e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities

ISSN: 1823-884x
Volume 23, Issue 2, DOI: https://doi.org/10.17576/ebangi.2026.2302.09

Original Research Article

Digitally-Gamified Learning for Water Sustainability: Investigating Knowledge and Attitude Links among Urban Malaysian Learners

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Received: 22 November 2025 / Accepted: 18 May 2026

Abstract. Urban water challenges in Malaysia highlight the urgent need to strengthen water literacy, including knowledge, attitudes, and behaviours necessary for sustainable water use. Although digital gamification has been widely promoted as an effective instructional strategy for sustainability education, its ability to connect cognitive gains with attitudinal change remains theoretically uncertain, particularly within Southeast Asian urban contexts shaped by diverse social norms and everyday water practices. This study investigates whether improvements in students' water-related knowledge correspond with changes in attitude following a digitally gamified learning intervention. Using a quasi-experimental design, Pearson correlation analysis was conducted on post-test data from a treatment group exposed to a gamified digital module and a control group receiving conventional instruction. Findings revealed a very weak and non-significant positive relationship between post-test knowledge and attitude in the treatment group ($r = .165$, $p = .375$), with a similarly weak association identified in the control group ($r = .184$, $p = .314$). Despite significant improvements in both knowledge and attitude at the group level, no meaningful individual-level alignment between cognition and affect was observed. These findings challenge linear Knowledge–Attitude assumptions commonly embedded in environmental education and suggest that gamified learning does not automatically bridge understanding with value-based orientation. The study highlights the importance of integrating emotional engagement, reflective learning, and culturally grounded experiences within sustainability education to support deeper attitudinal transformation.

Keywords Environmental education, water literacy; digital gamification; sustainability education; knowledge–attitude relationship

Introduction

The Urban water challenges are intensifying globally due to urbanisation, ageing infrastructure, climate variability, and fragmented governance systems (Santiago et al., 2024; Koop & Leeuwen, 2017). Malaysia is no exception. Cities like Kuala Lumpur and Johor Bahru continue to face persistent issues, including high non-revenue water losses, limited public awareness, and unsustainable water use behaviours (Luo, 2025; Keriwala & Patel, 2022). However, many responses to urban water stress continue to prioritize technical and infrastructural solutions, while the human dimension, particularly how citizens perceive, value, and prioritize water, receives comparatively less attention. This suggests that urban water sustainability is not only a matter of supply and management, but also one of learning processes and cultural change.

Water literacy, an integration of knowledge, attitudes, and behaviours related to water usage and conservation, is increasingly recognised as a foundational component of sustainability (Kang, 2022; Schneiderhan-Opel & Bogner, 2021). Knowledge is fundamental in developing sustainable water literacy because it provides students with scientific understanding related to water resources, pollution, conservation, and the hydrological cycle. Studies have shown that students with higher knowledge levels are generally more willing to participate in water conservation activities (Xu et al., 2019). However, environmental education

scholars have consistently argued that knowledge alone does not automatically lead to behavioural or attitudinal change due to the existence of the "knowledge–action gap" (Kollmuss & Agyeman, 2002). Although positive attitudes may strengthen the translation of knowledge into sustainable practices (Bilancini et al., 2023; Fatimah et al., 2023), pro-environmental outcomes are often influenced by broader psycho-social and emotional factors beyond cognition alone (Bamberg & Möser, 2007; Pooley & O'Connor, 2000). Consequently, despite growing attention to the relationship between knowledge and attitude in sustainability education, few studies have critically examined how these domains interact within digitally gamified water literacy contexts, particularly among urban secondary school students in Southeast Asia.

Digital gamification, involving the use of game-based mechanics such as rewards, feedback, and storytelling in non-game settings, has emerged as a potentially engaging approach to environmental education (Boncu et al., 2022; Hamdan & Arufe-Giráldez, 2023). Among younger learners, gamified platforms have been linked to increased motivation and engagement, and in some cases, positive shifts in attitude (Janakiraman et al., 2021; Bootsma & Ciocarlan, 2023). However, the broader gamification literature cautions that effectiveness is highly context-dependent and that positive outcomes do not generalise consistently across learning settings, targeted outcomes, or learner groups (Hamari et al., 2014). Furthermore, gamified systems may increase short-term engagement through extrinsic incentives without necessarily fostering intrinsic commitment or value-based endorsement of sustainability goals (Seaborn & Fels, 2015). At the level of specific gamification elements, empirical evidence suggests that mechanisms such as points, badges, and leaderboards can enhance performance while leaving intrinsic motivation largely unchanged, indicating a potential separation between behavioural success and deeper personal concern (Mekler et al., 2017). Taken together, these findings indicate that while gamification can support participation and learning performance, it should not be assumed to reliably connect cognitive gains with affective or value-based change through design alone.

Empirical findings on this issue remain inconclusive. While several studies report parallel improvements in knowledge and attitudes, others demonstrate weak or non-significant associations between these domains (Rosmalah et al., 2023; Miao et al., 2022). In addition, much of the existing evidence is grounded in Western educational contexts, with comparatively limited empirical work emerging from Southeast Asia. This limitation is significant because water literacy in Southeast Asia is shaped by distinct socio-hydrological conditions, governance structures, and everyday water practices that influence how learners understand sustainability as a lived experience rather than a purely instructional concept (Maniam et al., 2021). In the Malaysian context, national water literacy initiatives and public engagement efforts further suggest that contextual factors actively shape the formation and stabilisation of attitudes, rather than serving merely as a background condition (Maniam et al., 2024). Among Malaysian urban youth, who are simultaneously digitally literate and environmentally vulnerable, it remains unclear whether gamified learning approaches can effectively link cognitive understanding with sustained attitudinal change (Nalumenya et al., 2024; Keriwala & Patel, 2022). Taken together, treating Malaysia and Southeast Asia as analytically consequential rather than as neutral settings strengthens the case for examining how cognitive and affective dimensions align under gamified instructional designs.

