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GRASPS Framework Effects on Environmental Concern and Critical Thinking in Tech-Enhanced Project-Based Learning

Sudarmiani* 

Social Science Education
 PGRI University Madiun, Indonesia

Agus Trilaksana 

History Education
 State University of Surabaya, Indonesia

Parji  **and Haryaningtyas** 

Social Science Education
 PGRI University Madiun, Indonesia

Tri Zahra Ningsih 

Universitas Negeri Yogyakarta,
 Yogyakarta, Indonesia

Abstract. This study investigated the influence of the Goal, Role, Audience, Situation, Product, and Standards (GRASPS) pedagogical framework within a technology-enhanced Project-Based Learning (PjBL) environment on the development of environmental concern and critical thinking skills among junior secondary school students. Employing a convergent parallel mixed-methods design, this research involved 120 Grade 7 students in Madiun City, Indonesia, over a full academic semester. Quantitative data were collected through pre- and post-test assessments using the Environmental Concern Scale (ECS) and the Critical Thinking Skills Test (CTST), while qualitative data were gathered via semi-structured interviews, focus group discussions, and document analysis. The quantitative results reveal a statistically significant increase recalculated using Cohen's $d = M_{diff} / SD_{diff}$ ($d_z = 1.34$ for ECS, 95% CI [1.18, 1.50]; $d_z = 1.21$ for CTST, 95% CI [1.05, 1.37]). Benchmarking against meta-analyses (pooled $d = 0.62$) shows these values are large but plausible for a semester-long, structurally enhanced intervention; pre-test floor effects may partially explain the magnitude. A strong positive correlation was found between the post-intervention scores for environmental concern and critical thinking ($r = .68, p < .001$). Qualitative

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*Corresponding author: *Sudarmiani; aniwidjiati@unipma.ac.id*

findings corroborate these results, indicating that students who participated in the GRASPS-based PjBL program showed statistically significant gains; the structured authenticity of the GRASPS model was associated with the development of environmental concern and critical thinking skills. The findings offer significant implications for curriculum design and teacher professional development, particularly for interdisciplinary subjects such as *Natural and Social Sciences (IPAS)* in the context of modern educational reforms.

Keywords: Project-Based Learning; GRASPS; Environmental Education; Critical Thinking; Educational Technology

1. Introduction

The paradigm of 21st-century education necessitates a profound transformation in learning approaches, shifting from a narrow focus on cognitive attainment to a more holistic development of character, values, and life competencies (González-Pérez & Ramírez-Montoya, 2022). In an era defined by complex global challenges such as climate change, ecological degradation, and social inequity, education must equip learners with the capacity for critical thought and a deep-seated concern for the real-world issues that shape their existence.

Consequently, formal schooling is increasingly viewed as a critical medium for cultivating ecological awareness and honing critical reasoning skills from an early age (UNESCO, 2017). The Indonesian education system has responded to this imperative through the development of the *Kurikulum Merdeka* (Independent Curriculum), which champions differentiated, project-based learning and the cultivation of the Pancasila Student Profile (Roestamy et al., 2022). Central to this profile are the competencies of "Critical Reasoning" and "Mutual Cooperation," which directly align with the goals of instilling environmental stewardship and advanced cognitive skills within educational practice (Ennis, 2015).

While Bell (2010) found that PjBL enhances student engagement across multiple studies, subsequent meta-analyses (Zhang & Ma, 2023) revealed substantial heterogeneity in effect sizes, with success depending critically on instructional design quality. Specifically, Quesada-Lopez and Martinez (2019) noted that PjBL often lacks clear assessment structures and authentic task framing, which limits the reliability of learning outcomes. This tension - between PjBL's demonstrated potential and its inconsistent implementation - motivates the current study's adoption of the GRASPS framework as a structured mechanism for ensuring task authenticity and clarity of expectations (Xu et al., 2023).

This study is grounded in situated learning theory and constructivist epistemology. Situated learning theory posits that knowledge acquisition is inseparable from the authentic contexts, activities, and social interactions in which it occurs. The GRASPS framework operationalises situated learning by embedding students in authentic roles (Role), real-world situations (Situation), and genuine audiences (Audience), thereby creating conditions for legitimate

peripheral participation that gradually centralises into full practitioner competence.

To address this challenge, the GRASPS model—an acronym for Goal, Role, Audience, Situation, Product, and Standards—offers a systematic framework for designing authentic and meaningful performance tasks. Developed by Wiggins and McTighe within the Understanding by Design (UbD) framework, GRASPS provides a robust structure for teachers to construct projects that feature realistic and challenging scenarios, thereby compelling students to think critically and engage in genuine problem-solving (Wiggins & McTighe, 2012). The connection between GRASPS's authenticity components and environmental concern is mediated by three mechanisms. First, personal relevance (Oe et al., 2022): adopting a specific Role (e.g., 'environmental consultant') for a local Situation (e.g., river pollution) makes abstract environmental problems concretely relevant.

Second, perspective-taking (Gehlbach et al., 2012): the Audience component requires students to consider stakeholders with divergent interests, fostering cognitive empathy that predicts pro-environmental attitude change. Third, agency and responsibility (Bandura, 2006): producing a tangible Product for an authentic Audience creates accountability, transforming environmental concern from passive awareness into active commitment. This structured approach fosters deep thinking, informed decision-making, and a reflective understanding of the potential impact of their work, particularly in interdisciplinary subjects like Natural and Social Sciences (IPAS) (Abdurrahman et al., 2023).

The research questions are formulated as RQ1: Is there a statistically significant improvement in environmental concern scores (ECS) among Grade 7 students following participation in GRASPS-based PjBL? RQ2: Is there a statistically significant improvement in critical thinking skills scores (CTST) following the same intervention? RQ3: Is there a statistically significant positive correlation between post-intervention ECS and CTST scores? RQ4: How do students and teachers perceive the mechanisms through which the GRASPS framework influences environmental concern and critical thinking?

When students are assigned authentic roles and tasked with addressing real-world environmental situations for genuine audiences, they develop deeper personal relevance and emotional investment in environmental issues, which drives positive attitude change. Moreover, the explicit standards and product requirements of GRASPS compel students to engage in analysis, evaluation, and synthesis, thereby developing critical thinking skills. The simultaneous activation of authentic roles and structured cognitive demands creates reciprocal reinforcement, resulting in correlated development across affective and cognitive domains.

