Contemporary Educational Technology, 2024, **16**(3), ep521
ISSN: 1309-517X (Online)

OPEN ACCESS

Research Article

Strengthening student empathy in GeoCapabilities: Digital learning innovations and pedagogical strategies for disaster mitigation

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Citation: Sugiyanto, Muryani, C., & Ni'matussyahara, D. (2024). Strengthening student empathy in GeoCapabilities: Digital learning innovations and pedagogical strategies for disaster mitigation. *Contemporary Educational Technology, 16*(3), ep521. https://doi.org/10.30935/cedtech/14913

ARTICLE INFO

Received: 16 May 2024

Accepted: 6 Jul 2024

ABSTRACT

Indonesia's geographical positioning along the 'Ring of Fire' exposes it to frequent seismic activities, making effective disaster mitigation education crucial. Current educational strategies may not adequately foster the necessary empathy and understanding among students regarding the socio-environmental impacts of disasters. This study aims to develop and evaluate a digital learning platform designed to enhance GeoCapabilities in students, particularly focusing on the social-environmental empathy dimension. The objective is to improve students' empathetic responses to disaster scenarios through integrated disaster mitigation pedagogy. Utilizing the design-based research method, this research involved a systematic blend of iterative development and evaluation phases to refine educational interventions. Data collection was achieved through a combination of qualitative feedback from students and quantitative pre- and post-test measures to assess empathy levels. Data analysis involved statistical testing to determine the effectiveness of the digital learning platform in enhancing empathetic capabilities among learners. The research reveals that the digital learning platform (D-Learning), significantly improves students' empathy towards disaster impacts. Students demonstrated a deeper understanding and emotional engagement with the content, highlighting an increase in their ability to empathize with affected communities. The findings suggest that the scalability of D-Learning can be tailored to different regions, providing a valuable tool for enhancing disaster preparedness worldwide. The integration of technology and empathy-focused pedagogy in disaster education could serve as a model for developing similar educational programs globally, aiming to foster a more resilient and empathetic future generation.

Keywords: digital learning, disaster mitigation, empathy, GeoCapabilities

INTRODUCTION

GeoCapabilities, a structured approach to enhancing students' understanding of geographical concepts and their practical application in addressing global issues, has attracted considerable attention from researchers focused on geography curricula and teacher development worldwide (Bladh, 2020). Integrating GeoCapabilities into the educational curriculum is crucial for fostering students' geographical understanding and their ability to navigate and address global challenges (Biddulph et al., 2020). The positive impact of this approach includes the development of critical thinking (Maude, 2020), spatial awareness (Mitchell et al., 2022), and global citizenship skills (Franklin et al., 2022; Labianca, 2021; Vega, 2022). Despite its proven benefits in

fostering geographical understanding and critical thinking, there remains a significant gap in integrating empathy and digital learning platforms into GeoCapabilities, especially for enhancing disaster preparedness among students.

GeoCapabilities is intrinsically linked to the enhancement of student empathy by enriching their understanding of diverse cultures, environments, and the interconnectedness of global communities (Biddulph et al., 2020). According to Bustin et al. (2020), GeoCapabilities provides a valuable framework for incorporating geography into educational curricula, facilitating the development of empathy among students through exposure to various cultural and environmental contexts and global interdependencies. By enhancing students' empathetic abilities, GeoCapabilities prepares them to act with compassion and responsibility in a globally interconnected world, highlighting the importance of its inclusion in educational programs (Seremet et al., 2021). The GeoCapabilities framework within the dimension of social-environmental empathy encompasses knowledge of issues, knowledge of action strategies, locus of control, attitudes, and a sense of individual responsibility (Siddiqua et al., 2022).

Geography has the potential to train students to think critically about the earth and global infrastructure by emphasizing perspectives on place and space, socio-environmental relationships, and future environmental scenarios (Skarstein & Wolff, 2022). This potential can be realized through empathy (Sheppard, 2022), which involves the capacity to emotionally perceive and understand nature, especially when it is under threat. Empathy merges cognitive and emotional faculties with environmental awareness, fostering a reciprocal relationship (Brown et al., 2019; Fido & Richardson, 2019). It supports learner pedagogy by contributing to the development of geographical competence (Tracey & Hutchinson, 2019). Effective delivery and application of empathy in education can be achieved through both synchronous and asynchronous approaches, enhancing learner engagement (i.e., behavioral, cognitive, affective, and social) and considering the learning context (i.e., physical, technological, and social environmental features) to create meaningful learning experiences (Morel, 2021; Walker & Weidenbenner, 2019). Creating meaningful learning has been a challenge for educators long before the advent of digital learning (Bagoly-Simó et al., 2020).

