



Enhancing Urban Water Resilience Awareness through Interactive Geospatial Learning

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Article Info

Article history:

Received: February 20, 2026

Revised: May 17, 2026

Accepted: June 10, 2026

Keywords:

Environmental Education,
Interactive Geospatial Media,
Quasi-Experimental Study,
Spatial Cognition,
Urban Water Resilience.

Abstract

Urban water resilience has become an essential component of environmental education, yet students often struggle to understand the complex relationships among hydrological processes, spatial vulnerability, and mitigation strategies using conventional instructional media. This study investigated the effectiveness of interactive geospatial learning in enhancing students' urban water resilience awareness. A quasi-experimental pretest-posttest control group design was conducted with 120 eleventh-grade students from two intact classes in Jakarta. Students in the experimental group learned through an interactive geospatial platform that enabled exploration of hydrological layers, spatial risk visualization, and scenario-based environmental analysis, whereas the control group received conventional instruction using static visual materials. Urban water resilience awareness was assessed using a situational judgment test measuring hydrological understanding, spatial vulnerability, and mitigation decision-making. The findings indicate that students who learned with interactive geospatial media demonstrated substantially greater improvement than those receiving conventional instruction. Most students in the experimental group achieved high levels of learning improvement and successfully met the expected learning mastery criteria. These findings suggest that interactive geospatial learning provides an effective technology-enhanced approach for strengthening spatial reasoning, environmental literacy, and urban water resilience awareness in secondary education.

To cite this article: Nasrudin, A., Indra, T. L., Hanita, M., & Ras, A. R. (2026). Enhancing urban water resilience awareness through interactive geospatial learning. *Online Learning in Educational Research*, 6(1), 245-256. <https://doi.org/10.58524/oler.v6i1.984>

INTRODUCTION

There are various threats to urban areas, such as land subsidence, frequent floods, declining levels of underground water, and rising sea level that have become a challenge in terms of urban water resilience (Atmojo & Wardana, 2025). From the perspective of environmental education, learning urban ecosystem dynamics with particular emphasis on urban water resilience requires learners to develop strong spatial cognition (Rohmah et al., 2023). The current explanations of multidimensional phenomena like tidal flood vulnerability (Takagi et al., 2016), seawater intrusion, and land subsidence (Abdullah et al., 2021; Abidin et al., 2005) can no longer work using conventional methods. Therefore, the incorporation of the use of interactive media technology and HCI techniques is very necessary in turning the hydrological data into understandable information (Alegre, 2023; Fan et al., 2023; Johan et al., 2024).

In spite of an increasing awareness regarding the importance of technology for environmental education (Alshammari et al., 2023; Ayu et al., 2025), the development of instructional media for this

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area still lags behind similar advances made in other fundamental sciences. Past literature indicates that there is a large research gap regarding the empirical analysis of geospatial media as instructional media inside or outside the classroom environment (Oje et al., 2025). At present, most media used for environmental education are characterized by linearity or static representation, which reduces the learners' participation in the learning process (Boateng & Kalonde, 2024). Studies investigating the use of interactive geospatial media in the context of teaching about urban water resilience are scarce (Azisah et al., 2025).

As a solution to this gap, this research brings novelty in developing and validating interactive geospatial media that will serve as a technology-enhanced learning environment (Andriani et al., 2023; Hakim et al., 2025; Reyes et al., 2024). Unlike the existing research in which GIS is presented as a tool used for analyzing geographic information by experts, this research aims to develop interactive geospatial technology and integrate it in a learning platform to facilitate the learning of urban water resilience (Thiagarajan & Semmel, 1976). The learners can interact in various ways with the geospatial media, including manipulating water management layers, simulating sea level rise cases, and assessing spatial risks in real time (Amri et al., 2024; Rahmawati et al., 2022; Wang et al., 2024).

As coastal megacities face a race against time against the climate crisis, accelerating public environmental literacy through digital interventions has become an urgent necessity (Andreas et al., 2018; Taftazani et al., 2022). Learning media that fail to facilitate deep understanding will result in a sluggish shift toward pro-environmental behavior in society (Zhou & Wang, 2022). Responding to these challenges, this study aims to evaluate the effectiveness of interactive geospatial media in increasing urban water resilience awareness (Hakim et al., 2020). Utilizing a quasi-experimental research design (Pretest-Posttest Control Group Design), this study empirically measures differences in comprehension improvement through normalized gain scores (Coletta, 2023; Coletta & Steinert, 2020) between a treatment group facilitated by interactive media technology and a control group using conventional static visual media. Figure 1 illustrates the urban water vulnerability context in Jakarta that served as the geographical basis for the development of the instructional materials used in this study.