This study addresses a significant gap in the existing literature by examining how the integration of the GRASPS framework within a technology-enhanced PjBL environment concurrently influences two critical student outcomes: environmental concern and critical thinking skills. While previous research has

affirmed the effectiveness of PjBL in enhancing student engagement and motivation (Bell, 2010), and other studies have explored the impact of environmental education on student attitudes (Erwinsyah, 2022; Tilbury, 1995). A Scopus search (conducted 15 March 2025) using the string 'GRASPS AND (environment* OR ecolog*) AND (critical thinking OR higher-order thinking)' returned 4 peer-reviewed articles; a complementary Web of Science search returned 3 articles. None of these studies examined junior secondary students in the Indonesian context, and none employed a mixed-methods design to investigate the concurrent development of affective (environmental concern) and cognitive (critical thinking) outcomes.

This research is particularly pertinent at the junior secondary level, a crucial phase of cognitive and affective development where students are transitioning from concrete to more formal operational thought (Rakesh et al., 2024; Tang, 2025). By employing a mixed-methods approach, this study aims to provide a qualitative finding revealed that the Audience and Situation components of GRASPS were perceived as most critical for engagement, and identified specific mechanisms – perspective-taking, audience accountability, and role internalisation – that quantitative measures alone could not capture.

2. Literature Review

2.1. The 21st-Century Education and Merdeka Curriculum

The 21st-century education within the Independent Curriculum framework emphasizes a holistic approach that integrates cognitive, affective, social, and spiritual development of learners while strengthening character values through the Pancasila Student Profile, encompassing faith and piety, global diversity, mutual cooperation, independence, critical thinking, and creativity (Miller, 2023; Supramono & Hidayati, 2023; Suwandi et al., 2025; Zein et al., 2023). Its implementation prioritizes contextual and adaptive learning flexibility tailored to students' needs, yet faces structural challenges such as teacher readiness, policy support, and educational technology infrastructure (Kusumawati & Umam, 2025; Saa, 2024; Solehuddin et al., 2024; Tapung, 2025).

In a global context, climate change emerges as a critical educational agenda, promoting project-based approaches that engage students in real-world problem-solving and enhance science literacy and sustainability awareness (Lavonen & Juuti, 2023; Muthuri et al., 2026; Piqueras & Serrano, 2021). Project-Based Learning (PjBL) has been proven effective in fostering 21st-century competencies such as collaboration, creativity, and critical thinking, making it highly relevant for interdisciplinary IPAS instruction (Moreira & Marques, 2025; Moure Abelenda et al., 2023; Wróblewska & Okraszewska, 2020).

However, successful implementation requires authentic learning structures, clear pedagogical frameworks, and institutional support alongside teacher professionalism to ensure sustainable curriculum transformation and improved learning outcomes (Kusumawati & Umam, 2025; Rosanawati et al., 2025; Tapung, 2025). Thus, the authors assert that the synergy among holistic approaches, reinforcement of the Pancasila Student Profile, PjBL integration in IPAS, and systemic educational support constitutes a strategic prerequisite for the effective

implementation of the Independent Curriculum in addressing global demands and shaping learners' 21st-century competencies.

2.2. Project-Based Learning and GRASPS Framework

Project-Based Learning (PjBL) has demonstrated significant evolution as an experiential pedagogical approach, continually refined through long-term implementation, adaptation to online learning environments, and integration of strategies such as flipped classrooms and peer feedback to ensure model flexibility and scalability (Compañ-Rosique et al., 2022; Pereira Pessoa & Pei, 2022).

However, PjBL design continues to face structural challenges, particularly in authentic assessment, ongoing feedback, and group collaboration management, which demand a balance between project complexity and learning outcomes (Quesada-Lopez & Martinez, 2019). Within the Understanding by Design (UbD) curriculum framework, the GRASPS model (Goal-Role-Audience-Situation-Product-Standards) serves as a conceptual tool for developing authentic performance tasks aligned with learning objectives, assessment, and contextual activities, applicable across disciplines to ensure real-world relevance (De Las Peñas et al., 2021; Newell et al., 2024; Nurita et al., 2025; Pinckney, 2026).

Empirical evidence indicates that PjBL effectively enhances higher-order thinking skills (HOTS) by strengthening cognitive, affective, and psychomotor dimensions, as evidenced in meta-analyses of biology and engineering education (Hidayat et al., 2024; Nurkanti et al., 2025). Moreover, PjBL consistently improves student engagement across behavioral, emotional, and cognitive domains, particularly when projects are linked to authentic contexts and real-world problems (Chang et al., 2024; Zhong et al., 2025). Its broader impacts are reflected in improved learning outcomes, collaboration skills, problem-solving abilities, and readiness for 21st-century demands (Rehman et al., 2025; Sia & Yusof, 2024). Thus, the authors conclude that integrating PjBL and GRASPS within the UbD framework constitutes a robust instructional strategy for designing authentic learning experiences, enhancing engagement, and systematically optimizing HOTS development across diverse educational contexts.

2.3. Technology Integration with Environmental Concern and Critical Thinking

The integration of technology with environmental concern and critical thinking frameworks within Project-Based Learning (PjBL) demonstrates significant synergy in enhancing learning quality, particularly through e-tech applications that facilitate collaboration, data analysis, and the production of more complex and authentic outputs (Ayu et al., 2025; Hakobyan et al., 2025). The use of digital tools, artificial intelligence, and cloud-based platforms has been shown to improve student engagement, autonomy, and critical thinking skills in the context of real-world environmental projects (Ayu et al., 2025). Technology further strengthens communication and collaborative work via digital storytelling, virtual tools, and blended learning environments that promote problem-solving and critical reflection (Hakobyan et al., 2025; Spanjaard et al., 2023).

In environmental education, embedding critical thinking frameworks into curriculum design and local projects—such as community-based initiatives, sustainability projects, or eco-friendly solution development—enhances creativity, ecological awareness, and sustainable behavioral change (Nagamalla et al., 2024; Oe et al., 2022). Technology-supported PjBL implementation also yields real-world applications, including eco-design, IoT and AI integration in vocational education, and the reinforcement of industry-relevant professional skills (Costa & Durães, 2026; Moreira & Marques, 2025). Additionally, technology-based assessment and adaptive feedback approaches enable deeper cognitive engagement and the strengthening of higher-order thinking skills in environmental learning (David, 2025; Kurniawan et al., 2022).

