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ENHANCING MALAYSIA'S WATER LITERACY AGENDA THROUGH DIGITAL GAMIFICATION: A CONCEPTUAL FRAMEWORK FOR SECONDARY EDUCATION

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Abstract:

Water is a critical resource for human well-being and socio-economic development, particularly in rapidly developing countries such as Malaysia, where domestic and industrial water demand continues to increase. Despite receiving high annual rainfall, persistent issues related to excessive consumption, water wastage, pollution, and limited public awareness indicate weaknesses in sustainable water management practices. These conditions reflect an unsatisfactory level of water literacy, especially among young people who will become future water users and decision-makers. Existing teacher-centred instructional approaches have demonstrated limitations in addressing abstract and systems-based water concepts, often resulting in fragmented conceptual understanding and weak attitudinal orientation toward sustainable water use. Interactive digital gamification is positioned as an experiential and learner-centred pedagogical approach that supports deeper cognitive engagement with water-related concepts. This paper presents the conceptual design and instructional framework of an interactive digital gamification module, Water Warriors: Save the World, developed to enhance water literacy among Malaysian secondary school students. The framework integrates game-based mechanics, classroom-oriented learning design, and experiential elements to strengthen students' water-related knowledge and attitudes toward sustainable water use. The paper further discusses the projected educational outcomes, implementation challenges, and theoretical as well as practical implications of integrating digital gamification into water education to support the development of environmentally responsible future citizens.

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Introduction

Malaysia receives high annual rainfall, averaging about 2,000–4,000 mm, and is endowed with abundant water resources, yet the country continues to experience recurring water crises (Ministry of Natural Resources and Environmental Sustainability [NRES], 2024). These challenges arise mainly from unsustainable consumption patterns, water pollution, and deficiencies in water infrastructure (Amin et al., 2022; Mokhtar et al., 2015; Tan et al., 2022). Rapid urbanisation and industrialisation have intensified pressure on water systems, resulting in periodic shortages and supply disruptions that affect millions of residents and multiple economic sectors. Sustainable water resource management, therefore, requires not only technical interventions but also behavioural change supported by strong public understanding and awareness.

Water literacy plays a critical role in shaping responsible water-use behaviour. Defined as the combination of knowledge, attitudes, and behaviours related to water (McCarroll & Hamann, 2020; Meilinda et al., 2023), water literacy enables individuals to evaluate water systems objectively and reflectively, promoting stronger human–water relationships (Otaki et al., 2015). In educational contexts, water literacy also supports socio-hydrological understanding and socio-scientific reasoning (Owens et al., 2020). As students represent future users and decision-makers, nurturing water literacy at an early age is essential for ensuring long-term sustainability.

However, existing evidence suggests that Malaysians generally exhibit low levels of water conservation awareness. SPAN (2022) reports highlight excessive domestic consumption, limited appreciation of water scarcity, and insufficient civic responsibility in water resource management. Such trends indicate that many individuals, especially younger populations, lack a deep understanding of sustainable water practices. Climate change further exacerbates these vulnerabilities, with more frequent droughts and increasingly unpredictable rainfall patterns placing additional stresses on national water security (Fulazzaky et al., 2023; Tang, 2019). Without targeted educational interventions, Malaysia risks facing more severe water-related consequences affecting health, economic stability, and overall quality of life.

Strengthening water literacy among students is therefore crucial. Improved water literacy is associated with more efficient water use, reduced wastage, and greater environmental sensitivity, enabling students to make more informed daily decisions (Memon et al., 2020; Njoku et al., 2022). However, despite its importance, water literacy has not been systematically embedded within Malaysia's educational practices. Conventional teaching approaches often lack interactivity and contextual relevance, making it difficult for students to internalise complex socio-hydrological issues.

Digital games are increasingly recognised as practical tools for environmental and water education (Mezga et al., 2021; Nazarova, 2020; Zhang et al., 2013). Serious games allow students to experience realistic water management scenarios in a safe, simulated environment. Kraker et al. (2021) demonstrated that Sustainable Delta promotes perspective-taking among

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stakeholders, enhancing collaborative problem-solving. Digital game features such as simulation, feedback, narrative, and challenge also align with global pedagogical trends and the United Nations Sustainable Development Goals, promoting digital innovation in learning (UNESCO, 2020).

