.977	0.331	Normal

Table 6. Test of Homogeneity of Variances (Levene's Test – Pretest)

Variable	F	df1	df2	p-value	Interpretation
Total Pretest	0.888	1	118	0.348	Homogeneous
Psychomotor Pretest	0.864	1	118	0.354	Homogeneous
Affective Pretest	0.759	1	118	0.385	Homogeneous
Cognitive Pretest	0.915	1	118	0.341	Homogeneous

Table 7. Baseline Equivalence Test (One-Way ANOVA – Pretest)

Variable	F	p-value	Interpretation
Total Pretest	0.166	0.684	No significant difference
Psychomotor Pretest	0.142	0.706	No significant difference
Affective Pretest	0.172	0.679	No significant difference
Cognitive Pretest	0.180	0.672	No significant difference

Baseline Equivalence

To ensure the internal validity of the study, baseline equivalence between the experimental and control groups was examined using independent samples t-tests across all pretest variables. The results indicated that there were no statistically significant differences between groups in total competence scores, $t(118) = -0.407$, $p = .684$, psychomotor competence, $t(118) = -0.377$, $p = .706$, affective competence, $t(118) = -0.414$, $p = .679$, and cognitive competence, $t(118) = -0.425$, $p = .672$. The observed mean differences between groups were minimal, ranging from -0.039 to -0.044, and all 95% confidence intervals included zero, indicating the absence of systematic baseline differences between the experimental and control groups. In addition, Levene's tests confirmed that the assumption of homogeneity of variances was satisfied for all pretest variables ($p > .05$). Collectively, these findings demonstrate that both groups were statistically comparable prior to the intervention, thereby supporting group equivalence and strengthening the internal validity of the subsequent analyses.

Table 8. Baseline Equivalence Between Experimental and Control Groups (Pretest Scores)

Variable	Group	N	Mean	SD	T	Df	p-value	Mean Difference	95% CI
Total	Experimental	60	2.816	0.545	-0.407	118	0.684	-0.042	[-0.247, 0.163]
	Control	60	2.859	0.590					
Psychomotor	Experimental	60	2.815	0.551	-0.377	118	0.706	-0.039	[-0.246, 0.167]
	Control	60	2.854	0.593					
Affective	Experimental	60	2.811	0.552	-0.414	118	0.679	-0.043	[-0.250, 0.164]
	Control	60	2.854	0.593					
Cognitive	Experimental	60	2.823	0.540	-0.425	118	0.672	-0.044	[-0.249, 0.161]
	Control	60	2.867	0.591					

Mixed-Design ANOVA

The mixed-design ANOVA revealed a significant main effect of time, $F(1,112) = 122.02$, $p < .001$, $\eta^2_p = .521$, indicating a substantial improvement in water rescue competence from pretest to posttest across participants. The large effect size suggests a strong overall improvement over the intervention period.

Importantly, a significant interaction between time and group was found, $F(1,112) = 16.12$, $p < .001$, $\eta^2_p = .126$, demonstrating that the magnitude of improvement differed between groups. Specifically, the experimental group showed a greater increase in competence scores (Pretest: M = 2.816; Posttest: M = 3.478) compared to the control group (Pretest: M = 2.859; Posttest: M = 3.167), suggesting that the PjBL intervention supported by selected game-based elements contributed to greater competence improvement over time.

The time × ability interaction was also significant, $F(1,112) = 23.28$, $p < .001$, $\eta^2_p = .172$, indicating that improvement trajectories differed according to participants' initial ability levels. As presented in Table 11, participants with lower initial ability demonstrated substantially greater gains from pretest to posttest (+0.70) compared to participants with higher initial ability (+0.27). Nevertheless, participants in the higher-ability group maintained higher overall performance levels across both measurement points. This pattern of findings may indicate that the intervention provided meaningful support across different proficiency levels, particularly for participants with lower initial competence.

In contrast, the time × gender interaction was not significant, $F(1,112) = 0.01$, $p = .933$, $\eta^2_p = .000$, indicating that improvements over time were comparable between male and female participants. Additionally, higher-order interaction effects involving gender and ability were not statistically significant ($p > .05$), suggesting no combined moderating effects among these variables.