This study addresses the identified gap by examining the effects of a gamified digital module on water literacy among urban Malaysian secondary school students. Rather than presuming a direct or strong relationship between knowledge and attitude, the study adopts an exploratory stance that considers the mediating roles of contextual, cultural, and emotional factors in shaping learning outcomes. Specifically, the article challenges cognitively centred assumptions commonly associated with digital gamification by examining whether post-intervention gains in knowledge correspond with attitudinal shifts at the individual level, rather than relying solely on group-mean effects. In doing so, the study seeks to generate locally grounded insights that can inform both educational policy and instructional design for environmental sustainability. While gamification may enrich environmental learning experiences, its capacity to connect cognitive understanding with attitudinal change remains complex and context dependent, underscoring the need for a deeper examination of how these domains interact in the development of meaningful and transformative sustainability education interventions. Rather than testing whether gamification simply

'works', this study interrogates a more fundamental question: whether gamified learning meaningfully aligns cognitive gains with affective orientation in sustainability education.

Methodology

This study adopted a quasi-experimental design with a non-equivalent pre-test–post-test control group to investigate the relationship between students' water-related knowledge and attitudes and to evaluate the impact of a digitally gamified instructional approach on these outcomes. This design is appropriate for authentic school contexts where random assignment at the student level is not feasible, while still allowing structured comparison between intervention and non-intervention groups. To clarify the limits of causal inference inherent in quasi-experiments, the design is treated as evaluative and exploratory rather than fully causal (Shadish et al., 2002)**.** Overall, the research design supports credible group comparison while remaining transparent about causal limits.

Participants and Sampling

A total of 63 Form 1 students from two urban secondary schools in Sarawak, Malaysia, participated in the study. Schools were selected through purposive sampling based on three criteria: (1) the "Water Resources" topic had not yet been taught in the Geography curriculum; (2) availability of functioning computer labs with reliable internet access; and (3) teacher readiness to deliver the planned instruction. Two eligible schools were then assigned to either the treatment group (n = 31) or the control group (n = 32), thereby reducing the risk of cross-group contamination and facilitating practical implementation. Overall, the sampling and grouping strategy prioritised ecological validity while maintaining reasonable comparability between groups.

Instrumentation

Data were collected using a structured questionnaire adapted from Maniam et al. (2024) and Sözcü and Türker (2020) to measure two constructs: water-related knowledge and attitude. The knowledge component consisted of 20 multiple-choice items covering water cycles, conservation practices, and sustainable usage, while the attitude component contained 15 Likert-scale items measuring perceptions, values, and emotional orientations toward water conservation. The instrument underwent expert review and pilot testing, with Cronbach's alpha values of 0.820 (knowledge) and 0.805 (attitude), indicating acceptable internal consistency for research use. To strengthen reporting transparency, internal consistency is interpreted as reliability (not validity) in line with standard measurement guidance (Tavakol & Dennick, 2011)**.** Overall, the measurement approach supports stable construct assessment suitable for comparative and correlational analysis.

Gamified Module and Instructional Design

The intervention module, *Water Warriors: Save the World*, was developed following the ADDIE instructional design model (Branch, 2022). The module integrates interactive storytelling, mission-based tasks, and collaborative problem-solving activities delivered through Minecraft Education Edition. Following pilot refinement, the module was implemented over eight weeks. The treatment group engaged in weekly 90-minute sessions facilitated by trained teachers using the gamified module, whereas the control group received conventional instruction (lecture and textbook-based activities) covering equivalent content and duration without gamification features. Overall, the instructional design ensured content equivalence across groups while isolating the delivery approach as the primary difference.

Module Validation

Prior to its classroom implementation, the Water Warriors: Save the World module underwent a comprehensive validation process to ensure alignment with both pedagogical principles and technical requirements. A diverse panel of nine experts, specialising in pedagogy, human–computer interaction, gamification, water resource education, and multimedia design, was convened to evaluate the module from

multiple disciplinary perspectives. This cross-disciplinary review enabled a thorough appraisal encompassing content relevance, instructional effectiveness, and system functionality.

A structured rubric was used for evaluation, applying a 7-point Likert scale across four core dimensions: technical robustness, interface usability, multimedia integration, and instructional interactivity. These categories were deliberately chosen as they represent key indicators of quality in digital gamified learning environments, particularly in terms of usability, learner engagement, and educational alignment. The assessment results were interpreted using a standard scale as presented in Table 1.