Numerous studies focus on integrating extensive geographical knowledge into educational curricula and enhancing GeoCapabilities. Research by Ryan and Aasetre (2020) illustrates that digital learning systems can improve learning experiences, critical thinking, and problem-solving by offering immersive and interactive environments. Similarly, Peter and Sprenger (2022) also elucidate that digitalization is critical to geography education as it contributes to opportunities and challenges from a subject- and education-specific perspective. Sonrum and Worapun (2023) discovered that problem-based learning activities simulating real-world disaster scenarios enable students to develop critical thinking skills and respond effectively under pressure. Similarly, Collins et al. (2022) emphasized the importance of collaboration and communication among students, which are essential skills in disaster response.

In addition to these approaches, gamification has emerged as a powerful tool in education, leveraging game design elements to enhance learner engagement and motivation (Hellín et al., 2023). Incorporating gamification into GeoCapabilities can provide a more interactive and engaging learning experience, fostering a deeper understanding of geographical concepts and empathy through immersive simulations (Saleem et al., 2021). Studies have shown that gamification can significantly improve student motivation and learning outcomes by making educational content more engaging and relevant (Lampropoulos & Sidiropoulos, 2024).

Mitchell (2022) addresses curriculum development in geography education by emphasizing holistic student development, integrating geographical skills and competencies into practical applications. In teacher training, Mitchell et al. (2022) highlight diverse methods, including project-based learning (PjBL) and digital teaching adaptation. Social justice in geography education, as detailed by Biddulph et al. (2020), integrates equity and advocacy into teaching practices, emphasizing critical pedagogy and the role of educators in promoting inclusive, responsive education. Many studies focus on integrating substantial geographical knowledge into educational curricula and enhancing GeoCapabilities, yet they do not explicitly address the incorporation of technology-integrated empathy within their research methodologies. The absence of comprehensive empathy-based digital learning systems, despite the use of various technological tools, limits students' geographical capabilities, such as disaster mitigation, while platforms that incorporate empathy-based learning improve interaction, teamwork, and emotional support during simulations. Embedding digital

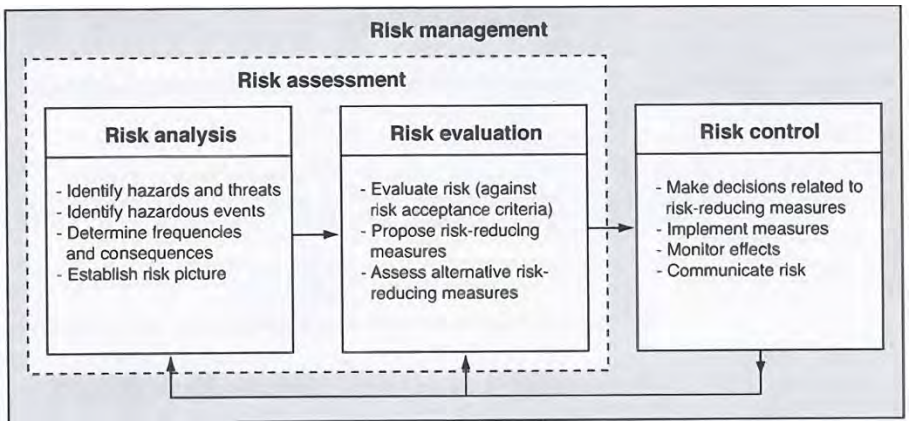

Figure 1. Disaster risk management (Source: Authors)

technologies in geography curricula can enhance spatial thinking and structured exploration, enabling students to better understand and respond to environmental challenges (Kerski, 2023).

The critical need for this research is highlighted by the increasing frequency and intensity of natural disasters globally, with disaster-prone regions such as Indonesia being particularly affected. Indonesia's location on the 'Ring of Fire' renders it highly vulnerable to natural disasters, emphasizing the necessity for early education on disaster management (Prawoto & Octavia, 2021). Due to geological, geomorphological, climatological, and anthropogenic factors, the archipelago has experienced numerous natural disasters, impacting millions and underscoring the essential requirement for comprehensive disaster preparedness (Amri et al., 2021; Ayuningtyas et al., 2021). Current geography education in Indonesia has not yet developed the necessary competencies to adequately prepare students for these challenges. Therefore, there is an urgent need for innovative educational approaches that incorporate digital technologies and empathy to enhance disaster preparedness and resilience from an early age.