For between-subjects effects, ability showed a significant main effect, $F(1,112) = 48.70$, $p < .001$, $\eta^2_p = .303$, indicating that overall competence differed significantly between ability groups. However, the main effect of group was marginal, $F(1,112) = 3.70$, $p = .057$, and the main effect of gender was not significant, $F(1,112) = 1.35$, $p = .247$.

From an assumption-testing standpoint, Box's M test was not significant ($p = .367$), indicating homogeneity of covariance matrices across groups. Mauchly's test of sphericity also confirmed that the assumption of sphericity was met ($W = 1.00$). Although Levene's test indicated a variance inequality at the pretest stage ($p = .018$), the balanced sample design and robustness of mixed ANOVA procedures reduce the likelihood of substantial bias in the analysis.

Table 9. Mixed-Design ANOVA Results for Water Rescue Competence (Total Score)

Effect	F(1,112)	p-value	Partial η^2	Interpretation
TIME	122.02	< .001	.521	Significant
TIME × GROUP	16.12	< .001	.126	Significant
TIME × GENDER	0.01	.933	.000	Not significant
TIME × ABILITY	23.28	< .001	.172	Significant
TIME × GROUP × GENDER	0.03	.856	.000	Not significant
TIME × GROUP × ABILITY	0.55	.462	.005	Not significant
TIME × GENDER × ABILITY	1.88	.173	.017	Not significant
TIME × GROUP × GENDER × ABILITY	0.10	.756	.001	Not significant

Table 10. Between-Subjects Effects

Effect	F(1,112)	p-value	Partial η^2	Interpretation
GROUP	3.70	.057	.032	Marginal (ns)
GENDER	1.35	.247	.012	Not significant
ABILITY	48.70	< .001	.303	Significant

Table 11. Descriptive Statistics by Ability Level Across Time

Ability Level	Pretest M (SD)	Posttest M (SD)	Mean Difference
High Ability	3.19 (0.51)	3.46 (0.46)	+0.27
Low Ability	2.49 (0.38)	3.19 (0.49)	+0.70

Pairwise Comparisons for Time Effect

Pairwise comparisons with Bonferroni adjustment confirmed a statistically significant increase in performance from pretest to posttest, $M_{diff} = 0.485$, $SE = 0.044$, $p < .001$, 95% CI [0.398, 0.572], further supporting the robustness of the observed time effect across participants.

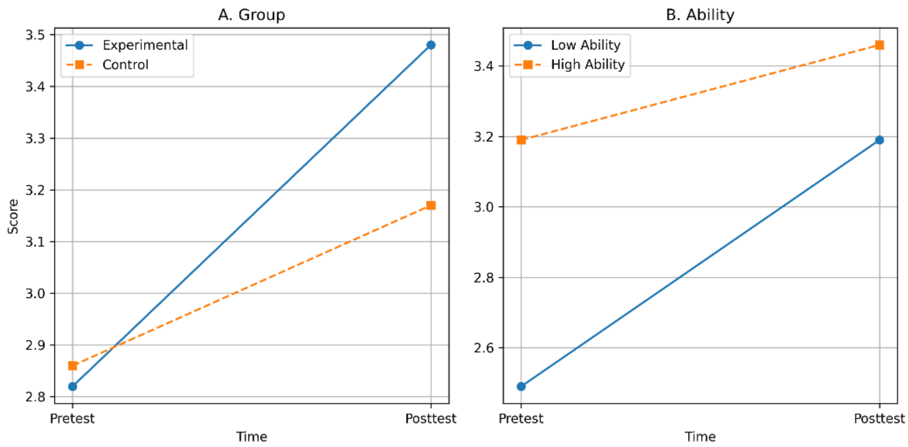
Table 12. Pairwise Comparison for Time Effect

Comparison	Mean Difference	SE	95% CI	p-value
Posttest – Pretest	0.485	0.044	[0.398, 0.572]	< .001

Interaction Effects Visualization

The interaction effects are illustrated in Figure 1. As shown in Figure 1A, both groups demonstrated improvements in water rescue competence over time; however, the experimental group exhibited a markedly steeper increase compared to the control group, visually reinforcing the significant time × group interaction effect. Furthermore, Figure 1B indicates that participants with lower initial ability demonstrated greater relative gains from pretest to posttest compared to those with higher initial ability, although the higher-ability group maintained higher overall performance across both measurement points. This pattern is consistent with the significant time × ability interaction. In contrast, no meaningful divergence in improvement trajectories was observed based on gender (not shown), aligning with the non-significant time × gender interaction effect.