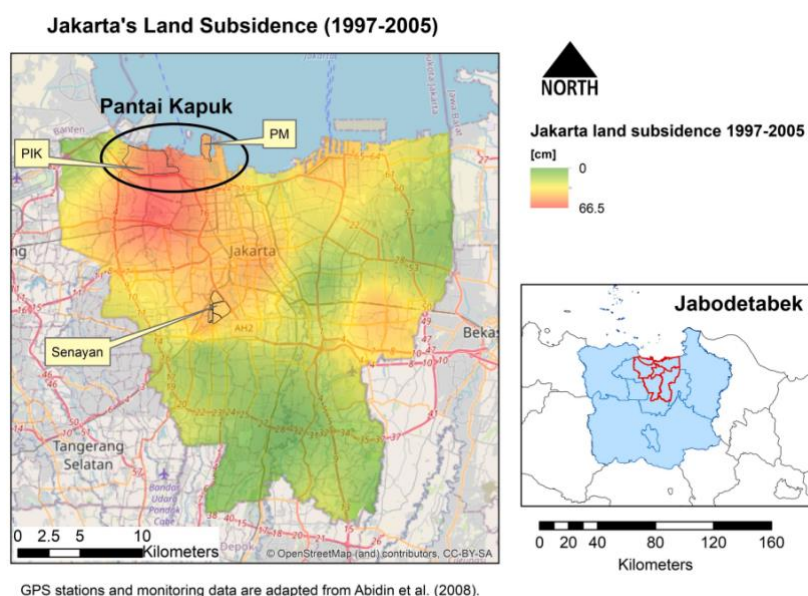


Fig. 1. Jakarta's land subsidence (1997–2005).

Figure 1. Urban Water Vulnerability Context in Jakarta used as the Geographical Basis for the Instructional Materials.

Theoretically, the findings of this study will provide a significant contribution to Human-Computer Interaction (HCI) literature in education, specifically regarding how spatial interactivity facilitates knowledge transfer for complex socio-scientific issues (Rozikin & Palas, 2021; Taupik & Fitria, 2023). Grounded in the stages of cognitive development (Cherry, 2024), the use of interactive media—such as virtual simulations and virtual laboratories—has been proven to enhance science

literacy and students' critical thinking skills (Putri et al., 2021; Rahmania, 2021). Practically, this study provides a blueprint for educators to implement technology-assisted inquiry or project-based learning models (Allanta & Puspita, 2021; Aulia & Yuliani, 2023; Bulu & Tanggur, 2021; Herlita et al., 2023). These approaches have demonstrated efficacy in increasing motivation and learning outcomes (De Freitas, 2018; Petrusly et al., 2024; Rahayu & Setiana, 2024), ultimately serving to build climate-literate and disaster-resilient communities.

METHOD

The research methodology applied in this research is quantitative, with the use of a quasi-experimental design involving a non-equivalent control group (Creswell, 2009). The choice of the quantitative framework enables the researcher to compile empirical data in order to be able to statistically compare the cognitive results obtained by the students after the digital intervention. It can be seen in Table 1 that the Pre-test/Post-test Control Group Design was adopted.

Table 1. Pretest-Posttest Control Group Design.

Class	Pre-test	Treatment	Post-test
Experimental	O_1	X	O_2
Control	O_3	-	O_4

Note. O_1 and O_3 represent the pretest observations, whereas O_2 and O_4 represent the posttest observations for the experimental and control groups, respectively.

The pedagogical intervention for the Experimental Group (X_1) lies in the Technology-Enhanced Learning (TEL) system that utilizes Interactive Geospatial Media. In this scenario, students work with interactive maps using built-in hydrological and spatial data sets in order to visualize the immediate spatial impacts of certain actions. On the other hand, the Control Group (X_2) uses the conventional pedagogical approach through which students use the static cartographic visualization methods along with didactic text instructions.