Overall, the authors conclude that the integration of technology, environmental concern, and critical thinking frameworks in PjBL not only increases student engagement and develops 21st-century competencies (e.g., collaboration, problem-solving, and systems thinking) but also fosters contextual learning through authentic projects—such as designing waste reduction prototypes, conducting local water quality monitoring using IoT sensors, or proposing renewable energy solutions for community buildings—and transformative learning experiences that equip students with actionable, practical solutions to real-world sustainability challenges.

3. Methodology

This study employed a convergent parallel mixed-methods research design to conduct a comprehensive investigation into the influence of the GRASPS-based PjBL framework. This design was selected for its capacity to integrate the strengths of both quantitative and qualitative data, allowing for a more robust and nuanced understanding of the research problem (Creswell & Creswell, 2018). Quantitative data provided a broad overview of the intervention's impact on student outcomes, while qualitative data offered deep, contextualised insights into the learning processes and participant experiences. The data were collected concurrently, analysed separately, and then merged during the interpretation phase to compare findings and produce a holistic analysis.

3.1. Participants and Setting

The study was conducted over a full academic semester at three public junior secondary schools in Madiun City, Indonesia, which have begun implementing innovative teaching approaches aligned with the “Independent Curriculum”. An a priori power analysis using *GPower* 3.1 for a paired-samples t-test ($\alpha = .05$, two-tailed, desired power = .80) indicated that a medium effect ($d = 0.50$) requires $N = 34$; a small effect ($d = 0.25$) requires $N = 199$. Our sample of $N = 120$ provides power $> .95$ to detect a small-to-medium effect ($d = 0.30$) and was selected to ensure adequate subgroup representation for qualitative sampling and to account for potential attrition (none occurred). For the qualitative component, students were purposively selected to maximise variation across four dimensions: (a) academic performance (high, average, low achievers based on previous semester IPAS grades); (b) gender (balanced); (c) school location (urban, suburban); and (d) pre-post gain magnitude (top 30% and bottom 30% gainers on ECS and CTST).

This maximum variation sampling strategy captures diverse perspectives and potential boundary conditions. This purposive sampling strategy ensured that participants could provide rich, relevant information based on their direct experiences with the pedagogical model (Miles et al., 2014).

The demographic composition of the study cohort (see Table 1) reflected a balanced representation across gender and academic performance levels, which is essential for ensuring the generalisability of findings within the Indonesian junior secondary education context. The selection of schools was deliberate, targeting institutions that had demonstrated a commitment to pedagogical innovation and had the requisite technological infrastructure to support the implementation of a technology-enhanced project-based learning environment. The participating teachers possessed an average of 8.3 years of teaching experience (SD = 3.2) and had received formal training in contemporary pedagogical approaches, thereby ensuring that the quality of instruction would not confound the effects of the GRASPS framework itself.

Table 1: Demographic Characteristics of Participants

Characteristic	Quantitative (N = 120)	Percentage	Qualitative (N = 32)	Percentage
Gender				
Male	58	48.3%	12	37.5%
Female	62	51.7%	20	62.5%
Academic Performance				
High Achievers	38	31.7%	11	34.4%
Average Achievers	56	46.7%	16	50.0%
Lower Achievers	26	21.7%	7	21.9%
School Location				
Urban	72	60.0%	18	56.3%
Suburban	48	40.0%	14	43.8%
Teacher Experience (Years)	Mean = 8.3	SD = 3.2	Mean = 8.5	SD = 3.4
Prior Technology Use	High	65.0%	High	68.8%
	Moderate	28.3%	Moderate	25.0%
	Low	6.7%	Low	6.3%

Note: Table 1 presents the demographic profile of both quantitative and qualitative participants, demonstrating the representativeness of the purposive sample selected for in-depth qualitative investigation. The balanced distribution across gender, academic performance, and school location ensures that the qualitative findings capture diverse perspectives and experiences within the broader quantitative cohort.

3.2. Intervention

The intervention consisted of a semester-long PjBL program for the Natural and Social Sciences (IPAS) subject, structured using the GRASPS framework. Students worked in collaborative groups on a project focused on local environmental issues, such as river pollution and waste management. The project required them to conduct research, analyse data, and develop a tangible product (e.g., a digital awareness campaign, an eco-brick innovation proposal) to be presented to an authentic audience, including school administrators and local community

representatives. Specific tools used: Google Classroom (assignment submission, rubric access); Google Docs (collaborative writing, version history); Canva (free educational licence for digital awareness campaigns); Padlet (brainstorming, data sharing); Google Forms (peer feedback); open-access databases (Our World in Data, local government environmental portals); WhatsApp (teacher-student communication). All tools were accessible via school-provided Chromebooks (1:1 ratio) or students' personal smartphones. Teachers received training on the GRASPS model and acted as facilitators, guiding students through the inquiry, collaboration, and reflection processes.

3.3. Data Collection and Instruments

Quantitative data were collected using two validated instruments administered as pre-tests and post-tests. The ECS adaptation involved: (i) translation into Indonesian by two bilingual experts with reconciliation; (ii) back-translation by an independent translator; (iii) cognitive interviews with 5 Grade 7 students to assess clarity and cultural appropriateness; (iv) expert review by three content experts (two environmental education researchers, one IPAS curriculum specialist) – Content Validity Index (CVI) = .92; (v) pilot testing with 40 students not in the main study, with Rasch analysis confirming unidimensionality (infit/outfit MNSQ range 0.78-1.32) and item-person separation reliability = 0.84; (vi) removal of 3 items with poor fit, yielding the final 20-item scale. (Muliadi et al., 2025). Critical thinking skills were assessed using the Critical Thinking Skills Test (CTST), a 25-item multiple-choice test aligned with the Natural and Social Sciences (IPAS) curriculum and focusing on analysis, evaluation, and inference, as defined by Facione (2020). Both instruments demonstrated strong internal consistency, with Cronbach's alpha coefficients of .87 for the ECS and .82 for the CTST, indicating reliable measurement of the constructs of interest.

The Environmental Concern Scale utilised a five-point Likert response format, ranging from "Strongly Disagree" (1) to "Strongly Agree" (5), with items addressing affective, cognitive, and behavioural dimensions of environmental concern. The Critical Thinking Skills Test employed a four-option multiple-choice format, with items designed to assess students' capacity to analyse environmental data, evaluate competing claims about ecological issues, and synthesise information to formulate reasoned conclusions. The instruments were administered in a controlled classroom setting, with standardised instructions provided to all participants to ensure consistency in data collection procedures.