Digital tools that incorporate empathy can provide realistic disaster simulations, enabling students to comprehend the dynamics of disasters and think critically about potential solutions (Sim et al., 2020). Research indicates that using technology to simulate disaster scenarios helps students develop a deeper understanding and preparedness for real-life events. Experts have found that realistic simulations can enhance the cognitive and practical skills needed for effective disaster response (Luzi et al., 2021). Embedding these simulations in the curriculum provides students with practical insights and readiness for emergencies, significantly improving their ability to manage real-world disaster situations (Drumhiller, 2021). Furthermore, integrating digital simulations in geography education allows for a more engaging and immersive learning environment, fostering essential skills in disaster preparedness and response (Perpiñá-Galvañ et al., 2021). Early disaster education is essential as it fosters a culture of preparedness and resilience from a young age, significantly enhancing community response to disasters (Krishna, 2021). This method not only improves students' cognitive skills but also builds empathetic and proactive citizens capable of managing crises effectively (Røe et al., 2022).

To further understand the role of education in disaster preparedness, it is essential to consider the interconnectedness of various concepts in disaster risk reduction. **Figure 1** depicts the interconnectedness of the three principal concepts in disaster risk reduction, underscoring their mutual relationship. Effective disaster risk reduction management requires a balanced integration of these concepts (Nohrstedt et al., 2021). Preparedness, as a critical element of disaster mitigation, plays a pivotal role. Establishing equilibrium among these concepts ensures a comprehensive and resilient approach to disaster risk management, with each concept reinforcing the others (Shi et al., 2020). This balanced framework is crucial for enhancing community resilience and reducing the adverse impacts of disasters. The limited disaster preparedness and mitigation knowledge among the Indonesian population, which predominantly focuses on adults, exacerbates disaster impacts. Consequently, education plays a vital role in enhancing disaster mitigation capabilities through improved technology and information quality, and by strengthening the disaster preparedness education system in schools (Ayuningtyas et al., 2021; Hoffmann & Blecha, 2020; Satchwell et al., 2024).

The current state of geography education in Indonesia has not yet achieved the desired capabilities, as this level of learning development has primarily been attained by several European countries (Uhlenwinkel et al., 2017). European countries, particularly those with a strong emphasis on education, have made significant advancements in the level of learning development in geography education. These advancements include comprehensive curricula that integrate modern teaching methods, technology, and up-to-date information. According to a study by Granados-Sánchez (2022), geography educators in Europe are actively integrating sustainability into their curricula, which has a transformative impact on students' understanding of geography and its applications. In contrast, the geography education system in Indonesia has not yet achieved the desired capabilities. This is partly due to limited resources, less emphasis on geography in the educational curriculum, and insufficient integration of modern technology and teaching methodologies. Kamil et al. (2020) highlight the limited disaster preparedness and mitigation knowledge among the Indonesian population, which exacerbates the impacts of disasters.

To address these challenges, it is essential to focus on developing GeoCapabilities, which encompass a combination of behaviors, skills, processes, and knowledge that influence competency outcomes in both educational settings and daily life (Bladh, 2020; Banfield & Dovidio, 2012; Gouramanis & MoralesRamirez, 2020; Maude, 2020; Su, 2014). According to Walkington et al. (2018), GeoCapabilities comprise five essential components that geography educators and learners must possess:

(1) geographic imagination,

(2) empathy and caring,

(3) integrative thinking,

(4) spatial thinking, and

(5) structured exploration of place.

These capabilities are particularly vital for students in a geologically active region like Indonesia (Thouret et al., 2022). Thus, there is a pressing need for geography learning resources aimed at fostering students' social-environmental empathy through spatial knowledge (Sebastián-López & González, 2020). Such educational resources can cultivate students into active citizens with resilient disaster preparedness capabilities (Hosseini & Izadkhah, 2020).

Previous research on GeoCapabilities in geography education has several limitations. These studies emphasize integrating geographical knowledge into curricula and developing GeoCapabilities but fail to incorporate technology-integrated empathy. The lack of empathy-based digital learning systems restricts students' ability to develop crucial geographical skills, such as disaster mitigation. Additionally, most research has focused on adult disaster preparedness education, neglecting the vital role of younger demographics in disaster response and resilience (Kamil et al., 2020). This gap results in a lack of pedagogical content aimed at enhancing students' social-environmental empathy, essential for effective disaster management and mitigation (Satchwell et al., 2024; Tkachuck et al., 2018).

This study addresses the gap in traditional geography education by developing a Digital Learning (D-Learning) platform to enhance students' GeoCapabilities, particularly in the dimension of social-environmental empathy. D-Learning serves as a disaster mitigation support system designed to strengthen students' pedagogical and affective behaviors (Di Fabio & Kenny, 2021) through content feedback and adaptive empathy acquisition (Wu et al., 2020). The implementation of D-Learning as a digital technology platform aims to improve students' educational experiences by addressing the limitations and weaknesses of conventional learning methods (Khanal et al., 2022; Song et al., 2023). This comprehensive digital media-based disaster mitigation learning support system provides an effective approach to fostering empathy and enhancing pedagogical outcomes.