Table 1. Interpretation of Mean Score

Mean Score	Interpretation
5.81 – 7.00	Very High
4.61 – 5.80	High
3.41 – 4.60	Moderate
2.21 – 3.40	Low
1.00 – 2.20	Very Low

The validation outcomes indicated uniformly strong levels of approval across all evaluation criteria. The average technical quality score was 6.6, while user interface design and multimedia integration each had a mean of 6.7. Instructional interactivity scored slightly higher at 6.8. These results placed the module within the "very high" category on the evaluation scale (5.81–7.00), demonstrating its effectiveness in balancing instructional value with engaging digital design. Furthermore, qualitative comments from the review panel underscored the module's strength in embedding curriculum-aligned content within interactive, real-world learning experiences that foster hands-on engagement. These favourable findings validated the module's readiness for classroom deployment and simultaneously informed several minor refinements. The final version thus achieved both curricular relevance and adaptability to students' digital learning preferences, reinforcing its potential as a robust and transferable framework for water literacy education.

Implementation in Treatment and Control Groups

Following validation by subject-matter experts, the Water Warriors: Save the World module was implemented in an authentic classroom environment with both treatment and control groups. Although both groups covered the same Form 1 Geography topic, the instructional approach differed markedly. The treatment group engaged with a digitally gamified module delivered through Minecraft Education Edition, incorporating scenario-based simulations, mission-driven tasks, and collaborative digital challenges that visualised real hydrological processes. In contrast, the control group received conventional instruction through lectures, textbook exercises, and teacher-led discussions.

To maintain internal validity, both groups received equal instructional time, equivalent content coverage, and identical learning outcomes. Thus, any differences observed in post-test results may be more plausibly attributed to the instructional approach rather than curriculum exposure, although causal conclusions remain limited by the quasi-experimental design (Shadish et al., 2002). Figures 1 and 2 help contextualise this distinction.

Figure 1 illustrates four purpose-built Minecraft environmental simulations: a toxic waste site, an erosion-and-runoff model, a forested catchment area, and a traditional Iban longhouse. Each simulation is designed to immerse learners in realistic water-related scenarios. These environments allow students to explore pollution pathways, observe erosion processes, understand ecosystem buffering functions, and connect water issues to cultural community contexts, thereby addressing the cognitive, ecological, and socio-cultural dimensions of water literacy.

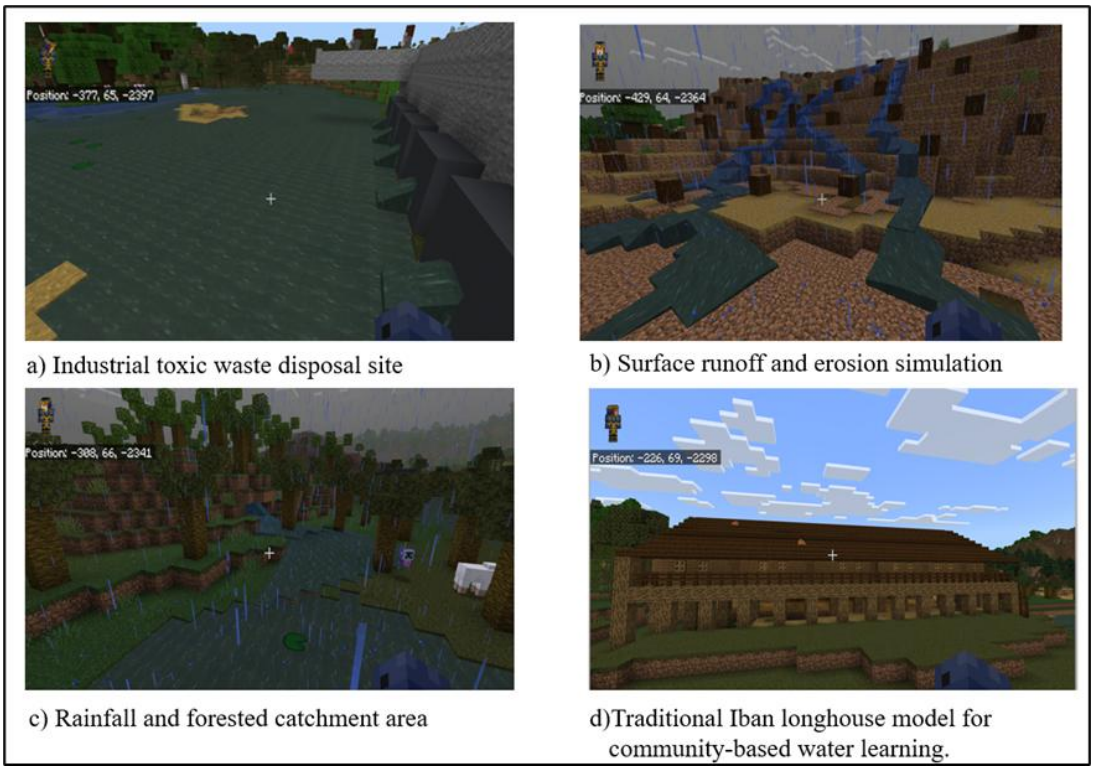

Figure 1. Illustration of Minecraft-based environmental simulations used in the gamified module.