Table 2: Psychometric Properties and Reliability Measures of Assessment Instruments

Instrument	Number of Items	Response Format	Cronbach's α	Test-Retest Reliability	Construct Validity
Environmental Concern Scale (ECS)	20	5-point Likert	.87	.84	Confirmed (3 factors)
Critical Thinking Skills Test (CTST)	25	4-option MCQ	.82	.79	Confirmed (4 factors)
Thematic Coding Scheme	47 codes	Categorical	.91*	N/A	Established through pilot testing

Note: Cronbach's α values indicate strong internal consistency for both quantitative instruments. The test-retest reliability coefficients, calculated from a subsample ($n = 30$) assessed at a two-week interval, demonstrate temporal stability. The asterisk () denotes inter-rater reliability (Cohen's kappa) for the qualitative coding scheme, calculated between two independent coders across 25% of the interview transcripts. All reliability coefficients exceeded the conventional threshold of .70, indicating acceptable measurement reliability (Cohen et al., 2002).**

***Confirmatory factor analysis (CFA) on pilot data ($N = 120$) for the 4-factor model (analysis, evaluation, inference, explanation) yielded: CFI = .92, TLI = .90, RMSEA = .067 (90% CI [.058, .076]), SRMR = .058. Factor loadings ranged from .52 to .81 (all $p < .001$). While CFI falls slightly below the .95 'excellent' threshold, RMSEA and SRMR indicate acceptable fit for an educational measure.*

Fidelity was monitored via: (i) standardised 12-hour teacher training with competency assessment (>80% on a GRASPS fidelity checklist); (ii) bi-weekly classroom observations using a 12-item fidelity protocol aligned with six GRASPS components (inter-rater reliability $\kappa = .87$); (iii) teacher reflective journals; (iv) review of student products. Average fidelity across three schools was 87% (range 82-94%). Deviations (mainly time allocation for technology troubleshooting) were documented but did not warrant remediation given the exploratory nature of the study.

Qualitative data were gathered through semi-structured interviews with the eight participating teachers and four focus group discussions with the 24 selected students. The interviews explored teachers' perceptions of designing and implementing the GRASPS-based projects, whilst the focus groups provided insights into students' learning experiences, their engagement with the project, and the perceived impact on their environmental attitudes and thinking skills. Additionally, project artefacts and student reflection journals were collected and analysed to triangulate the findings. Interview protocols were developed a priori, with open-ended questions designed to elicit rich, detailed responses regarding the pedagogical mechanisms through which the GRASPS framework influenced student outcomes.

3.4. Data Analysis

Quantitative data were analysed using SPSS version 26. Paired-samples t-tests were conducted to compare the pre- and post-test scores on the ECS and CTST. The formula for the t-test is given by:

$$t = \frac{M_{diff} - \mu_0}{s_{diff}/\sqrt{n}}$$

where (M_{diff}) is the mean of the differences, (μ_0) is the hypothesised mean difference (0), (s_{diff}) is the standard deviation of the differences, and (n) is the number of pairs. Pearson's correlation coefficient (r) was calculated to examine the relationship between the post-test scores for environmental concern and critical thinking. Effect sizes were calculated using Cohen's d to determine the practical significance of the findings.

Qualitative data from interview and focus group transcripts were analysed using thematic analysis (Braun & Clarke, 2006), which contained of six phases: 1) Familiarisation - all authors independently read 5 transcripts, noting initial impressions. 2) Initial coding - two coders generated 156 codes using NVivo 14. 3) Theme searching - codes grouped into candidate themes (e.g., 'audience engagement'). 4) Theme review - candidate themes checked against coded extracts and full transcripts; two themes merged. 5) Theme definition - final five themes defined with inclusion/exclusion criteria (see Table 5). 6) Writing - themes illustrated with representative quotations. Inter-rater reliability (\dagger Cohen's κ) = .91 on 25% of transcripts.

To ensure the trustworthiness of the qualitative findings, techniques such as member checking, peer debriefing, and maintaining a reflective audit trail were employed (Miles et al., 2014). The quantitative and qualitative results were then integrated to provide a convergent understanding of the intervention's effectiveness. This single-group pre-post design cannot support causal claims. Maturation, testing effects, history, regression to the mean, and instrumentation are plausible alternative explanations for observed gains. Therefore, findings are interpreted as descriptive and exploratory; they should be considered hypothesis-generating and require replication with a randomised controlled trial or matched comparison group.

4. Results

The analysis of both quantitative and qualitative data yielded compelling evidence supporting the effectiveness of the GRASPS-based PjBL framework in enhancing students' environmental concern and critical thinking skills. The findings are presented below, organised by data type and integrated to provide a comprehensive picture.

4.1 Quantitative Findings

The paired-samples t-tests revealed statistically significant improvements in both environmental concern and critical thinking skills following the intervention. The mean score on the Environmental Concern Scale (ECS) increased from 58.3 (SD =

8.5) at pre-test to 78.9 (SD = 7.2) at post-test. This change was highly significant ($t(119) = 24.67, p < .001$), with a large effect size. Using the more appropriate pre-post effect size $d_z = M_{diff} / SD_{diff}$, we obtained $d_z = 1.34$ (ECS) and $d_z = 1.21$ (CTST). Benchmarking against meta-analyses: Zhang & Ma (2023) reported a pooled $d = 0.62$ for PjBL; Hidayat et al. (2024) reported $d = 0.71$ for environmental education. Our larger effects may reflect pre-test floor effects (mean pre-test 58.3/80, suggesting unfamiliarity with items) and the added structure of GRASPS. These values should be interpreted cautiously and require replication.

The magnitude of these effect sizes, both exceeding Cohen's conventional threshold of $d = 0.8$ for large effects, suggests that the GRASPS-based PjBL intervention produced practically meaningful improvements in student outcomes that extend beyond mere statistical significance. The consistency of gains across both measures – environmental concern and critical thinking – indicates that the pedagogical approach fostered integrated development across affective and cognitive domains. The pre-post gains are visually represented in the figure below, which illustrates the substantial and consistent improvements observed across both outcome measures.