Despite these advantages, the use of digital gamification in Malaysia's water education landscape remains limited. While global studies have demonstrated its effectiveness in enhancing environmental literacy (Betaubun & Nasrawati, 2020; Reihana et al., 2019; Ricoy & Sánchez-Martínez, 2022), empirical research assessing digital game-based interventions for water literacy among Malaysian secondary school students is scarce. This gap underscores the need for innovative, engaging, and contextually relevant educational tools that can strengthen students' water knowledge and attitudes toward sustainable water use. To address this gap, the present paper proposes developing an interactive digital gamification module to improve water literacy, specifically students' knowledge and attitudes toward sustainable water use. Accordingly, this paper presents a conceptual digital gamification framework to strengthen students' water knowledge and attitudes toward sustainable water use in secondary education.

Literature Review

Digital games have gained substantial recognition as powerful tools for enhancing water literacy, offering interactive and immersive experiences that help students understand water-related concepts such as hydrological processes, pollution, and resource management. A vast body of research demonstrates the potential of such games to simplify complex scientific content through experiential learning. For example, Robertson (2022) showed that the Hydrologic Cycle Game significantly improved undergraduate comprehension of hydrological cycles by using a box model to visualise terminology and mechanisms. Pre- and post-test results confirmed notable learning gains, reinforcing the effectiveness of game-based approaches in Earth systems education. Similarly, Reeves et al. (2020) found that Mission HydroSci, a three-dimensional digital learning environment, enhanced middle school students' understanding of water systems. Complementing these findings, Araujo-Junior and Bodzin (2024) reported that the Watershed Explorers game improved middle school students' watershed literacy through place-based digital tasks that strengthened conceptual links between local and broader ecosystems. Collectively, these studies affirm that interactive digital games can support water literacy across different educational levels.

Despite the widespread use of teacher-centred instruction in environmental education, several studies suggest that such approaches are often limited in their ability to address abstract and systems-based water concepts. Conventional instruction that relies heavily on verbal explanation and textbook representation may constrain students' ability to visualise dynamic hydrological processes and interconnections within water systems (Bogusevschi et al., 2020; Robertson, 2022). As a result, learners may demonstrate a surface-level understanding without fully grasping causal relationships or system dynamics. This limitation has prompted increasing attention toward learner-centred and experiential approaches, including digital game-based learning, that enable active exploration and visualisation of complex water phenomena. From a cognitive neuroscience perspective, interactive game-based learning supports attention regulation, processing of immediate feedback, and formation of experiential memory, processes that are critical for consolidating abstract and system-based environmental concepts (Robertson, 2022; Reeves et al., 2020).

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While research highlights the potential of game-based water education, several studies identify both strengths and limitations that affect its practical use. Many researchers (Chang & Chen, 2023; Cheng et al., 2013; Hamdan et al., 2023; Janakiraman et al., 2021; Wang et al., 2023) have studied digital game-based learning in environmental settings and reported positive impacts on engagement, motivation, and understanding. For example, Saraiva et al. (2024) found that combining fieldwork with game-based learning improved students' teamwork skills and knowledge of water resources. Bogusevschi et al. (2020) showed that 3D virtual reality platforms improve secondary students' understanding of the water cycle by allowing immersive interactions with scientific processes. However, these high-tech solutions often need significant technological capacity. Reeves et al. (2020) pointed out that Mission HydroSci requires substantial computational resources, which can be challenging for under-resourced schools. These findings emphasize the need for scalable, affordable game-based methods that maintain learning effectiveness while reducing the technological demands.

Learning analytics is also a growing area in game-based environmental education. Lu et al. (2023) emphasized that telemetry data from serious games can be used to develop predictive learning models, allowing teachers to monitor student progress and adapt learning activities accordingly. Robertson (2022) similarly highlighted the importance of repeated assessment, noting strong retention patterns among students who engaged with the Hydrologic Cycle Game. While learning analytics offer valuable diagnostic insights, their widespread use raises ethical and privacy concerns. Therefore, future digital learning initiatives must balance data-driven instructional improvements with responsible and ethical data management practices.

Several research gaps identified in the literature concern the limited integration of broader ecological contexts in water-related digital games. Saraiva et al. (2024) effectively connected water quality and conservation concepts to local ecosystems through hybrid game-and-fieldwork activities, helping students interpret water issues within their immediate environments. Conversely, Parekh et al. (2021) found that many existing digital games focus on isolated water concepts without adequately linking them to ecosystem interdependencies. Another significant gap involves the prevalence of short-term evaluations. While many studies report immediate knowledge gains, far fewer investigate long-term effects on attitudes and values, which are vital components of environmental literacy.