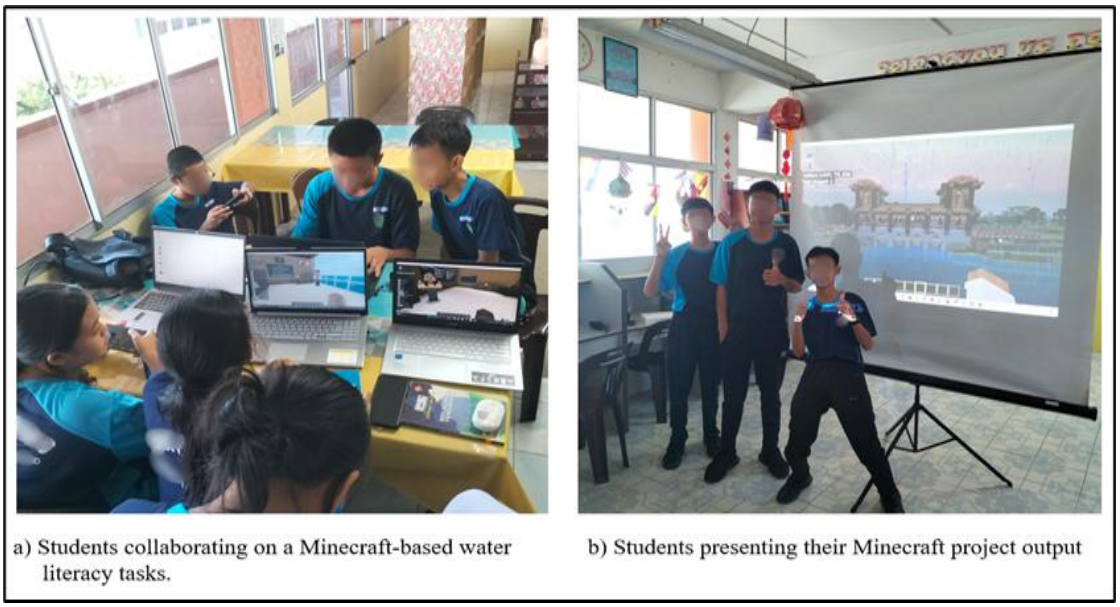

Figure 2. Illustration of students engaging with the Minecraft-based water literacy activities.

Figure 2 illustrates how students interacted with the gamified module during the intervention. The images show learners collaborating around devices, jointly solving environmental challenges, and later presenting their completed outputs to peers. These scenes demonstrate the module's emphasis on teamwork, communication, reflective explanation, and authentic project-based learning. The images also validate the ecological authenticity of the study, as the intervention took place in real classroom conditions using standard school equipment. Overall, the implementation created a learning environment that differed substantially from traditional pedagogy, characterised by immersion, collaboration, and cultural contextualisation, providing a clear basis for interpreting the enhanced learning outcomes observed in the treatment group.

Implementation Fidelity

Implementation fidelity was explicitly considered to strengthen internal validity and reduce the likelihood that outcome differences were driven by delivery variation rather than the intervention itself. Across both groups, instructional time (90 minutes weekly) and topic coverage were kept equivalent. The treatment group followed a fixed module sequence aligned to the module design, while the control group followed conventional instruction aligned to the same learning outcomes. However, formal fidelity checks (e.g., observation checklists, adherence scoring, or structured monitoring logs) were not conducted, so variation in teacher delivery cannot be fully ruled out. Overall, implementation fidelity was maintained through the standardisation of the schedule and content, while remaining limitations are acknowledged when interpreting causal claims.

Data Analysis

Descriptive statistics (means and standard deviations) were computed to summarise pre-test and post-test scores for knowledge and attitude in both groups. Independent samples t-tests were conducted to assess baseline equivalence (pre-test) and post-intervention differences (post-test) between the treatment and control groups. The Pearson correlation coefficient (r) was then computed within each group to examine the strength of association between post-test knowledge and post-test attitude. Pearson correlation was selected because the study aimed to provide an initial, exploratory test of linear association between two continuous variables, consistent with the article's evaluative stance and modest sample size. While the study is theoretically informed by TPB and KAB, more complex modelling (e.g., regression with covariates or mediation analysis) is positioned as a future analytical extension that could better capture non-linear or indirect pathways if supported by larger samples and additional mediators. Overall, the analysis strategy aligns with the study's objective of testing the plausibility of a knowledge–attitude linkage without over-claiming causal mechanisms.

The Findings

Descriptive statistics were first conducted to assess the mean and standard deviation of knowledge and attitude scores for both the control and treatment groups at the pre-test and post-test stages. This initial analysis provided an overview of learners' baseline performance and the changes observed following the intervention. Taken together, these descriptives establish the baseline context needed to determine whether later differences reflect meaningful change rather than initial group differences. To determine whether the two groups were statistically equivalent before the intervention, independent samples t-tests were performed on the pre-test scores.

As shown in Table 2, significant differences in post-test knowledge scores were observed between the two groups following the intervention. The treatment group demonstrated a substantially higher mean score ($M = 15.84$, $SD = 1.16$) than the control group ($M = 13.13$, $SD = 1.41$), with the difference statistically significant, $t(61) = 8.340$, $p < .001$.

Table 2. Independent Samples t-test for pre- and post-test knowledge between two groups

	Control M	**Control SD**	**Treatment M**	**Treatment SD**	**df**	**t**	**p**
Pre-test	11.7188	1.37335	11.3871	1.20215	61	-1.019	0.312
Post-test	13.1250	1.40850	15.8387	1.15749	61	8.340	.000

Table 3 presents the independent samples t-test results for attitude scores. No significant differences were observed during the pre-test stage, indicating comparable baseline attitudes between groups. However, significant differences emerged in the post-test, with the treatment group reporting higher attitude scores ($M = 64.65$, $SD = 2.48$) compared to the control group ($M = 61.16$, $SD = 2.44$), $t(61) = 5.627$, $p < .001$.