Population and Sampling Strategy

The research was carried out at the state senior high school in Jakarta, which is a strategically selected setting because of the school's position as a "living lab" for the water crisis problems and rapid land subsidence in an urban environment. The target population consisted of the Grade XI students focusing on Geography and Environmental Science subjects. In the research, two intact Grade XI classes were used as a sample, in line with the current organization of the classrooms in the selected school, which is common in quasi-experimental studies in education.

Psychometric Instrumentation and Validation

Environmental Literacy and Awareness will be assessed using an Environmental Literacy and Awareness Test, which has been developed as a Situational Judgment Test (SJT). Unlike conventional tests, which are based on recall, the SJT demands spatial reasoning for resolving practical urban resilience problems.

For the validation of the instrument, a two-step procedure was followed:

- **Content and Face Validity:** The items were evaluated by four subject matter experts, including two from Hydrological Engineering and two from Instructional Design. Qualitative inputs were obtained from these experts regarding the relevancy, appropriateness, and consistency of each item with the construct.
- **Pilot Testing:** The instrument was administered to another group of respondents ($n = 30$) to obtain Cronbach's Alpha and the Point-Biserial Correlation scores.

Furthermore, a fidelity-of-implementation checklist, which was administered using the Guttman Scale, was also used to ensure the consistency between the lessons taught and delivered by the teachers in both groups.

Data Analytical Procedure

Data analysis employed a hierarchical statistical approach. Immediately after the experiment was over, all pre-test and post-test scores were converted into digits and cleansed. Before any inferential tests, the assumption of Levene's Test for Homogeneity of Variance was carried out to ensure the validity of parametric analysis. The reliability of the tool was firstly verified in the course of classical item analysis. The Item difficulty index ($P = B/N$) was measured as the ratio of the number of students who gave a right answer to an item to the total number of students. In turn, the Discrimination index (D) served as an indicator of how well an item can differentiate between better and worse performing students. The interpretation of the difficulty and discrimination indices was done in accordance with Ebel and Frisbie (1991) guidelines.

The key hypothesis of the study was tested via an independent-samples t-test to compare the mean post-test score and N-Gain between two groups following the verification of baseline equivalence via pre-test comparison. Finally, to overcome the limitations of p-value, Cohen's d Effect Size was calculated to determine the effect size of the intervention.

RESULTS AND DISCUSSION

Instrument Feasibility Analysis

Before applying the pre-test and post-test to the experimental group and control group, the research tools used were empirically tested to check for their validity and reliability. The test was concerned with the measurement of urban water resilience awareness through situational judgment. Table 2 below shows the validity and reliability test results of the initial testing tool.

Table 2. Validity and Reliability of the Initial Test Instrument.

Aspect	Item	Pearson Correlation (r)	Sig. (2-tailed)	Cronbach's Alpha	Status
Hydrological Concepts	1	0.682	0.000	0.845	Valid
Spatial Vulnerability	2	0.715	0.000	0.845	Valid
Spatial Vulnerability	3	0.594	0.001	0.845	Valid
Mitigation Strategies	4	0.812	0.000	0.845	Valid
Mitigation Strategies	5	0.640	0.000	0.845	Valid

The instrument consisted of five scenario-based items designed to assess three dimensions of urban water resilience awareness: hydrological concepts, spatial vulnerability, and mitigation strategies. Each item represented an authentic environmental situation requiring students to apply conceptual understanding within a contextual decision-making task. Based on Table 2, all items obtained a Pearson Correlation value (r_{count}) greater than the r_{table} (0.361) with a significance level below 0.05. Furthermore, the instrument demonstrated acceptable internal consistency, with a Cronbach's alpha coefficient of 0.845 in the pilot sample.

Following the validity and reliability tests, the difficulty level and discrimination index of each item were analyzed to ensure that the questions adequately differentiate between high- and low-achieving students, and are neither too difficult nor too easy. The results are summarized in Table 3.

Table 3. Item Difficulty and Discrimination Index.