Additionally, prior research shows that information-driven methods, such as factual reports and short-term instructional interventions, often fall short of fostering sustained awareness and values related to water sustainability. While many studies report immediate improvements in water-related knowledge, fewer provide evidence of lasting attitude changes or internalized concern for water conservation (Parekh et al., 2021; Saraiva et al., 2024). This indicates that exposure to information alone may not lead to meaningful awareness or responsible perspectives about water use. Therefore, educational interventions that combine cognitive understanding with emotional and experiential engagement are increasingly seen as necessary to enhance water awareness within environmental learning settings.

Digital games also support scientific thinking and socio-emotional growth, promoting positive attitudes toward sustainable water practices. Saraiva et al. (2024) reported improvements in inquiry skills, collaboration, and analytical thinking when game-based learning was combined with field activities. Araujo-Junior and Bodzin (2024) similarly found that place-based digital tools helped students apply theoretical knowledge to real-world watershed scenarios. Notably,

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socio-emotional engagement works closely with cognitive processes, enhancing conceptual understanding and value formation. However, Lu et al. (2023) warned that engagement alone does not ensure deep learning, highlighting the importance of teacher-guided reflection to reinforce understanding. This highlights the need to include structured discussion, debriefing, and reflection alongside gameplay.

Overall, contemporary research supports the value of interactive digital games in strengthening water literacy. Scholars such as Robertson (2022), Saraiva et al. (2024), and Reeves et al. (2020) consistently highlight the educational benefits of digital game-based learning while acknowledging limitations related to cost, accessibility, and content scope. Robertson (2022) recommends developing simplified, accessible game designs to broaden institutional adoption, while Reeves et al. (2020) suggest adapting computationally demanding platforms to more feasible mobile or augmented reality formats. Beyond cognitive learning outcomes, several studies emphasise the socio-emotional dimension of digital games, noting that role-playing and scenario-based activities can foster ethical reasoning and empathy related to water management challenges. Integrating cognitive and socio-emotional dimensions, therefore, provides a holistic learning experience that strengthens both understanding and values related to sustainable water use.

These insights are synthesised in the conceptual framework presented in Figure 1, which outlines the quasi-experimental comparison between digital gamification and conventional instruction in enhancing students' water knowledge and attitudes toward sustainable water use.

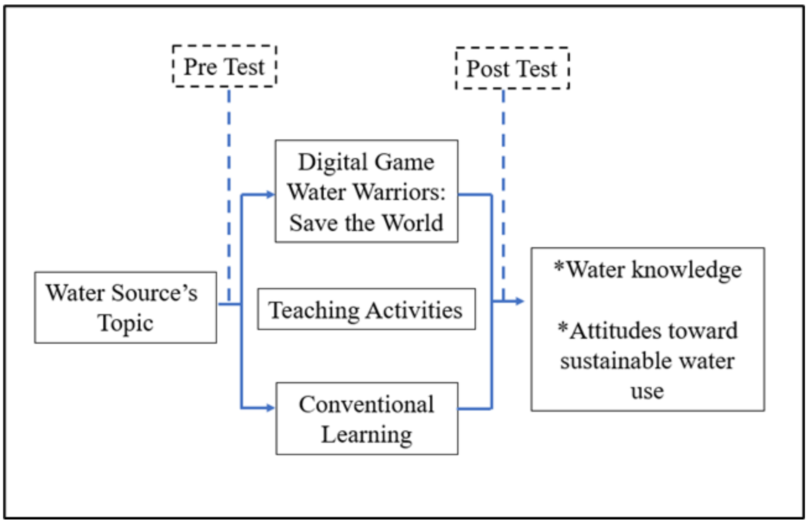

Figure 1: Conceptual Framework

Method

Research Design

This paper adopts a conceptual and methodological framework informed by a quantitative quasi-experimental approach using a non-equivalent pretest–posttest control group structure. Quasi-experimental designs are commonly referenced in educational research as suitable approaches when random assignment is impractical, particularly in authentic classroom settings that rely on intact classes (Thyer, 1993; Creswell & Creswell, 2018). In this paper, the

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design is presented to illustrate a feasible evaluation strategy that may be employed to examine the instructional potential of the proposed digital gamification module, while maintaining ecological validity within real classroom contexts. The methodological description is intentionally framed to illustrate feasibility and instructional coherence rather than to report empirical outcomes or causal claims at this conceptual stage.

