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The Impact of Project-Based Learning in a Metaverse Setting on Programming Performance and Attitudes among Malaysian Secondary Students

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ABSTRACT: Learning computer programming is often perceived as a challenging task for secondary students, leading to low achievement and negative attitudes. This research examines the influence of Project-Based Learning (PBL) when combined with a metaverse platform on students' performance, retention, and attitudes toward programming. Guided by Bruner's Cognitive Learning Theory, the study employed a quasi-experimental design involving 60 Form Four students from two urban schools in Kedah. Thirty students were placed in the experimental group and taught using metaverse-based PBL, while another thirty received conventional instruction. The assessment tools consisted of a Programming Achievement Test aligned with the national curriculum and a modified Computer Science Attitude Survey (CSAS). Results from independent-samples t-tests showed significant differences favoring the experimental group in programming achievement ($t(58) = -4.77$, $p < .01$), retention of knowledge ($t(58) = -5.86$, $p < .01$), and positive attitudes toward programming ($t(58) = -3.83$, $p < .01$). No significant differences were observed for attitude retention. Overall, the findings demonstrate that PBL integrated with metaverse technologies can promote creativity, engagement, and deeper conceptual understanding. Recommendations are provided for teachers and policymakers to leverage immersive tools in cultivating 21st-century skills.

INTRODUCTION

Computer programming has increasingly become an essential subject in secondary and tertiary education, yet it remains one of the most difficult areas for students to master (Hwang et al., 2012; Kose & Kose, 2012). The complexity of abstract logic, coding syntax, and debugging often leads to frustration, low performance, and in some cases, dropout (Gálvez et al., 2009; Tuparov et al., 2012). Traditional instruction, while structured, is often insufficient to sustain interest and meet the needs of diverse learners (El Galad et al., 2024). Project-Based Learning (PBL) provides a student-centered alternative that emphasizes inquiry, teamwork, and the development of tangible products (Thomas, 2000). Research highlights its effectiveness in improving engagement, collaboration, and problem-solving in STEM fields (Kokotsaki et al., 2016). Meanwhile, the emergence of the metaverse an immersive 3D virtual environment offers new opportunities to enhance interactive learning and contextualize abstract concepts (Duan et al., 2021; Jaaffar & Adnan, 2025). Despite this potential, little empirical work has

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been done to evaluate PBL integrated with metaverse applications in Malaysian secondary programming classrooms. This study addresses that gap by exploring the effects of metaverse-based PBL on students' achievement, retention, and attitudes. The research is underpinned by Bruner's (1966) theory of cognitive development, which emphasizes progression through enactive, iconic, and symbolic modes of representation. These stages align well with programming pedagogy, particularly when learning is scaffolded through immersive environments.

BACKGROUND OF STUDY

Computer programming is widely perceived as one of the more demanding subjects in secondary education because it requires learners to apply abstract reasoning, logical thinking, and structured problem-solving. Many students face difficulties in grasping these fundamental skills, which often results in poor performance, low motivation, and negative perceptions of the subject (Hwang et al., 2012; Gálvez et al., 2009). In the Malaysian context, similar concerns have been highlighted, where teachers report challenges such as inadequate resources, insufficient training, and varying student readiness in delivering computer science lessons (Abdul Razak et al., 2024). To overcome these issues, Project-Based Learning (PBL) has emerged as an alternative approach that emphasizes active participation, collaboration and problem-solving through real-world tasks. Despite the growing emphasis on computer programming in secondary education, many students continue to demonstrate low achievement, weak conceptual understanding and negative attitudes toward programming. The abstract and logic-intensive nature of programming, often taught through conventional lecture-based approaches, limits student engagement and meaningful learning, resulting in frustration and poor performance (Hwang et al., 2012; Gálvez et al., 2009). In Malaysia, these challenges are further exacerbated by limited instructional resources, insufficient teacher preparedness and diverse levels of student readiness (Abdul Razak et al., 2024). Although Project-Based Learning (PBL) is promoted as a student-centred approach to enhance engagement and problem-solving skills, its effectiveness depends heavily on instructional design and implementation (Thomas, 2000; Kokotsaki et al., 2016). Recent advances in immersive technologies, particularly metaverse environments, offer promising opportunities to support interactive and contextualised learning (Duan et al., 2021; Jaaffar & Adnan, 2025). However, empirical evidence on the effectiveness of integrating PBL with metaverse-based learning in Malaysian secondary education remains limited. Research conducted in Malaysia indicates that PBL enhances student engagement and achievement Che Isa and Azid (2021), aligning with international findings that link PBL with creativity, motivation and deeper conceptual understanding (Thomas, 2000; Kokotsaki et al., 2016). Meanwhile, the rise of the metaverse as an immersive digital platform offers further opportunities for creating interactive and meaningful learning experiences, enabling students to engage with content and peers in authentic virtual environments (Duan et al., 2021; Hong & Kanaparan, 2024). Although these innovations show promise, there is still a lack of empirical studies exploring the integration of PBL with metaverse technologies in Malaysian secondary programming education. This study aims to address this gap by investigating their combined impact on students' programming achievement, retention, and attitudes.

RESEARCH METHODOLOGY

The research employed a quasi-experimental design involving two intact Form Four classes from different schools. This approach minimized potential cross-group contamination while allowing pretest, posttest, and retention comparisons between groups.