Table 3. Independent Samples t-test for pre- and post-test Attitude between two groups

	Control M	Control SD	Treatment M	Treatment SD	df	t	p
Pre-test	57.7500	1.56576	57.6452	2.37414	61	-0.208	0.836
Post-test	61.1563	2.43773	64.6452	2.48393	61	5.627	.000

These findings indicate that the treatment group achieved significantly higher post-test scores in both knowledge and attitude than the control group, suggesting an advantage of the gamified instructional approach in this study context. While the independent t-tests revealed significant differences in post-test knowledge and attitude scores between groups, further analysis examined the relationship between these two variables. Specifically, Pearson correlation analysis was employed to determine whether post-test knowledge was associated with post-test attitudes towards water literacy within each group. Crucially, this correlation test addresses a different question from the t-tests: whether individual-level gains in knowledge align with individual-level attitudinal alignment, as often implied by linear Knowledge–Attitude models.

Table 4 presents the results of the Pearson correlation analysis examining the relationship between post-test knowledge and post-test attitude among participants in the treatment group. A very weak positive correlation was observed ($r = 0.165$; $p = 0.375$). This result is not statistically significant, indicating that the observed association is likely due to chance. Therefore, there is insufficient evidence to conclude that increased knowledge following the intervention is associated with a meaningful change in attitude. By implication, the weak and non-significant association suggests that higher knowledge scores did not systematically co-vary with stronger attitudes at the individual level, despite the group-level improvement observed in the treatment condition.

Table 4. Pearson Correlation Between Knowledge and Attitude in the Treatment Group

Variable		Knowledge	Attitude
Knowledge	Pearson Correlation	1	0.165
	Sig. (2-tailed)		0.375
	N	31	31
Attitude	Pearson Correlation	0.165	1
	Sig. (2-tailed)	0.375	
	N	31	31

Table 5. Pearson Correlation Between Knowledge and Attitude in the Control Group

Variable		Knowledge	Attitude
Knowledge	Pearson Correlation	1	0.184
	Sig. (2-tailed)		0.314
	N	32	32
Attitude	Pearson Correlation	0.184	1
	Sig. (2-tailed)	0.314	
	N	32	32

Similarly, Table 5 displays the correlation results for the control group. A very weak positive correlation was also observed ($r = 0.184$; $p = 0.314$). This result is likewise not statistically significant, suggesting no meaningful relationship between knowledge and attitude among participants who did not receive the intervention. Consistently, the absence of a significant knowledge–attitude association in both

groups strengthens the interpretation that cognitive and affective outcomes are not automatically coupled in this dataset, which is theoretically relevant to debates surrounding linear Knowledge–Attitude–Behaviour assumptions.

Discussion

The results of this study suggest that digital gamification can serve as a viable instructional method for improving students' understanding of water-related issues and their environmental attitudes. The Minecraft-based intervention led to statistically significant gains in both knowledge and attitudinal scores, supporting the educational value of gamified learning environments. These findings align with prior research highlighting the potential of gamification to enhance student engagement and improve learning outcomes (Boncu et al., 2022; Janakiraman et al., 2021). At the same time, the present study contributes conceptually by showing that "improvement in both outcomes" does not necessarily imply a tight knowledge–attitude coupling at the individual level, thereby problematising cognitive-first assumptions often attached to gamified sustainability learning (Hamari et al., 2014). Taken together, the findings position gamification as effective for outcome gains, but not as evidence of a linear cognitive-to-affective pathway.

Nonetheless, the Pearson correlation analysis revealed a weak, non-significant association between knowledge and attitudes, suggesting that the cognitive and affective aspects of learning may not be strongly interconnected. This outcome challenges the notion that increasing environmental knowledge will automatically yield corresponding attitudinal change. Rather, it reinforces arguments in the literature that suggest attitudinal development is often shaped by emotional resonance, contextual appropriateness, and social interaction (Xu et al., 2019; Paolo & Pizziol, 2023). This weak linkage is theoretically meaningful because it mirrors the broader "knowledge–action/attitude gap" argument: information can rise while deeper dispositions remain uneven, mediated by barriers beyond cognition (Kollmuss & Agyeman, 2002). In short, the correlation result is not a null detail; it is central evidence that knowledge and attitude may move on partly independent tracks.

The observed knowledge gains in the treatment group are likely attributable to the gamified module's structured design, which adhered to the ADDIE instructional model. Elements such as scenario-based tasks, immediate feedback, and experiential challenges appeared to enhance students' understanding of key concepts in water conservation and use. Previous studies have shown that immersive, goal-oriented digital environments can significantly aid cognitive retention, particularly when instructional components are clearly aligned with learning goals (Tan, 2023; Bootsma & Ciocarlan, 2023). This interpretation is consistent with evidence that gamification effects are highly context-dependent and often strongest for proximal learning outcomes such as engagement and performance under well-aligned task structures (Hamari et al., 2014). Accordingly, the module's design quality plausibly explains why knowledge increased robustly in the treatment group.

There were also positive shifts in attitudes within the treatment group, suggesting that learners may have internalised certain emotional or value-driven messages from the gameplay experience. Features such as role-play, storytelling, and peer collaboration likely contributed to this effect. Bilancini et al. (2023) have similarly noted that narrative-driven and socially interactive game elements can support the development of environmental empathy and social norms. However, attitude change in environmental education is often anchored in what learners feel and believe, rather than merely in what they understand, implying that affective design must be deliberately deep rather than incidental (Pooley & O'Connor, 2000). Thus, the attitude gains are encouraging, yet they do not automatically imply strong cognitive–affective integration.