Item	Difficulty Index	Category	Discrimination Index	Category
1	0.65	Medium	0.45	Excellent
2	0.42	Medium	0.52	Excellent
3	0.75	Easy	0.38	Good
4	0.35	Medium	0.61	Excellent
5	0.58	Medium	0.40	Excellent

It can be seen from Table 3 that most of the questions lie in the medium level of difficulty, which makes it apt for an experimental pretest/posttest design. Discrimination indices are between good and excellent levels, which indicate that these questions have discriminative ability among the spatial and environmental concepts taught to students. Figure 2 shows the user interface of the interactive geospatial learning module employed for the intervention.

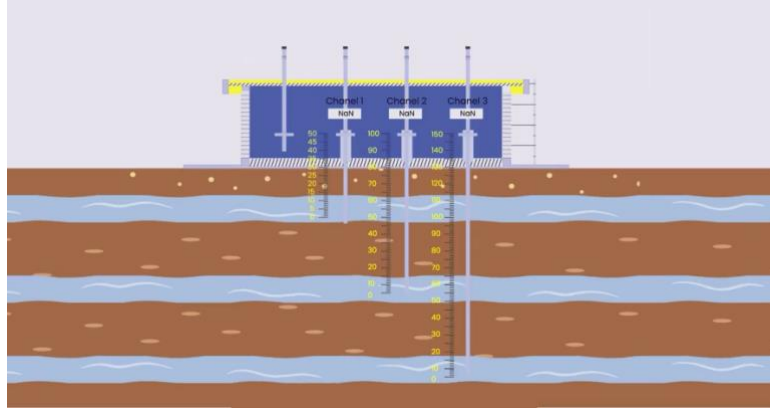


Figure 2. Main Display of the Interactive Geospatial Learning Module.

Implementation of Interactive Geospatial Media

The procedure for implementation was observed by two evaluators separately using an identical observation checklist, and any inconsistencies were ironed out by discussions after every observation period. The observers employed a Guttman scale observation checklist to measure the competence of the teacher in conducting the spatial simulation among the learners. This was done over three observation sessions as shown in Table 4.

Table 4. Results of Observation on the Learning Process.

Meeting	Observer 1 (%)	Observer 2 (%)	Average (%)	Category
1	82.50	85.00	83.75	Very Good
2	88.00	86.50	87.25	Very Good
3	92.50	90.00	91.25	Very Good

The outcomes of the observations presented in Table 4 indicate that there has been an improvement in how the technology-assisted learning environment has been applied. The average score on the observations increased from 83.75% in the first session to 91.25% in the last session. 'Very Good' in all sessions indicates that the very high scores on the observations demonstrate that the teaching process has been appropriately applied according to the intervention plan.

Hypothesis Testing (Independent Samples T-Test)

To determine whether there is a significant difference in the urban water resilience awareness between the experimental group and the control group after the intervention, an Independent Samples T-Test was conducted on the post-test scores. Before the t-test, Levene's Test for Equality of Variances was performed to ensure the data met the homogeneity assumption. The results of the hypothesis testing are presented in Table 5.

Table 5. Independent Samples T-Test Results for N-Gain Scores.

Variable	Experimental (n = 60) M ± SD	Control (n = 60) M ± SD	Mean Difference	t(df)	p
N-Gain Score	0.72 ± 0.115	0.41 ± 0.108	0.31	8.654 (118)	< .001

From Table 5, the experimental group obtained significantly higher N-Gain scores compared to the control group. From the t-test output, there is a significance value (2-tailed) of 0.001, which is less than 0.05 alpha level ($p < 0.05$). It shows that the null hypothesis (H_0) is rejected while the alternative hypothesis (H_1) is accepted. Thus, the experimental group obtained significantly higher N-Gain scores compared to the control group, $t(118) = 8.654$, $p < .001$. In order to assess whether the improvement brought by the intervention has practical significance, an effect size using Cohen's d method was calculated. The effect size analysis showed that the value of Cohen's d is 2.78, showing a very large effect based on Cohen's (1988) criteria.

Effectiveness Analysis (N-Gain Score)

Although the t-test reveals a statistical significance between the scores obtained at the end by both groups, it is still not enough to determine the exact measure of the progression of the students from pre-test to post-test. In order to analyze the comparative improvement in students' performance results, the concept of normalized gain (N-Gain) has been applied. The use of N-Gain acts as a very reliable tool to measure the score gain after the conceptual inventory instructions have been imparted to the students. Descriptive statistics of the N-Gain scores for both cohorts encompassing minimum and maximum values, the mean, and standard deviation, are detailed in Table 6.