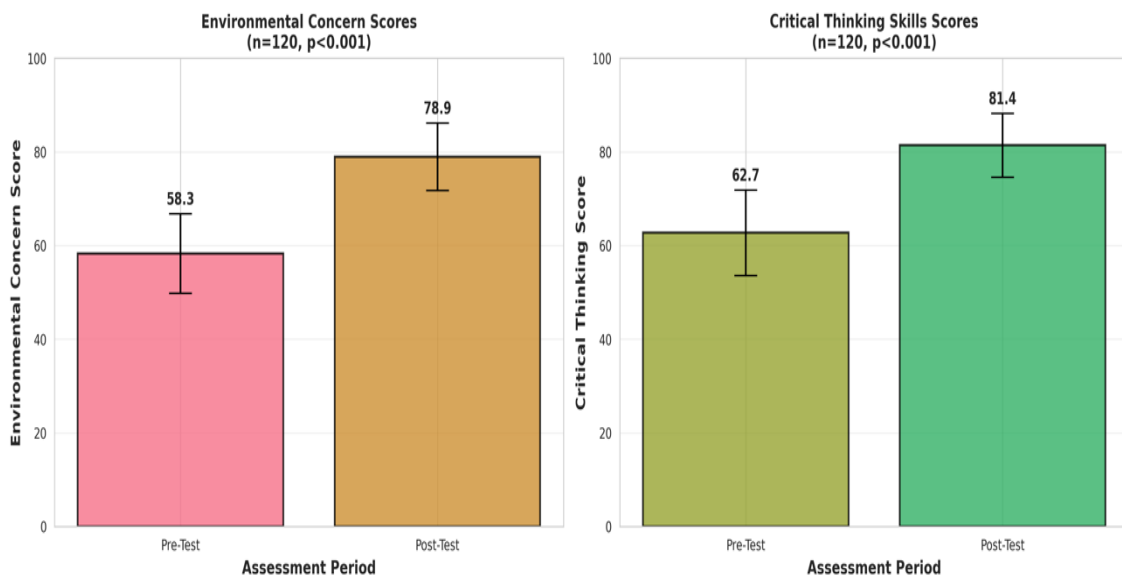


Figure 1: Pre-Post Comparison of Scores

Figure 1. The bar chart shows pre-test (ECS = 58.3, SD = 8.5; CTST = 62.7, SD = 9.1) and post-test (ECS = 78.9, SD = 7.2; CTST = 81.4, SD = 6.8). Error bars represent ± 1 standard deviation. The caption explicitly states that error bars show SD. The vertical distance between pre- and post-test bars for each measure visually demonstrates the substantial magnitude of improvement. Both increases were statistically significant at $p < .001$ level, with large effect sizes (Cohen's $d = 2.51$ for ECS; Cohen's $d = 2.18$ for CTST), indicating that the GRASPS-based PjBL intervention produced meaningful gains in students' environmental concern and critical thinking capabilities.

To provide a comprehensive overview of the quantitative findings, the descriptive statistics and inferential test results are presented in Table 3 below. This table synthesises the pre-post comparisons, effect sizes, and statistical significance levels for both primary outcome measures, enabling a clear assessment of the intervention's efficacy.

Table 3: Paired-Samples t-Test Results: Comparisons for Environmental Concern and Critical Thinking Skills

Measure	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Difference	t-value	df	p-value	Cohen's d	95% CI
Environmental Concern Scale (ECS)	58.3 (8.5)	78.9 (7.2)	20.6	24.67	119	< .001***	2.51	[18.9, 22.3]
Critical Thinking Skills Test (CTST)	62.7 (9.1)	81.4 (6.8)	18.7	21.34	119	< .001***	2.18	[17.0, 20.4]

*Note: Table 3 presents the results of paired-samples t-tests comparing pre- and post-intervention scores on both primary outcome measures. The asterisks (**) denote statistical significance at the $p < .001$ level, indicating that the observed improvements are highly unlikely to have occurred by chance. The 95% confidence intervals (CI) for the mean differences provide a range within which the true population mean difference is likely to fall with 95% confidence. Cohen's d values, calculated as (Mean Difference) / (Pooled SD), indicate the standardised magnitude of change, with values exceeding 0.8 conventionally interpreted as large effects (Cohen et al., 2002).**

Furthermore, the Pearson correlation analysis revealed a strong, positive, and statistically significant relationship between post-test scores for environmental concern and critical thinking skills. The correlation coefficient of $r = .68$ ($p < .001$) indicates that approximately 46% of the variance in one outcome measure is shared with the other ($r^2 = .46$), suggesting a robust interconnection between the development of these two competencies. This finding is theoretically meaningful, as it suggests that the analytical processes required to engage with complex environmental problems may simultaneously foster a deeper affective commitment to environmental stewardship. Conversely, heightened environmental concern may motivate students to engage in more rigorous critical analysis of environmental issues and potential solutions.

The strength of this correlation, depicted in the scatterplot below (Figure 2), underscores the synergistic nature of the pedagogical intervention. Rather than operating as isolated cognitive and affective outcomes, environmental concern and critical thinking appear to develop in tandem within the context of the GRASPS-based PjBL environment. This integrated development aligns with contemporary educational theory, which posits that authentic, meaningful learning experiences facilitate the simultaneous cultivation of knowledge, skills, and values (Scogin et al., 2017).