Figure 1. Interaction effects of time with group and ability on performance outcomes



Note: (A) (A) The interaction plot illustrates that the experimental group experienced a greater increase in scores from pretest to posttest relative to the control group. (B) The interaction between time and ability level suggests that participants with lower initial ability demonstrated larger gains over time compared to participants with higher initial ability.

Discussion

The present study examined the effectiveness of a Project-Based Learning (PjBL) intervention supported by selected game-based elements in enhancing water rescue competence among university students. The findings demonstrate a significant improvement in overall competence across the intervention period, with a meaningful interaction effect between time and instructional group, indicating that the observed gains were not solely attributable to repeated exposure but were associated with the structured pedagogical approach implemented in the intervention

These findings reinforce the principles of active and experiential learning, which posit that competence is most effectively developed through authentic, participatory, and contextually meaningful experiences. The integration of sustained engagement, collaborative problem-solving, and contextualized practice appears to support multidimensional learning processes, encompassing cognitive understanding, affective development, and psychomotor performance (Morris, 2020; Croft et al., 2021; Almalag et al., 2022; Varman et al., 2023).

A key contribution of this study lies in the implementation of Project-Based Learning supported by selected game-based elements. Rather than implementing a comprehensive gamification system, the intervention incorporated specific elements such as points, badges, challenge-based activities, and continuous feedback to support student engagement throughout the project process (Subhash & Cudney, 2018; Junior et al., 2019; Huang et al., 2023). Previous studies have suggested that such elements can enhance participation, motivation, and engagement when embedded within meaningful educational activities and authentic learning tasks (Deterding et al., 2011; Hamari et al., 2014; González et al., 2018; Kapp, 2019; Saggah et al., 2020; Prieto et al., 2020; Rivera & Garden, 2021; Sánchez-Silva & Prieto, 2021; Z. Luo, 2022; Tanouri et al., 2024; Triantafyllou et al., 2025; Jastrow et al., 2022; Camacho-Sánchez et al., 2023; Sotos-Martínez et al., 2024).

Within the present study, these game-based elements were used to reinforce project progression, support participation in project milestones, and provide ongoing performance feedback. Their contribution therefore appears to be closely linked to the broader instructional structure of PjBL, which emphasizes sustained inquiry, collaboration, and authentic problem solving. This combination may have helped maintain student involvement throughout the intervention while preserving the educational focus of the learning activities.

Similarly, the implementation of PjBL adhered to its defining characteristics, including sustained inquiry, collaborative design processes, and the production of tangible outputs presented to an authentic audience (Krajcik & Czerniak, 2018; Wibowo et al., 2025; Sánchez-García & Reyes-de-Cózar, 2025). This distinction is critical, as it differentiates the present intervention from problem-based or case-based approaches. The incorporation of selected game-based elements within PjBL appears to create a supportive learning environment in which engagement-enhancing features complement project-based inquiry, collaboration, and authentic problem solving.

At the domain level, improvements were observed across cognitive, affective, and psychomotor components. Although gains in the cognitive domain were more modest compared to psychomotor and affective outcomes, the findings still suggest that the intervention supported conceptual understanding alongside practical skill execution. This pattern may reflect the differing learning dynamics across domains, where conceptual understanding develops progressively through repeated exposure and reflection, while psychomotor performance benefits more directly from structured practice and simulation. These findings are consistent with previous research in aquatic safety and physical education, which emphasizes that effective learning integrates knowledge, attitudes, and skills (Bánfai et al., 2018; Calle-Molina & Sanz-Arribas, 2024).