Participants and Group Assignment
The proposed framework is situated within lower secondary Geography classrooms, where intact classes are typically maintained by school administration. In line with quasi-experimental principles, existing class groupings may serve as comparison units rather than randomly assigned samples (Creswell, 2014). Pre-intervention measures are conceptualised as baseline indicators to support meaningful comparisons between instructional conditions, consistent with methodological recommendations for non-randomised designs (Shadish et al., 2002).

Teacher Selection and Instructional Control
Teachers involved in the proposed framework are expected to be existing Geography teachers appointed by the school administration, consistent with the intact group approach commonly used in quasi-experimental educational research. The researcher envisages no teacher reassignment or recruitment to preserve the authenticity of classroom instruction (Creswell, 2014). To minimise instructional bias, instructional content, learning objectives, and instructional duration are conceptually aligned across instructional conditions.

Within this framework, teachers implementing the digital gamification module may receive prior briefing and structured preparation to support systematic implementation and alignment with curriculum requirements. Structured instructional planning is emphasised to reduce variation arising from differences in teacher readiness or instructional emphasis (Hong, 2010; Patten & Newhart, 2017). In comparison, conventional instruction is conceptualised as teacher-centred lessons involving explanation, questioning, guided discussion, and written exercises, following standard classroom practices to maintain comparable instructional effort.

Intervention Structure
The treatment group will participate in structured learning sessions using the interactive digital game Water Warriors: Save the World, implemented through Minecraft Education Edition. Sessions will be conducted in a computer-supported learning environment, with students having individual access to digital learning resources. The proposed digital module is designed to support experiential and problem-based learning, incorporating:

i. Contextual virtual environments simulating real-world water-related challenges
ii. Mission-based tasks requiring learners to identify problems, make decisions, and propose sustainable solutions
iii. Interactive exploration enabling observation of cause–and–effect relationships within water systems
iv. Collaborative elements encouraging peer discussion and shared problem-solving
v. Immediate feedback, allowing students to reflect on the consequences of their actions

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Digital game-based learning environments that integrate simulation, feedback, and problem-solving have been shown to support meaningful learning and conceptual understanding in environmental education (Reeves et al., 2020; Robertson, 2022; Saraiva et al., 2024). Within this instructional setting, the teacher is expected to function primarily as a facilitator, guiding task completion, clarifying objectives, and supporting reflection rather than delivering continuous direct instruction. Guided facilitation is essential to prevent superficial engagement and to reinforce conceptual understanding during game-based learning (Lu et al., 2023; Reeves et al., 2020).

Meanwhile, the control group will receive instruction through conventional teacher-centred pedagogical methods, including lectures, question-and-answer sessions, guided discussions, and written exercises. Teaching will be conducted in a regular classroom environment, following the treatment group's curriculum, learning objectives, and instructional duration. The control condition is proposed as a structured instructional approach that requires systematic lesson planning and active teacher engagement. This ensures that any observed differences in learning outcomes can be attributed to instructional approach rather than disparities in instructional quality or effort (Hong, 2010; Patten & Newhart, 2017).

Data Collection Instruments

Data collection is proposed to be conducted using a water literacy questionnaire administered as both a pre-test and a post-test. The instrument will measure three dimensions of water literacy: knowledge, attitudes, and behaviours, reflecting the multidimensional nature of environmental literacy (McCarroll & Hamann, 2020; Owens et al., 2020). The knowledge component will consist of multiple-choice items scored dichotomously, while the attitude and behaviour components will employ five-point Likert-scale items. Instrument adaptation and validation will follow established methodological guidelines to ensure contextual relevance and measurement accuracy (Creswell & Creswell, 2018; Bhattacherjee, 2012).

Data Analysis

Data obtained from the Water Literacy Questionnaire are proposed for analysis using descriptive and inferential statistical procedures to examine changes in students' water knowledge and attitudes toward water sustainability. Prior to analysis, responses will be screened for completeness and coded accordingly. Reliability analysis is proposed to assess internal consistency, with the knowledge construct evaluated using Kuder–Richardson 20 (KR-20) and the attitude construct assessed using Cronbach's alpha. Descriptive statistics, including frequencies, means, and standard deviations, will be used to summarise students' demographic characteristics and overall patterns of knowledge and attitude scores.