However, the lack of a strong correlation between knowledge and attitude in this study echoes findings from previous research that question the linearity of the Knowledge–Attitude–Behaviour (KAB) model. Anusrita (2022), for example, found that students with high levels of environmental knowledge did not always exhibit corresponding attitudes or behaviours. Likewise, Kang (2022) highlighted the influence of personal values, emotional factors, and cultural context on attitudinal outcomes in sustainability education. In this sense, the present results do not merely "confirm" a known pattern; they clarify that even within a digitally

engaging, locally contextualized gamified module, knowledge and attitude may remain weakly linked, challenging the assumption that gamification inherently bridges this gap. In short, the study redefines gamification as a tool that increases scores without ensuring cognitive–affective coherence.

One possible reason for the weak association observed in this study may be the module's level of emotional engagement. Xu et al. (2019) emphasised that emotional connection serves as a key mediator between knowledge acquisition and behavioural intent. While the *Water Warriors: Save the World* module incorporated affective features such as mission-based gameplay and environmental heroes, it may not have generated the depth of emotional involvement necessary to provoke lasting attitudinal change. This possibility supports the idea that superficial "game layer" rewards can encourage participation but might not effectively lead to internalizing value unless emotional meaning is explicitly facilitated. Therefore, stronger emotional connections and reflection may be necessary to reinforce the link between knowledge and attitudes.

Another consideration is the limited duration of the intervention. Literature suggests that attitudinal transformation often requires sustained engagement and reinforcement over time (Boncu et al., 2023; Hamdan & Arufe-Giráldez, 2023). Although the gamified module led to short-term improvements in attitude, the absence of a longitudinal component limits conclusions about the persistence of these effects. Studies such as Bilancini et al. (2023) have shown that ongoing reinforcement through family involvement, follow-up activities, or community integration is essential for long-term behavioural change. Therefore, the observed decoupling may partly result from a timing issue: cognitive gains can emerge quickly, whereas attitudinal consolidation may require longer reinforcement periods. In short, duration probably affects not only "how much change" but also "how tightly outcomes connect".

Cultural and demographic differences may have also influenced the results. Research indicates that learners' backgrounds, including socioeconomic status, digital literacy, and cultural values, affect how they perceive and engage with gamified learning (Saad & Mahmud, 2023). The participants in the present study likely represent a digitally engaged group, yet one with diverse cultural and linguistic contexts that may affect emotional and cognitive engagement differently. Here, the Malaysian/Southeast Asian context is important analytically because water attitudes may be influenced by everyday household practices, social norms, and local meanings of stewardship that cannot be reduced to classroom knowledge. Therefore, the weak correlation suggests that local socio-cultural factors may mediate the effect of knowledge on attitudes among urban youth. In short, context is not just a background; it is part of the process.

From a theoretical perspective, the findings suggest moving beyond linear models of behavioural change and adopting more comprehensive frameworks, such as the Theory of Planned Behaviour (TPB) and Self-Determination Theory (SDT). TPB posits that behaviour is influenced not only by knowledge and attitude, but also by perceived control and social norms (Ajzen, 1991). SDT, on the other hand, highlights the role of intrinsic and extrinsic motivation in shaping learner engagement and behavioural intention (Ryan & Deci, 2000; Ryan & Deci, 2017). It is possible that the gamified module in this study successfully enhanced extrinsic motivation through scores, competition, and reward without equally fostering intrinsic motivation tied to personal values or environmental commitment. This aligns with empirical research showing that specific gamification elements can influence motivation and performance in subtle ways, depending on how they are perceived and incorporated into meaningful activity (Mekler et al., 2017). In short, theory indicates that motivation and norms may serve as the "missing link" between knowledge gains and attitude coherence.

While mechanics such as points, feedback, cooperation, and narrative immersion are widely recognised for their instructional potential (Janakiraman et al., 2021; Boncu et al., 2022), their effectiveness in connecting knowledge and attitudes appears to depend heavily on the contextual and cultural fit of the implementation. For instance, Paolo and Pizziol (2023) reported more pronounced attitudinal changes when gamification was paired with localised content and community narratives, suggesting that contextual alignment enhances affective outcomes. Therefore, the present study suggests that "gamification + localisation" can improve outcomes, but it still requires careful design to support reflective and emotional integration and strengthen the connection between domains. In short, design fit and meaning-making are the key factors, not gamification itself.

Reflective learning plays an important role in bridging the gap between cognition and emotion. Álvarez and Gavilanes (2024) demonstrated that reflection-based tasks within game-based environments can help learners critically assess their values and attitudes, facilitating deeper internalisation. While the Water Warriors module encouraged active problem-solving, it may have been further strengthened by incorporating structured opportunities for personal reflection, such as journaling or discussion-based debriefing sessions. Therefore, a practical approach is to combine gameplay with guided debriefing that prompts learners to link their in-game decisions to real-world water practices, norms, and constraints. In essence, reflection can effectively transform "game success" into a clear understanding of value.