Notably, the substantial improvement observed in the psychomotor domain in the experimental group indicates that project-based learning environments enriched with selected game-based elements do not necessarily compromise physical skill development. Instead, when combined with structured practice and realistic simulation, such approaches can simultaneously foster technical proficiency, decision-making, and behavioral preparedness in simulated high-risk contexts. This is particularly relevant in water rescue education, where effective performance depends not only on physical execution but also on situational awareness and risk-sensitive decision-making (Turgut, 2012; Royal Life Saving Society, 2014; Stallman, Moran, et al., 2014; Baker, 2019).

The significant interaction between time and instructional group confirms that the Project-Based Learning intervention supported by selected game-based elements produced greater improvements compared to conventional instruction. This finding is important in addressing a common limitation of pretest–posttest designs, where improvements may be attributed to practice effects. The inclusion of a control group and the establishment of baseline equivalence strengthen the internal validity of the study, suggesting that the observed gains are associated with the pedagogical design rather than mere repetition.

The moderating role of initial swimming ability further highlights the importance of foundational competence in aquatic education. The significant time × ability interaction indicates that improvement trajectories differed across ability levels. Importantly, this pattern reflects relative change rather than absolute performance differences. The findings suggest that participants with lower initial ability demonstrated greater relative gains over time, which may indicate that the intervention provided adaptive support across different proficiency levels. This interpretation is consistent with principles of scaffolding and differentiated instruction, where structured guidance and progressive challenges facilitate learning across heterogeneous groups (Jiang et al., 2023; Ribeiro et al., 2024; Pritchard & Dockerty, 2025; Bessa et al., 2021; Dapp et al., 2021; Eikeland & Ohna, 2022; Ferriz-Valero et al., 2023; Goyibova et al., 2025).

In contrast, gender did not significantly influence competence improvement, indicating that the intervention was similarly effective for male and female participants. This finding aligns with research suggesting that structured, collaborative, and context-based learning environments can reduce gender disparities in physical education outcomes (Rejman et al., 2020; Guerrero & Guerrero Puerta, 2023; Sakamoto et al., 2020). Although gender differences in aquatic competence have been reported in epidemiological contexts (Santibañez-Gutierrez et al., 2022; Roberts et al., 2024), the present results suggest that pedagogical design plays a critical role in promoting equitable learning outcomes.

Despite these contributions, several limitations should be acknowledged. First, although the study employed a quasi-experimental design with a control group and baseline equivalence, the absence of randomization limits causal inference. Second, the use of a researcher-developed instrument, while grounded in established frameworks, may limit comparability with other studies. Third, the intervention duration does not allow conclusions regarding long-term retention or transfer of competence to real-world rescue situations. Additionally, the sample was limited to physical education and sport science students, which may restrict generalizability.

Future research should therefore employ randomized controlled designs, utilize standardized and validated assessment tools for water rescue competence, and examine long-term retention and transfer effects in real-world or high-risk aquatic environments. Further investigation is also needed to explore how Project-Based Learning approaches supported by selected game-based elements can be optimized to support both skill acquisition and safety-related competencies across diverse populations.

Conclusions

This study demonstrated that a Project-Based Learning (PjBL) approach supported by selected game-based elements was associated with significant improvements in water rescue competence among university students. The findings revealed significant time and time × group effects, indicating greater competence gains in the experimental group compared with conventional instruction. Improvements were observed across psychomotor, affective, and cognitive domains, with the largest gains occurring in psychomotor competence, while cognitive improvements were comparatively more modest. Participants with lower initial swimming ability demonstrated greater relative improvement over time, although those with higher initial ability maintained superior overall performance. Gender did not significantly influence competence development. These findings suggest that incorporating selected game-based elements, such as points, badges, challenges, and feedback, as complementary supports within a structured Project-Based Learning environment may enhance student engagement and participation while facilitating the development of water rescue competence in aquatic education. The results further support the potential of learner-centered and project-based instructional approaches for promoting integrated cognitive, affective, and psychomotor learning outcomes in water safety education. Nevertheless, the findings should be interpreted in light of several limitations, including the quasi-experimental design, the use of a researcher-developed assessment instrument, and the absence of long-term follow-up measures. Future studies are encouraged to employ randomized controlled designs, standardized assessment tools, and longitudinal evaluations to further examine the sustainability and transferability of water rescue competence in authentic aquatic contexts.

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