Students' attitudes toward water sustainability, which reflect motivational orientation and awareness, are measured using Likert-scale items in the questionnaire. Representative attitude items include: "*Saya sanggup berjimat air di rumah dengan bersungguh-sungguh*" and "*Saya sedar bahawa air sangat berharga dan perlu dijaga untuk generasi akan datang*." These items are intended to capture students' values, sense of responsibility, and willingness to support sustainable water practices. Knowledge outcomes are measured using multiple-choice items assessing understanding of water concepts and issues.

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To examine changes over time, paired-sample t-tests are proposed to compare pre-test and post-test scores for water knowledge and attitudes within each group. Independent-samples t-tests are proposed to compare post-test scores between the treatment and control groups. Statistical significance will be evaluated at the 0.05 level, and effect sizes using Cohen's d will be reported to indicate the magnitude of any observed differences. Although learning activities encourage active participation, only knowledge and attitude constructs are analysed as outcome variables in this proposed study. Behavioural outcomes are not analysed in this conceptual framework to maintain alignment with the paper's focus on instructional design rather than behavioural impact evaluation.

Discussion

In the Malaysian education context, current policies increasingly emphasise integrating technology and environmental awareness to address sustainability challenges, including water scarcity and water resource management. As water-related issues intensify due to environmental and human pressures, educational approaches that position water as a finite and valuable resource are increasingly important. Digital game-based learning aligns with these priorities by offering learner-centred, technology-enhanced strategies that promote meaningful engagement with water-related concepts in formal education settings.

Digital game-based learning shows substantial potential to enhance students' water literacy by transforming complex, abstract water-related concepts into interactive, experiential learning experiences. Through structured gameplay, hydrological processes, watershed dynamics, and water quality interactions can be translated into interactive and accessible visual simulations that are often difficult to convey through conventional instruction alone. Prior studies consistently report that such interactive modalities support conceptual clarity and retention by enabling learners to actively engage with scientific mechanisms rather than passively receive information (Robertson, 2022; Reeves et al., 2020; Araujo-Junior & Bodzin, 2024).

In contrast, conventional teacher-centred instruction in environmental education is often limited in its ability to address the dynamic, systems-based nature of water-related concepts. Approaches that rely heavily on verbal explanation and textbook representation may restrict students' ability to visualise interconnected hydrological processes and temporal changes within water systems (Bogusevschi et al., 2020; Robertson, 2022). Consequently, learners may develop surface-level understanding without fully grasping causal relationships or system complexity. This limitation has prompted increasing attention toward learner-centred and experiential approaches, including digital game-based learning.

Within digital game-based environments, learning occurs through direct interaction with simulated systems rather than static representations. In the proposed *Water Warriors: Save the World* module, students engage in scenario-based decision-making and consequence-driven gameplay focused on water scarcity, pollution control, and resource management. By observing the outcomes of their actions within the game environment, abstract hydrological concepts are contextualised into meaningful experiences. This design approach is consistent with earlier findings that place-based and simulation-driven digital games strengthen conceptual connections between local water issues and broader environmental systems (Araujo-Junior & Bodzin, 2024; Saraiva et al., 2024).

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Beyond cognitive outcomes, digital game-based learning also contributes to affective and socio-emotional dimensions of water literacy. Previous studies report improvements in student motivation, engagement, and environmental awareness through emotionally engaging and problem-based game scenarios (Janakiraman et al., 2021; Saraiva et al., 2024). Through role-based challenges, students are encouraged to reflect on the implications of water-related decisions, supporting the internalisation of environmental values. However, engagement alone does not necessarily guarantee deep learning, highlighting the importance of structured reflection and teacher-guided discussion to consolidate conceptual understanding (Lu et al., 2023).

Despite its pedagogical advantages, the literature highlights practical constraints associated with high-technology game-based solutions. Advanced platforms such as three-dimensional simulations and virtual reality environments often require substantial technological infrastructure, which may limit feasibility in under-resourced school contexts (Reeves et al., 2020; Bogusevschi et al., 2020). These challenges underscore the need for scalable and cost-effective digital game designs that preserve pedagogical impact while remaining accessible across diverse educational settings.