Taken together, this study highlights the potential of gamified learning to improve environmental knowledge and attitudes among urban Malaysian students while also demonstrating that cognitive gains do not necessarily align with attitudinal change. The findings suggest that sustainability education should incorporate stronger emotional engagement, reflective learning, and culturally meaningful experiences to support deeper attitudinal development. However, the findings should be interpreted cautiously due to several limitations, including the quasi-experimental design without random assignment, the short intervention duration, the modest sample size limited to urban schools in Sarawak, and the use of basic correlational analysis, all of which may affect the generalisability and explanatory depth of the study.

Conclusion

This study provides evidence that digital gamification can enhance both environmental knowledge and attitudes among urban Malaysian secondary school students. The "Water Warriors: Save the World" module, implemented through Minecraft Education Edition, improved students' understanding of water conservation in both cognitive and emotional domains. These results highlight the potential of interactive, locally relevant digital tools to support environmental literacy within formal education settings. Despite these positive outcomes, the analysis revealed only a weak and statistically nonsignificant relationship between knowledge and attitude. This finding suggests that gains in one domain do not automatically result in improvements in the other. Conceptually, this challenges the linear Knowledge–Attitude assumptions often implicitly applied in gamified sustainability education, implying that cognitive gains and emotional alignment may progress through somewhat separate paths.

It also reflects the complexity of educational change, in which emotional engagement, social context, and cultural factors influence how learners internalise and act on new knowledge. From an instructional perspective, these findings emphasise the importance of designing gamified learning experiences that incorporate emotional and reflective components. Storytelling, collaboration, and structured reflection can complement cognitive content to promote more holistic and meaningful learning outcomes. In practice, pairing gameplay with guided debrief (such as short reflection prompts or discussion-based sense-making) may help translate in-game success into a stronger value-based approach to water stewardship.

To enhance explanatory power, future research should go beyond bivariate association by examining specific mediating pathways, such as subjective norms and perceived behavioral control (TPB), or intrinsic motivation and autonomy/competence (SDT), that may connect knowledge gains to attitudinal consolidation in gamified settings. Longer-term or follow-up measurements (e.g., delayed post-tests) would also help determine whether attitude changes last and if knowledge–attitude links strengthen over time. Overall, these suggestions can improve how digital gamification is theorized and designed for sustainability education, especially within Malaysian and Southeast Asian school systems. By empirically demonstrating the weak coupling between knowledge and attitude, this study reframes digital gamification not as a cognitive–affective bridge, but as a pedagogical tool whose transformative capacity depends on deliberate emotional, reflective, and contextual design

Acknowledgement: The author gratefully acknowledges the Ministry of Education Malaysia and the Sarawak State Education Department for granting permission to conduct this research in schools under their administration.

Funding:This research received financial support from Universiti Malaysia Sabah (UMS) through the UMSGreat Research Grant Scheme (Grant No. UMSG3346).

Conflict of Interest Statement: The author affirms that there are no financial, professional, or personal relationships that could be viewed as influencing the conduct or reporting of this study.

Informed Consent Statement: Prior to participation, written consent was obtained from all student participants and their guardians.

Ethical Considerations: This study was conducted in accordance with ethical research standards set by the Ministry of Education Malaysia. Approval for the research was obtained through the Educational Policy Planning and Research Division (EPRD), Ministry of Education, Malaysia. Informed consent was obtained from all participants before data collection, and confidentiality and anonymity were maintained throughout. The authors declare no conflict of interest.

References

Ajzen, I. (1991). *The theory of planned behavior*. Organizational Behavior and Human Decision Processes, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Álvarez, D. S. P., & Gavilanes, Á. P. V. (2024). Serious games for teaching and learning in environmental education. *Apertura, 16*(2), 66–79. https://doi.org/10.32870/ap.v16n2.2533

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology, 27*(1), 14–25. https://doi.org/10.1016/j.jenvp.2006.12.002

Bilancini, E., Boncinelli, L., & Di Paolo, R. (2023). Game-based education promotes practices supporting sustainable water use. *Ecological Economics, 208*, 107801. https://doi.org/10.1016/j.ecolecon.2023.107801

Boncu, S., Candel, O. S., & Popa, N. L. (2022). Gameful green: A systematic review on the use of serious computer games and gamified mobile apps to foster pro-environmental information, attitudes and behaviours. *Sustainability, 14*(16), 10400. https://doi.org/10.3390/su141610400

Boncu, Ș., Candel, O. S., Prundeanu, O., & Popa, N. L. (2023). Growing a digital iceberg for a polar bear: effects of a gamified mobile app on university students' pro-environmental behaviours. *International Journal of Sustainability in Higher Education, 24*(8), 1932-1948. https://doi.org/10.1108/IJSHE-03-2023-0092

Bootsma, R. E., & Ciocarlan, A. (2023, April). *Persuasive technology design for children: Changing behaviours, improving knowledge, and encouraging positive attitudes towards drinking water*. CEUR Workshop Proceedings.

Branch, R. M. (2022). *Instructional design: The ADDIE approach* (2nd ed.). Springer.