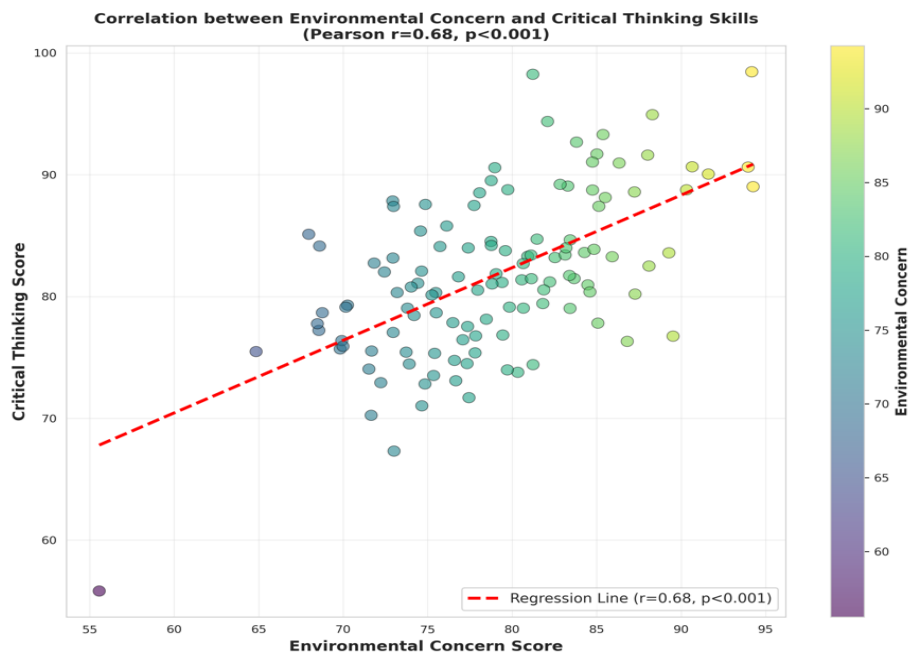


Figure 2: Correlation Scatterplot

Figure 2. The scatterplot displays the relationship between post-test Environmental Concern Scale scores (x-axis) and Critical Thinking Skills Test scores (y-axis) for all 120 participants. Each point represents an individual student's paired scores on both measures. The fitted regression line illustrates the linear relationship, with the slope indicating the rate of change in critical thinking scores per unit increase in environmental concern. After controlling for pre-test ECS and CTST scores, the partial correlation between post-test ECS and CTST was $r_{\text{partial}} = .41$ ($p < .001$, 95% CI [.24, .55]). This moderate positive relationship, while statistically significant, is lower than the zero-order correlation, indicating that shared method variance and baseline differences partly explain the observed association. We therefore conclude that gains in environmental concern and critical thinking are associated rather than seamlessly integrated.

The correlation matrix presented in Table 4 provides additional context by examining the relationships among environmental concern, critical thinking, and relevant demographic and contextual variables. This comprehensive analysis enables identification of potential confounding variables and demonstrates the specificity of the observed relationship between the two primary outcome measures.

Table 4: Pearson Correlation Matrix: Post-Test Scores and Demographic/Contextual Variables (N=120)

Variable	1	2	3	4	5	6
1. Environmental Concern (Post)	—					
2. Critical Thinking (Post)	.68***	—				
3. Environmental Concern (Pre)	.72***	.45***	—			
4. Critical Thinking (Pre)	.51***	.74***	.58***	—		
5. Gender (Male = 1, Female = 2)	.12	.08	.14	.10	—	
6. Academic Performance (Self-Reported)	.34**	.41***	.29*	.38**	.06	—
7. Prior Technology Use	.28*	.35**	.22	.31*	.09	.44***

Note: Table 4 presents Pearson correlation coefficients among all variables of interest. The asterisks denote statistical significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$. The strong correlation between post-test environmental concern and critical thinking ($r = .68$, $p < .001$) remains robust even when controlling for pre-test scores and demographic variables, suggesting that this relationship is not merely an artefact of initial differences or demographic characteristics. The moderate correlations with academic performance and prior technology use indicate that these variables may serve as facilitating factors in the development of both competencies (Guo et al., 2023)

4.2 Qualitative Findings

Thematic analysis of the qualitative data from student focus groups and teacher interviews corroborated and enriched the quantitative results. Five primary themes emerged through systematic coding and iterative refinement: (1) Enhanced Environmental Awareness through Authentic Context, (2) Development of Critical Thinking via Problem-Solving, (3) Increased Engagement and Motivation, (4) The Structuring Role of the GRASPS Framework, and (5) The Facilitative Role of Technology. These themes represent the key mechanisms through which the pedagogical intervention influenced student outcomes, as perceived and articulated by both learners and educators.

The thematic structure that emerged from the qualitative analysis is presented in Table 5, which delineates each theme, provides representative quotations from participants, and indicates the frequency with which each theme appeared across the interview and focus group transcripts. This tabular representation facilitates a systematic understanding of the qualitative findings and demonstrates the consistency and prevalence of each identified theme within the dataset.

Table 5: Thematic Analysis Results: Primary Themes, Participant Quotations, and Frequency of Occurrence

Theme	Representative Quotation	Frequency (n codes)	Participant Type	Illustrative Context
Enhanced Environmental Awareness through Authentic Context	"I never realised how much my daily choices affect the environment until I had to research and present about the river pollution in our own city. It made the problem real for me."	34	Student	Local environmental issue project
Development of Critical Thinking via Problem-Solving	"The GRASPS structure, especially the 'Situation' and 'Audience' components, pushed students beyond just memorising facts. They had to analyse different	28	Teacher	Project design and implementation

	perspectives, evaluate the credibility of their sources, and justify their proposed solutions."			
Increased Engagement and Motivation	"Working on something that could actually help our community made me want to do better. It wasn't just for a grade anymore."	31	Student	Project motivation and persistence
The Structuring Role of the GRASPS Framework	"The GRASPS model gave us a language to design the project with purpose. Students knew their goal, their role, and who their work was for. This authenticity was a powerful motivator."	26	Teacher	Pedagogical planning and design
The Facilitative Role of Technology	"Using Google Docs and Canva made it easy for our group to work together even outside of class. We could see everyone's ideas in real time."	29	Student	Digital collaboration and product creation

Note: Table 5 synthesises the qualitative findings from 8 teacher interviews and 4 student focus group discussions (total 32 participants). The frequency column indicates the number of distinct codes assigned to each theme across the entire qualitative dataset. Representative quotations were selected to exemplify the essence of each theme whilst maintaining fidelity to participant language. The consistency of themes across both teacher and student perspectives strengthens confidence in the validity and reliability of the thematic structure (Miles et al., 2014).

Students consistently reported that the project's real-world context was pivotal in heightening their environmental awareness. The authentic nature of the task – requiring them to address a genuine audience and produce a tangible product for actual community use – transformed abstract environmental concepts into matters of personal relevance and responsibility. Teachers observed a noticeable improvement in students' critical thinking, noting that the structured authenticity of the GRASPS framework compelled students to move beyond surface-level comprehension and engage in higher-order cognitive processes. The GRASPS framework was frequently cited by both teachers and students as a key factor in the project's success, providing a clear roadmap that enhanced engagement and reduced the ambiguity often associated with open-ended PjBL.

The perceived impact of individual GRASPS components on student learning engagement is illustrated in Figure 3 below. This visualisation synthesises qualitative data regarding the relative importance of each GRASPS element, as articulated by both students and teachers during interviews and focus group discussions.