Table 6. Descriptive Statistics of N-Gain Score.

Class	N	Minimum	Maximum
Experimental Class	60	0.45	0.92
Control Class	60	0.18	0.68

Table 6 presents the distribution range of the N-Gain scores observed in both groups. The experimental group showed a higher minimum and maximum gain than the control group, indicating a generally stronger improvement across participants. The integration of authentic land subsidence data in Jakarta—as mapped by Abidin et al. (2005), Abdullah et al. (2021), and Hakim et al. (2020)—demonstrably transforms abstract hydrological concepts into palpable visual realities. Such findings offer a global perspective that resonates with international scholarship; specifically, the efficacy of this technology-mediated instruction reinforces Alegre's (2023) observations in the Philippines regarding the synergy between innovation and student engagement. Furthermore, it aligns with Alshammari et al. (2023) in Saudi Arabia, who underscored the integration of technological pedagogical knowledge as a foundational step toward sustainable development. This consistency is further mirrored in the work of Zhou & Wang (2022) in China, where precise message visualization was found to catalyze pro-environmental behaviors.

Explicitly, the outcomes of this study corroborate several previously cited reputable frameworks, including:

- The SAMR Model and Motivation: Aligning with Boateng & Kalonde (2024), who posit that technology integration serves as the primary catalyst for unlocking learning motivation.
- Virtual Simulation and Inquiry: Consistent with findings by Amri et al. (2024), Putri et al. (2021), and Reyes et al. (2024), which demonstrate that virtual simulations and interactive laboratories significantly bolster conceptual mastery through experiential activities.
- Critical Thinking and Spatial Analysis: These findings strengthen the research of Allanta & Puspita (2021), Aulia & Yuliani (2023), Herlita et al. (2023), and Rohmah et al. (2023), all of whom indicated a positive correlation between interactive media and students' critical thinking and mathematical-spatial analytical skills.
- Experimental Learning: Supporting the meta-analysis by Wang et al. (2024), which asserts that the synthesis of real-world and virtual experimentation yields significant pedagogical advantages.

The higher proportion of students in the experimental group achieving the "High" N-Gain category may be explained by the Cognitive Theory of Multimedia Learning, which suggests that integrating visual and verbal information through interactive learning environments facilitates meaningful knowledge construction and improves learning outcomes (Mayer, 2009). The strategic use of gamification elements to mediate learning engagement was analyzed by Petrusly et al. (2024) and De Freitas (2018). To provide a more granular depiction of this progression, N-Gain scores for all

participants were classified into three distinct categories: High ($g \geq 0.70$), Medium ($0.30 \leq g < 0.70$), and Low ($g < 0.30$). The frequency distribution is detailed in Table 7.

Table 7. Frequency Distribution of N-Gain Categories.

N-Gain Category	Criteria	Experimental Group		Control Group	
		Frequency	Percentage (%)	Frequency	Percentage (%)
High	$g \geq 0.70$	42	70.0	0	0.0
Medium	$0.30 \leq g < 0.70$	18	30.0	51	85.0
Low	$g < 0.30$	0	0.0	9	15.0
Total		60	100	60	100

Given the empirical findings in Table 7, there is clearly a huge difference in terms of the effectiveness of instruction in the two groups. The experimental group was predominantly represented by the "High" category at 70% ($n=42$), while the control group did not yield any learners in this category. On the other hand, the control group was largely made up of the "Medium" category at 85% ($n=51$), with 15% in the "Low" category. It is clear from this finding that the use of interactive geospatial media is far better than conventional media in improving cognitive achievement. Analysis reveals that manipulation of dynamic spatial layers in the interactive geospatial medium reduces the cognitive load of the learners when dealing with hydrological data and spatial vulnerability of Jakarta mega-city.

The utilization of interactive geospatial media—integrating real-world land subsidence data as mapped by Abidin et al. (2005) and Abdullah et al. (2021)—effectively transforms abstract mathematical and spatial concepts into tangible visual realities. These findings reinforce the global perspective that the efficacy of technology-based education is contingent upon the synergy between media innovation and active student engagement, as reported by Alegre (2023) and Alshammari et al. (2023), who highlight the integration of technological pedagogical knowledge as an essential step toward sustainable development. This comparison confirms that accessible data visualization has become a new standard in modern education for overcoming cognitive barriers in complex subject matter.