Another limitation frequently identified across studies relates to the predominance of short-term evaluations. While many investigations report immediate gains in water-related knowledge, fewer examine sustained attitudinal change or long-term value formation (Parekh et al., 2021; Saraiva et al., 2024). This suggests that information-driven or short-duration interventions alone may be insufficient to cultivate enduring awareness and responsibility toward water sustainability. Consequently, educational designs that integrate cognitive understanding with affective engagement and repeated experiential exposure are increasingly viewed as necessary.

Overall, contemporary research supports the effectiveness of digital game-based learning in advancing water literacy by strengthening both knowledge acquisition and attitudinal development. Studies by Robertson (2022), Reeves et al. (2020), and Saraiva et al. (2024) consistently indicate that well-designed digital games enhance conceptual understanding while fostering socio-emotional engagement with water sustainability issues. Taken together, these studies suggest that digital game-based learning provides a promising conceptual foundation for integrating the cognitive and attitudinal dimensions of water literacy within educational contexts.

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References

Amin, M. H., Sajak, A. A. B., Jaafar, J., Husin, H. S., & Mohamad, S. (2022). Real time water quality monitoring system for smart city in Malaysia. *ASEAN Journal of Science and Engineering, 2*(1).

Araujo-Junior, R. M., & Bodzin, A. M. (2024). Effects of a place-based digital gameful learning experience on middle school students' watershed literacy and attitudes about

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 1227-1238
DOI: 10.35631/IJMOE.728084
desktop virtual reality gameplay. *Interactive Learning Environments, 32*(4), 1247–1265.

Betaubun, M., & Nasrawati, N. (2020). English for Specific Purposes: Revitalizing Climate Change awareness using digital literacy and gamification for engineering faculty in Papua. *Jurnal Iqra': Kajian Ilmu Pendidikan, 5*(2).

Bhattacherjee, A. (2012). *Social science research: Principles, methods, and practices* (2nd ed.). University of South Florida Scholar Commons.

Bogusevschi, D., Muntean, C., & Muntean, G.-M. (2020). Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school. *Journal of Computers in Mathematics and Science Teaching, 39*(1), 5–18.

Chang, C. L., & Chen, C. N. (2023). Practical impact of school-age children using digital games to learn environmental education. *E3S Web of Conferences*.

Cheng, Y. M., Lou, S. J., Kuo, S. H., & Shih, R. C. (2013). Investigating elementary school students' technology acceptance by applying digital game-based learning to environmental education. *Australasian Journal of Educational Technology*.

Creswell, J. W. (2014). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Pearson Education Limited.

Economic Planning Unit. (2022). *Water sector transformation 2040 (WST2040): Integrated water sector data centre (IWSDC) (Vol. III): Sub-sectoral final report*. Academy of Sciences Malaysia.

Fulazzaky, M. A., Syafiuddin, A., Muda, K., Martin, A. Y., Yusop, Z., & Ghani, N. H. A. (2023). A review of the management of water resources in Malaysia facing climate change. *Environmental Science and Pollution Research, 30*(58), 121865–121880.

Hamdan, F. A., Lara-Sánchez, A. J., & Arufe-Giráldez, V. (2023). Critical thinking in environmental education through digital games among students. *Environment and Social Psychology, 8*(2).

Hong, E. (2010). Quasi-experimentation: Two group design. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International encyclopedia of education* (3rd ed., pp. 128–133). Elsevier.

Janakiraman, S., Watson, S. L., & Watson, W. R. (2021). Exploring the effectiveness of digital games in producing pro-environmental behaviors when played collaboratively and individually: A mixed methods study in India. *TechTrends*.

Kraker, J. de, Offermans, A., & Wal, M. M. van der. (2021). Game-based social learning for socially sustainable water management. *Sustainability, 13*, 4646.

Li, R. Y. M., Li, H. C. Y., Mak, C. K., & Tang, T. B. (2016). Sustainable smart home and home automation: Big data analytics approach. *International Journal of Smart Home, 10*(8).

Lu, W., Griffin, J., Sadler, T. D., Laffey, J., & Goggins, S. P. (2023). Serious game analytics by design: Feature generation and selection using game telemetry and game metrics toward predictive model construction. *Journal of Learning Analytics, 10*(1).