Participants

The total of participants in this study are 60 students were included, divided evenly between the experimental (metaverse-PBL) and control (conventional instruction) groups. Both groups were similar in demographic profiles and prior academic ability. The students were selected based on their Classroom Assessment (Pentaksiran Bilik Darjah, PBD) scores, whereby those who obtained performance levels below Level 5 were identified as respondents. All student-related information and assessment data were obtained through the Assessment Unit of the State Education Department.

Instruments

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This study utilized two instruments. The first was the Programming Achievement Test, which included fifteen questions developed in line with the Form Four DSKP curriculum and verified by three Computer Science experts. The questions were distributed across three levels of difficulty, namely basic, intermediate, and advanced. The second instrument was the Computer Science Attitude Survey (CSAS), consisting of fifty-seven items designed to measure five domains: confidence, motivation, perceived usefulness, attitudes toward success, and gender-related perceptions. The survey was adapted, translated, and validated through expert evaluation. A pilot study involving 30 students produced Cronbach's alpha values exceeding .70, confirming that both instruments demonstrated strong reliability and internal consistency.

Procedures

The research was carried out across a period of seven weeks and followed a structured sequence of activities. In the first week, both the experimental and control groups were given pretests, which consisted of a programming achievement test and an attitude survey. These assessments were designed to establish baseline levels of knowledge and attitudes prior to the intervention. From the second to the fifth week, the intervention was implemented. Students in the experimental group participated in project-based learning (PBL) activities integrated with the metaverse platform, where they engaged in collaborative projects and problem-solving tasks within an immersive virtual environment. At the same time, the control group continued with conventional instruction that relied mainly on lecture-based teaching methods and traditional exercises. In the sixth week, both groups were reassessed using posttests to measure immediate gains in programming achievement and changes in attitudes toward computer science. Finally, in the seventh week, retention tests were administered to evaluate the extent to which students maintained their knowledge and attitudes after the intervention.

Data Analysis

Data were analyzed using SPSS v29. The Kolmogorov-Smirnov test and Levene's test confirmed assumptions of normality and homogeneity. Independent-samples t-tests were run to compare posttest and retention scores.

RESEARCH FINDINGS

The findings revealed that the experimental group achieved significantly higher scores in programming compared to the control group, $t(58) = -4.77$, $p < .01$. Similarly, their attitudes toward programming improved considerably after the intervention, $t(58) = -3.83$, $p < .01$. In terms of knowledge retention, the experimental group was able to sustain their learning more effectively than the control group, $t(58) = -5.86$, $p < .01$. However, no significant difference was found between the groups in attitude retention, as both showed only slight improvements when they returned to conventional instruction.

DISCUSSION

The findings confirm that combining PBL with metaverse environments significantly improves learning outcomes in programming. The positive effects on achievement and retention align with research showing that immersive learning supports knowledge transfer and long-term memory (Moreno, 2012; Duan et al., 2021). Short-term improvements in attitudes support the claim that PBL enhances motivation and engagement (Kokotsaki et al., 2016; Jaaffar & Adnan, 2025). However, the lack of sustained attitude differences suggests that without continuous innovative practices, motivational gains diminish once conventional methods resume. Similar observations were made by Hew and Cheung (2014), who reported that student enthusiasm declines if innovative pedagogy is not maintained consistently. Theoretically, this study supports Bruner's (1966) model of representation, where the metaverse provided concrete and visual stages (enactive and iconic) before transitioning to symbolic coding activities (Hong & Kanaparan, 2024). Practically, these results highlight the value of immersive digital tools in cultivating 21st-century competencies such as collaboration, creativity, and critical thinking skills emphasized in Malaysia's educational transformation.

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CONCLUSION

This research provides empirical evidence that PBL, when delivered in a metaverse environment, can significantly enhance programming achievement, retention, and short-term attitudes among secondary students. While findings confirm the pedagogical potential of the metaverse, sustaining motivation requires ongoing innovation beyond isolated interventions. This study demonstrates that integrating Project-Based Learning (PBL) within a metaverse environment significantly enhances secondary students' programming achievement, knowledge retention, and short-term attitudes toward programming. By embedding learning in immersive and collaborative virtual contexts, metaverse-based PBL supports deeper conceptual understanding and sustained cognitive engagement, consistent with prior research highlighting the effectiveness of PBL and immersive technologies in complex STEM learning (Thomas, 2000; Kokotsaki et al., 2016; Duan et al., 2021; Jaaffar & Adnan, 2025). The findings also align with Bruner's (1966) Cognitive Learning Theory, where learning progresses from concrete and visual representations to symbolic abstraction an instructional sequence well supported by metaverse affordances in programming education (Hong & Kanaparan, 2024). However, the absence of significant differences in attitude retention indicates that motivational benefits may diminish when innovative pedagogies are discontinued, reinforcing evidence that sustained instructional innovation is essential for long-term affective outcomes (Hew & Cheung, 2014). Educational policymakers and curriculum developers should consider incorporating metaverse-supported PBL into national instructional guidelines, teacher professional development programs, and digital infrastructure planning to better align programming education with 21st-century skill demands. Future research should extend retention periods, employ randomized designs and integrate qualitative insights to inform scalable and sustainable policy-driven implementation of immersive learning in secondary education.

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