Furthermore, the results align closely with the study by Boateng & Kalonde (2024) regarding the SAMR model, where technology integration catalyzes learning motivation. The use of interactive simulations in this research is consistent with findings by Amri et al. (2024) and Putri et al. (2021), which assert that virtual simulation tools significantly enhance conceptual mastery through inquiry-based activities. Moreover, the dominance of high N-Gain categories confirms the theories of Coletta (2023) and Coletta & Steinert (2020) regarding normalized gain score distributions as valid indicators of instructional effectiveness. This also resonates with the meta-analysis by Wang et al. (2024), which demonstrates that the combination of real and virtual experimentation yields significant learning advantages.

Theoretically, this study makes a tangible impact by bridging the gap between mathematical-spatial literacy and environmental literacy. Precise digital learning strategies are proven to effectively sharpen students' critical thinking skills, matching the findings of Allanta & Puspita (2021), Aulia & Yuliani (2023), and Herlita et al. (2023). The implication is that leveraging Human-Computer Interaction (HCI) based technology is not merely a trend but a critical strategy for fostering ecological awareness and data-analysis capabilities within the senior high school level.

To support the above-mentioned findings, along with the testing of significant differences and N-Gain indices, a proportion test was performed to see if the number of students who reached the minimum criterion of mastery (the score of ≥ 75) was greater than the classical mastery level of 75% ($p_0 = 0.75$). For this purpose, a one-tailed Z-test for a proportion was performed. The results of the proportion test to see if the proportion of students exceeded the defined effectiveness criterion of 75% are presented in full detail in Table 8.

Table 8. Proportion Test Results for Learning Mastery.

Group	Zcount	Ztable	Decision
Experimental	2.09	1.64	Reject H_0
Control	-2.98	1.64	Fail to reject H_0

Table 8 illustrates that students' overall ecological awareness levels exceeded expected benchmarks following interaction with the Interactive Geospatial Media. The one-tailed Z-test showed that the proportion of students in the experimental group achieving the predetermined mastery criterion exceeded the benchmark ($Z = 2.09$, $p < .05$), leading to the rejection of the null hypothesis. In contrast, the control group yielded a negative Z value ($Z = -2.98$), indicating that the observed proportion did not exceed the criterion; therefore, the null hypothesis was not rejected. These results underscore the efficacy of digital instruments in promoting 21st-century environmental literacy, specifically by enhancing spatial cognition, comprehension of hydrological systems, and disaster mitigation awareness within the context of urban water resilience.

In this study, the deployment of Interactive Geospatial Media offers a dynamic and transformative platform that augments environmental education by providing students with direct access to spatial simulations (Amri et al., 2024; Putri et al., 2021), geographical data visualizations (Fan et al., 2023), and the manipulation of environmental variables (Coletta & Steinert, 2020). Such pedagogical affordances are remarkably difficult to achieve through static maps or traditional lecture-based methods. The interactive nature of this medium fosters student agency and initiative (Boateng & Kalonde, 2024), empowering learners to independently explore the threats of water crises while receiving real-time feedback on their decisions. For instance, within spatial planning scenarios, this web-based tool provides elevation layer visualizations and tidal flood simulations that significantly bolster students' spatial understanding and analytical reasoning. Furthermore, the accessibility of this medium ensures that students can conduct in-depth investigations into geographical phenomena throughout the instructional process.

When integrated into the Environmental Education curriculum, Interactive Geospatial Media enhances pedagogical effectiveness by providing a more concrete and meaningful learning experience. These findings align with Zhou & Wang (2022), who reported that the implementation of geospatial visualization technology is highly effective in fostering climate crisis awareness. By interacting with authentic water management data within an experimental learning structure, students are given the opportunity to analyse real-world ecological challenges. Alshammari et al. (2023) further support this approach, noting that environmental simulations encourage student initiative, risk evaluation, and socio-scientific reasoning. Similarly, Alegre (2023) highlights that this interactive instructional model empowers learners to translate abstract data into urgent realities, thereby facilitating deeper learning. Unlike traditional didactic methods, geospatial media positions students as active analysts, accelerating their cognitive transformation by requiring them to observe, predict, and synthesize spatial information while addressing the threat of land subsidence.