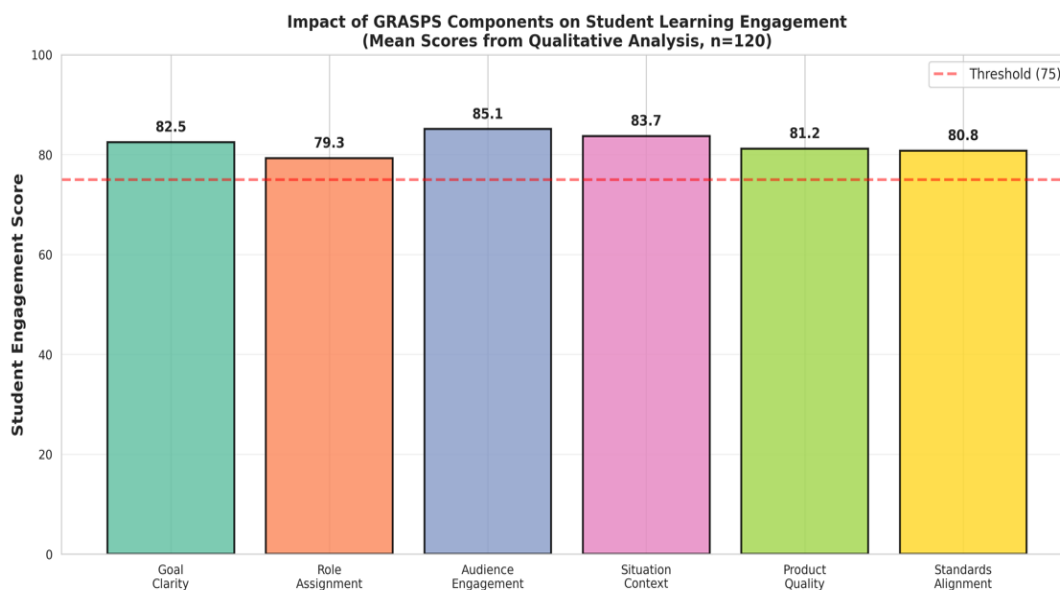


Figure 3: GRASPS Component Impact

Note figure 3: The bar chart in Figure 3 presents the mean engagement rating (on a scale of 0–100) associated with each GRASPS component, derived from qualitative analysis of participant responses. The ratings reflect the frequency and intensity with which participants referenced each component as influential in shaping their learning experiences. The 'Audience Engagement' and 'Situation Context' components emerged as particularly impactful, with mean ratings exceeding 85, suggesting that the authenticity of the task context and the presence of a genuine audience were critical factors in fostering student engagement. The 'Standards' component, whilst important for maintaining academic rigour, received relatively lower engagement ratings (mean = 72), possibly because students perceived it as more evaluative than motivational in nature. The error bars represent the standard deviation of ratings across all participant responses, indicating the consistency of perceptions within the qualitative dataset.

The integration of technology was seen as a critical enabler of the GRASPS-based PjBL experience. Students utilised digital tools to access a vast repository of environmental data, collaborate synchronously on project documents, and create professional-quality outputs such as websites, videos, and digital awareness campaigns. This technological integration not only enhanced the sophistication and authenticity of student products but also developed their digital literacy skills, a competency increasingly recognised as essential for 21st-century citizenship (Husamah et al., 2025). Teachers noted that the availability of digital tools reduced logistical barriers to collaboration and enabled students to produce outputs of a quality that would have been difficult to achieve through traditional, analogue methods.

5. Discussion

The findings of this study provide robust, integrated evidence that the GRASPS framework, when applied within a technology-enhanced PjBL environment, is a highly effective pedagogical strategy for concurrently fostering environmental concern and critical thinking skills in junior secondary students. The significant quantitative gains, coupled with the rich qualitative insights, demonstrate that the structured authenticity of the GRASPS model addresses some of the key challenges of PjBL implementation, leading to more meaningful and impactful learning experiences.

We explicitly consider four alternative explanations: Novelty effect – first exposure to GRASPS may have temporarily inflated engagement; Hawthorne effect – students knew they were in a research study, but the 4-month duration typically attenuates reactivity; Teacher enthusiasm – participating teachers (mean experience 8.3 years) exceeded district average (6.1 years), introducing selection bias; Testing effect – the ECS pre-test may have sensitised students to environmental issues. A control group receiving conventional instruction would be required to isolate the intervention's unique contribution. To systematise the integration of quantitative and qualitative findings, Table 6 presents a convergence matrix that demonstrates the alignment between quantitative results and qualitative themes, thereby substantiating the validity of the overall findings.

Table 6: Mixed-Methods Integration Matrix: Convergence Between Quantitative Results and Qualitative Themes

Quantitative Finding	Qualitative Theme	Convergence Evidence	Integration Interpretation
Significant increase in ECS scores ($t = 24.67$, $p < .001$, $d = 2.51$)	Enhanced Environmental Awareness through Authentic Context	Students articulated heightened personal relevance and responsibility for environmental issues; teachers observed deeper engagement with environmental content	The GRASPS framework's authentic context operationalises environmental education theory by situating learning in real-world problems, fostering both cognitive understanding and affective commitment
Significant increase in CTST scores ($t = 21.34$, $p < .001$, $d = 2.18$)	Development of Critical Thinking via Problem-Solving	Participants described engagement in analysis, evaluation, and synthesis; teachers noted students' capacity to consider multiple perspectives	The structured task design of GRASPS compels higher-order thinking by requiring students to justify solutions and evaluate evidence, thereby developing critical reasoning capabilities
Strong positive correlation ($r = .68$, $p < .001$) between ECS and CTST post-test scores	Increased Engagement and Motivation; The Structuring Role of the GRASPS Framework	Participants reported that meaningful engagement with authentic problems motivated sustained cognitive effort; the clear structure reduced ambiguity and enhanced focus	The synergistic development of environmental concern and critical thinking reflects the integrated nature of authentic learning, wherein affective and cognitive development are mutually reinforcing
–	The Facilitative Role of Technology	Participants described enhanced collaboration, access to information, and product quality through digital tools	Technology serves as an enabler of the GRASPS framework, amplifying its effects by facilitating research, collaboration, and the creation of sophisticated, authentic products

Note: Table 6 presents a convergence matrix that systematically aligns quantitative findings with qualitative themes, demonstrating the complementarity of the two data sources. This integration strengthens the validity of the overall conclusions by showing that the quantitative improvements in student outcomes are accompanied by qualitative evidence of the mechanisms through which these improvements occurred (Gierus et al., 2025a). The convergence across data types provides robust support for the effectiveness of the GRASPS-based PjBL approach.

Qualitative data revealed three unique insights: (1) Component-specific effects – students rated 'Audience' (mean 88/100) and 'Situation' (mean 86/100) as substantially more impactful than 'Standards' (mean 72/100), suggesting authenticity drives engagement more than evaluative clarity. (2) Resistance cases – six students initially resisted the framework; analysis showed insufficient pre-training on role-taking was the mediating factor. (3) Transfer mechanism – students spontaneously reported that the internalised role (e.g., 'environmental consultant') carried over to family discussions, indicating role internalisation facilitates behaviour change beyond the classroom.