Fatimah, S., Farida, I., & Sukmawardani, Y. (2023). Interactive learning for water pollution awareness: A game-based approach. *Journal of Educational Management and Learning, 1*(1), 31–36. https://doi.org/10.60084/jeml.v1i1.52

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *Proceedings of the 47th Hawaii International Conference on System Sciences (HICSS)*. https://doi.org/10.1109/HICSS.2014.377

Hamdan, F. A., & Arufe-Giráldez, V. (2023). Critical thinking in environmental education through digital games among students. *Environment & Social Psychology, 8*(2). https://doi.org/10.54517/ESP.V8I2.1725

Hashim, M., Yusri, I. N., Mahat, H., Nayan, N., & Saleh, Y. (2024). Penggunaan air secara lestari dalam kalangan warga Bandaraya Ipoh, Perak. *Geografia, 20*(1), 13–321. https://doi.org/10.17576/geo-2024-2001-02

Janakiraman, S., Watson, S. L., Watson, W. R., & Newby, T. J. (2021). Effectiveness of digital games in producing environmentally friendly attitudes and behaviors: A mixed methods study. *Computers & Education, 160*. https://doi.org/10.1016/j.compedu.2020.104043

Johnson, R. B., & Christensen, L. (2014). *Educational research: Quantitative, qualitative, and mixed approaches* (5th ed.). SAGE Publications.

Kang, T. (2022). Construction and empirical analysis of citizens' water literacy evaluation index system: A structural equation model. *Water Resources Management, 36*(4), 1393–1411. https://doi.org/10.1007/s11269-022-03089-1

Keriwala, N., & Patel, A. R. (2022). *Innovative roadmap for smart water cities: A global perspective*. https://doi.org/10.3390/materproc2022010001

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239–260. https://doi.org/10.1080/13504620220145401

Koop, S. H. A., & van Leeuwen, C. J. (2017). The challenges of water, waste and climate change in cities. *Environment, Development and Sustainability, 19*, 385–418. https://doi.org/10.1007/s10668-016-9760-4

Kunjuzwa, D. T., Scholtz, B., & Fashoro, I. (2023). *The importance of knowledge for influencing citizens' attitudes and practices of water sustainability: The case of the Eastern Cape*. https://doi.org/10.1007/978-3-031-28472-4_7

Luo, K. (2025). Sustainable urban water resource management in China: Challenges and innovations. *Applied and Computational Engineering, 128*(1), 31–36. https://doi.org/10.54254/2755-2721/2025.20203

Maniam, G., Chuah, L.-H., Wong, C. H. C., Gunasegaran, M. V., & Jamaludin, N. A. (2024). *What can we do more to promote water literacy in Malaysia?* Monash University Malaysia, WWF-Malaysia, & Watered Association. https://doi.org/10.26180/25546561.v1

Maniam, G., Poh, P. E., Htar, T. T., Poon, W. C., & Chuah, L. H. (2021). Water literacy in the Southeast Asian context: Are we there yet? *Water (Switzerland), 13*(16), Article 2311. https://doi.org/10.3390/w13162311

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior, 71*, 525–534. https://doi.org/10.1016/j.chb.2015.08.048

Miao, H. W., Saleh, M. S. M., & Zolkepli, I. A. (2022). Gamification as a learning tool for pro-environmental behavior: A systematic review. *Malaysian Journal of Social Sciences and Humanities, 7*(12), e001881. https://doi.org/10.47405/mjssh.v7i12.1881

Nalumenya, B., Rubinato, M., Kennedy, M., & Catterson, J. (2024). Can game-based learning help increase awareness of water management in Uganda? A case study for primary and secondary schools. *World, 5*(4), 981–1003. https://doi.org/10.3390/world5040050

Paolo, R. D., & Pizziol, V. (2023). Gamification and sustainable water use: The case of the Blutube educational program. *Simulation & Gaming*. https://doi.org/10.1177/10468781231181652

Pooley, J. A., & O'Connor, M. (2000). Environmental education and attitudes: Emotions and beliefs are what is needed. *Environment and Behavior, 32*(5), 711–723. https://doi.org/10.1177/0013916500325007

Rosmalah, R., Daud, F., & Danial, M. (2023). Hubungan pengetahuan dan sikap terhadap pengelolaan air bersih di Desa Padaidi Kecamatan Sebatik Kabupaten Nunukan. *UNM Journal of Biological Education*. https://doi.org/10.35580/ujbe.v6i2.46766

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Press.

Saad, N. W., & Mahmud, S. N. D. (2023). Uncovering gender differences in water literacy among high schoolers. *International Journal of Academic Research in Progressive Education and Development, 12*(1), 45–57. https://doi.org/10.6007/ijarped/v12-i1/16465

Santiago, C. D., Castro, M. A. S. D., Gonçalves, J. C., Pugliesi, É., & Valencio, N. (2024). City-resilience from the perspective of the water-energy-sanitation nexus. *Engenharia Urbana em Debate, 5*(2), 66–79. https://doi.org/10.14244/engurbdebate.v5i2.149

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of Human-Computer Studies, 74*, 14–31. https://doi.org/10.1016/j.ijhcs.2014.09.006

Schneiderhan-Opel, J., & Bogner, F. X. (2021). The effect of environmental values on German primary school students' knowledge on water supply. *Water, 13*(5). https://doi.org/10.3390/w13050702

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Houghton Mifflin.

Sözcü, U., & Türker, A. (2020). Development of water literacy scale. *Third Sector Journal of Social Economy, 55*(2), 1155–1168.

Tan, C. K., & Nurul-Asna, H. (2023). Serious games for environmental education. *Integrative Conservation, 2*(1), 19–42. https://doi.org/10.1002/inc3.18

Xu, R., Wang, W., Wang, Y., & Zhang, B. (2019). Can water knowledge change citizens' water behavior? A case study in Zhengzhou, China. *Ekoloji, 28*(107), 1019–1027.