Interactive Geospatial Media proved significantly more effective in increasing water resilience awareness compared to conventional media, particularly within the context of Jakarta's water management crisis. This corresponds with De Freitas (2018), who noted that spatial manipulation approaches are superior to textual learning in developing disaster literacy. By focusing on pressing environmental issues, this interactive medium successfully cultivates a sense of moral responsibility (Rahayu & Setiana, 2024). By analysing empirical data regarding groundwater extraction and its impact on residential areas, students were able to bridge the gap between their daily consumption habits and macro-threats on the city's northern coast. This perceived relevance, combined with the opportunity to approach problems from the perspective of urban planners or geographers (Atmojo & Wardana, 2025), motivates students to feel a sense of urgency regarding the crisis. The medium's emphasis on causal exploration not only sharpens spatial analysis skills but also nurtures pro-environmental attitudes, preparing students to become resilient, ecologically conscious urban citizens.

Several crucial factors distinguish the Interactive Geospatial Media developed in this study from other digital learning tools. First, it features time-sliders and parameter simulations that allow students to instantaneously test hypotheses regarding the impacts of groundwater pumping (Wang

et al., 2024) and visualize the expansion of flood-prone zones directly on their screens (Abidin et al., 2005). Second, it facilitates scenario-analysis tasks where students must identify correlations between water-pump density and land subsidence rates within an integrated interface. These situational evaluation activities challenge students to think critically, formulate spatial predictions, and devise mitigation solutions based on manipulated geospatial data. Such features provide significant benefits by allowing students to grasp complex Urban Water Resilience concepts through contextual, experiential learning (Petrusly et al., 2024; Taupik & Fitria, 2023). Furthermore, the synthesis of Human-Computer Interaction (HCI) elements into environmental education not only supports comprehensive theoretical understanding but also bridges the divide between scientific data and public awareness.

Though it is clear from the results that students in the experimental group were able to score much higher on urban water resilience awareness than those in the control group, the quasi-experimental nature of the design, along with the lack of complete control over possible confounding variables, calls for a careful analysis of the results. Hence, the differences noted can be taken to suggest the efficacy of the intervention rather than establish causation.

LIMITATIONS

This paper acknowledges various limitations that should be considered when interpreting the results. Some of these include a scope that is limited to the study of ecological dynamics in the Jakarta megacity and a sample size that is relatively small, which may limit the generalizability of the results to varied geographical contexts. In terms of technical challenges, the interactive geospatial media used may have hindered data rendering for learners with limited hardware capabilities and/or internet access. Moreover, the researchers were unable to completely control for any possible confounding variables such as the digital literacy of the instructors, the learners' spatial literacy, as well as the possibility of high cognitive load due to the complex nature of the visual interface presenting multiple data layers at once.

CONCLUSION

This study finds that the incorporation of interactive geospatial media technology is remarkably helpful in increasing awareness of urban water resilience among the learners, thus helping solve pedagogical issues in environmental education. The experimental group, which used this medium, has recorded increased comprehension and classical mastery scores as compared to the control group, which used traditional visual media. This is possible due to well-refined HCI technology that converts complex spatial hydrological data into self-controlled and dynamic visualization, which could be helpful for learners in processing complex spatial information. This interactivity allows shifting from a passive approach to an active approach in learning by allowing learners to understand the relationships between human activities and spatial vulnerabilities. This study finds that there is the ability of interactive geospatial media technology to increase the awareness of urban water resilience among the learners in environmental education. However, considering the quasi-experimental nature of the study and the inability to control confounding variables, more studies should be conducted using experimental designs.

AUTHOR CONTRIBUTIONS

AN contributed to conceptualization, investigation, data curation, formal analysis, methodology, visualization, and writing the original draft. TLI contributed to conceptualization, methodology, validation, supervision, and writing review and editing. MF contributed to validation, formal analysis, resources, and writing review and editing. ARR contributed to supervision, project administration, and writing review and editing. All authors have read and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the school principal, teachers, and students who participated in this study for their valuable cooperation throughout the research process. The authors also thank the experts who provided constructive feedback during the instrument validation stage. Their support and valuable insights greatly contributed to the successful completion of this research.

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