McCarroll, M., & Hamann, H. (2020). What we know about water: A water literacy review. *Water, 12*, 2803.

Meilinda, M., Khoiron, N., Riyanto, R., Anggraini, N., & Sukardi, R. R. (2023). Students' water literacy in South Sumatera, Indonesia: Does indigenous culture have influence? *Journal of Education, Teaching and Learning, 8*(1).

Memon, J. A., Alizai, M. Q., & Hussain, A. (2020). Who will think outside the sink? Farmers' willingness to invest in technologies for groundwater sustainability in Pakistan. *Environment, Development and Sustainability*.

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 1227-1238
DOI: 10.35631/IJMOE.728084
Mezga, K., Vrhovnik, P., Žmavc, J., & Gullon, L. (2021). The importance of educating younger generations about raw materials and their uses in our daily life. *Geologica Macedonica, 35*(1).

Ministry of Natural Resources and Environmental Sustainability. (2024). *Malaysia: Fourth national communication report (NC4) under the United Nations Framework Convention on Climate Change*. United Nations Framework Convention on Climate Change.

Mokhtar, M. I., Abdullah, R., & Baharuddin, A. (2015). An Islamic perspective on water quality: A case of Malaysia. *Water Policy, 17*(2).

Nazarova, Z. (2020). Organization of the game process of learning in the preschool education system. *JournalNX, 6*(6).

Njoku, P. O., Durowoju, O. S., Uhunamure, S. E., & Makungo, R. (2022). Investigating the attitude of domestic water use in urban and rural households in South Africa. *Water, 14*(2), 210.

Otaki, Y., Sakura, O., & Otaki, M. (2015). Advocating water literacy. *International Journal of Engineering and Technology, 1*, 36–40.

Owens, D. C., Petitt, D., Lally, D., & Forbes, C. (2020). Cultivating water literacy in STEM education: Undergraduates' socio-scientific reasoning about socio-hydrologic issues. *Water, 12*, 2857.

Parekh, P., Gee, E., Tran, K., Aguilera, E., Pérez Cortés, L. E., Kessner, T., & Siyahhan, S. (2021). Board game design: An educational tool for understanding environmental issues. *International Journal of Science Education, 43*(13), 2148–2168.

Patten, M. L., & Newhart, M. (2017). *Understanding research methods*. Taylor & Francis.

Reeves, T., Romine, W., Laffey, J., Sadler, T., & Goggins, S. (2020). *Distance learning through game-based 3D virtual learning environments: Mission HydroSci*. University of Georgia.

Reihana, K., Taura, Y., & Harcourt, N. (2019). He tohu o te wā—Hangarau pūtaiao / Signs of our times: Fusing technology with environmental sciences. *New Zealand Journal of Ecology, 43*(3).

Robertson, W. M. (2022). Increasing student engagement and comprehension of the global water cycle through game-based learning in undergraduate courses. *Journal of Geoscience Education, 70*(2), 161–175.

Saraiva, E., Faria, F., Ferreira, C., & Azevedo, M. M. (2024). Education for sustainability through field activities and game-based tasks. *Journal of Teacher Education for Sustainability, 26*(1), 119–140.

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

SPAN. (2022). *Malaysia water industry report 2022*. Suruhanjaya Perkhidmatan Air Negara.

Tan, E., Jaafar, N. F., Tan, S. H. A., & Mohd Zanuri, N. B. (2022). A review of plastic and microplastic pollution towards the Malaysian marine environment. *IOP Conference Series: Earth and Environmental Science, 1013*(1).

Tang, K. H. D. (2019). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Science of the Total Environment, 650*, 1858–1871.

Thyer, B. A. (1993). Single-system research design. In R. M. Gunnell (Ed.), *Social work, research and evaluation* (4th ed.). Peacock Publishers.

UNESCO. (2020). *Education for sustainable development: A roadmap*. Paris, France: United Nations Educational, Scientific and Cultural Organization.

Wang, X. M., Wang, S. M., Wang, J. N., Hwang, G. J., & Xu, S. (2023). Effects of a two-tier test strategy on students' digital game-based learning performances and flow experience in environmental education. *Journal of Educational Computing Research*.

Zhang, S., Xia, Z., Wang, T., Williams, B. K., Szaro, R. C., Shapiro, C. D.,Ross, L. (2013). Serious games: Improving public policy through game-based learning and simulation. *Environmental Modelling & Software*.