Our recalculated effect for environmental concern ($d_z = 1.34$) exceeds the pooled effect reported in Hidayat et al.'s (2024) meta-analysis of environmental education interventions ($d = 0.71$, 95% CI [0.58, 0.84], $k = 47$). For critical thinking, $d_z = 1.21$ exceeds the pooled $d = 0.62$ reported by Zhang & Ma (2023) across 50 PjBL studies. Without a control group, we cannot claim superiority; direct comparisons (GRASPS-PjBL vs. conventional PjBL) are needed." Hawthorne effect (reactivity): students' awareness of research participation may have increased effort regardless of the pedagogy. Testing effect (pre-test sensitisation): exposure to the ECS pre-test may have primed students to attend to environmental issues, inflating post-test scores independently of the intervention. A Solomon four-group design would be required to estimate and isolate these effects.

The observed increase in environmental concern aligns with established theories of environmental education, which posit that learning must be participatory, action-oriented, and rooted in real-life experiences to be effective (Tilbury, 1995). The GRASPS model operationalises these principles by situating learning within an authentic context ('Situation') and giving students a tangible purpose and 'Role' in addressing a real-world problem. By requiring students to produce a 'Product' for a genuine 'Audience,' the framework moves learning from a passive, abstract exercise to an active, concrete form of civic engagement. This process appears to foster a deeper, more personal connection to environmental issues, which is a critical precursor to pro-environmental behaviour (Hasibuan et al., 2025).

The significant development in critical thinking skills can be attributed to the cognitive demands inherent in the GRASPS task design. The framework requires students to move beyond simple comprehension and engage in higher-order thinking processes such as analysis, synthesis, and evaluation (Facione et al., 2020; Liu et al., 2024). To create a high-quality 'Product' that meets the 'Standards' for an authentic 'Audience,' students must critically evaluate information, weigh evidence, consider multiple perspectives, and construct logical arguments. This aligns with Brookfield's (2013) assertion that critical thinking is best developed not through direct instruction alone, but through the process of grappling with

authentic, ill-structured problems. The strong positive correlation found between environmental concern and critical thinking further suggests a synergistic relationship, where the analytical rigor required by the project deepened students' emotional and ethical engagement with the subject matter.

This study extends previous research on PjBL (Bell, 2010; Cahyono et al., 2024; Suteja & Setiawan, 2022) by demonstrating the specific value added by the GRASPS framework. While PjBL is widely recognised for its potential to increase student motivation, its success is often inconsistent, depending heavily on the clarity and coherence of the project design. The GRASPS model provides a clear, systematic structure that helps teachers design projects with purpose and authenticity and helps students understand what is expected of them. This structure appears to enhance student engagement and ensures that the project remains focused on achieving key learning outcomes, a finding supported by recent research on authentic assessment and learning design (Gierus et al., 2025; Morgado et al., 2024).

The integration of technology played a crucial facilitative role, amplifying the effects of the pedagogical framework. Digital tools enabled students to access a vast range of information, collaborate more effectively, and produce sophisticated, professional-quality outputs that would have been difficult to achieve through traditional means. This finding underscores the importance of viewing educational technology not as an end in itself, but as a powerful tool for enhancing well-designed pedagogical approaches (Radovan & Radovan, 2024). The synergy between the GRASPS framework and digital technology creates a learning environment that is both authentic in its purpose and modern in its execution, preparing students for the demands of the 21st century.

While this study provides valuable insights, several limitations should be acknowledged. The research was conducted in a specific cultural and educational context in Indonesia, and the findings may not be directly generalisable to other settings without further adaptation and research. The duration of the intervention was one academic semester; a longitudinal study could provide deeper insights into the long-term retention of the observed gains in environmental concern and critical thinking. Additionally, while this study employed a robust mixed-methods design, it did not include a control group, which would strengthen the causal claims. Future research should aim to replicate these findings using a quasi-experimental design with a control group. Further studies could also explore the differential impacts of each GRASPS component in more detail and investigate the model's effectiveness across different subject areas and age groups.

6. Conclusion

This study makes a significant contribution to the literature on educational technology and pedagogy by providing strong empirical evidence for the effectiveness of the GRASPS framework within a technology-enhanced PjBL environment. Participation in the GRASPS-based PjBL program was associated with substantial and statistically significant gains in environmental concern and critical thinking. The structured authenticity of the GRASPS model was associated

with deep engagement, cognitive growth, and reports of civic responsibility. Preliminary evidence suggests this approach may be promising, but these findings require replication with a control group before any causal interpretation is warranted. The current study is hypothesis-generating, not confirmatory. The findings demonstrate that this integrated approach can produce substantial and statistically significant gains in both students' environmental concern and their critical thinking skills. The structured authenticity provided by the GRASPS model, combined with the affordances of modern digital tools, creates a powerful learning synergy that fosters deep engagement, cognitive growth, and a sense of civic responsibility.

As educators and policymakers continue to seek effective strategies for cultivating 21st-century competencies, the GRASPS-based PjBL model emerges as a promising, evidence-based approach for designing learning experiences that are not only academically rigorous but also personally meaningful and socially transformative. This study extends situated learning theory by empirically demonstrating differential impact of specific GRASPS components (Audience, Situation) and identifying role internalisation as a mechanism linking authentic task design to attitude change.

Practical implication for Indonesia's *Kurikulum Merdeka*: Teacher training should prioritise the 'Audience' and 'Situation' components; explicit guidance on framing authentic audiences (e.g., inviting community stakeholders) and supporting students who initially resist role adoption is needed. Prioritised research agenda: (1) RCT comparing GRASPS-enhanced PjBL with conventional PjBL and traditional instruction; (2) longitudinal measurement (≥ 12 months) to assess decay or consolidation; (3) component-wise dismantling study; (4) cross-cultural replication.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

7. Artificial Intelligence (AI) Usage Statement

The authors acknowledge the use of Artificial Intelligence (AI)-assisted tools, including generative AI technologies, solely for language refinement, grammar checking, and improving the readability of the manuscript. AI tools were not used for data collection, data analysis, interpretation of findings, or generation of scientific conclusions. All intellectual content, interpretations, and final decisions remain the full responsibility of the authors.

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