D-Learning encompasses various elements such as in-depth material, e-modules, individual and group activities, case studies, analytical exercises, sample images, videos, assessments, and reflections (Bereczki & Kárpáti, 2021; Keengwe & Georgina, 2012). This platform utilizes both national and international disaster case studies to encourage the development of GeoCapabilities, particularly in the social empathy dimension, within students' environments (Sakurai & Shaw, 2022). The D-Learning platform is underpinned by advanced learning technology, facilitating multi-sensory interactions and human relational responses (Shulga, 2023).

Table 1. Percentage analysis validity criteria (Arikunto, 2010)

Percentage	Criteria
0% – 20%	Not feasible
21% – 40%	Not worth it
41% – 60%	Decent enough
61% – 80%	Worthy
81% – 100%	Very worthy

These features are crucial in fostering essential empathy characteristics among students, thereby enhancing their overall learning experience and effectiveness in disaster mitigation education.

In this study, the researchers developed D-Learning integrated with disaster mitigation pedagogical content to enhance GeoCapabilities in students, specifically focusing on the social-environmental empathy dimension related to disaster mitigation capability. This integration aims to cultivate a deep understanding of disaster mitigation among students, thereby improving their ability to empathize with affected communities and environments. D-Learning, combined with disaster pedagogy, facilitates students' comprehension of local disasters and mitigation strategies. The development integrates disaster mitigation pedagogy with students' empathy dimension, yielding a significant moral and transformative impact through quality learning. The D-Learning innovation is an effective solution to enhance GeoCapabilities in students' empathy towards disaster mitigation. Therefore, the D-Learning innovation developed in this research is expected to increase social-environmental empathy in students' disaster mitigation activities from an early age.

The research question guiding this study is: "How can the design and implementation of D-Learning enhance students' GeoCapabilities, particularly in the social-environmental empathy dimension, as a disaster mitigation support system?"

METHOD

This research was conducted under the framework of design-based research, incorporating both qualitative and quantitative methodologies as recommended by Goff and Getenet (2017). Design-based research, a collaborative endeavor between researchers and practitioners, emphasizes practical innovation in educational environments (Cochrane et al., 2023). By utilizing this framework, the research can systematically design, implement, and evaluate the digital-learning platform, ensuring that it effectively enhances students' social-environmental empathy.

The participant of this research comprised 72 eleventh-grade students from an Indonesian public high school, specifically chosen based on a needs analysis which highlighted low environmental empathy and recurring flood occurrences within the vicinity of the school. This selection was strategically made to target particular educational deficits and to gather empirical evidence concerning the impact of educational interventions. The methodologies employed for data collection encompassed observations, examinations, questionnaires, document reviews, and interviews. The research adopted qualitative and quantitative analyses to scrutinize the data, with a focus on evaluating the feasibility of the D-Learning model. This evaluation involved conducting tests for normality and homogeneity, as well as an independent sample t-test utilizing SPSS version 22, to determine statistical variances in empathy skills prior to and following the intervention.

The feasibility of the D-Learning framework was assessed based on two main dimensions: content quality and design quality, each comprising various indicators, as outlined in **Table 1**. The effectiveness of this platform was measured by comparing the empathy skill scores of students from the pre- to the post-test, employing statistical tests to ensure the integrity of the data. The results were classified according to Cohen's effect size standard, enabling a determination of the effectiveness level of the D-Learning platform when amalgamated with educational content on disaster mitigation (Ellis, 2010).

The methodology employed followed a structured four-stage process. The initial stage involved a need analysis focusing on the prevalent learning models utilized by teacher within the geography subject. Subsequently, an assessment of the requirements of both teachers and students was conducted to ascertain the necessity for an effective geography learning model aimed at fostering empathy in students within the context of disaster preparedness. This phase of practical problem analysis served as the foundation for

developing an initial prototype model as a viable solution to real-world challenges (Amiel & Reeves, 2008; Plomp & Nieveen, 2010). Employing a qualitative approach, the research subjects included teachers, and students, with data collection techniques encompassing in-depth interviews, classroom observations, and document analyses. Data analysis utilized the constant comparative method (Babbie, 2010). This stage focused on understanding the specific needs related to fostering empathy in students within the context of disaster preparedness. By identifying these gaps and challenges, the researchers ensured that the D-Learning platform addresses the real and practical needs of geography education.

The second stage was development of alternative solutions. This stage focused on designing the D-Learning platform using innovative educational technology and pedagogical principles. The methodology involved literature review and consultation with competent experts. Expert judgments were analyzed using constant comparative and descriptive statistical methods. The researcher prepared the prototype, conducted expert assessments, tested the model, and refined it accordingly. The design incorporated elements aimed at improving empathy and disaster mitigation understanding. The development of the D-Learning platform based on innovative educational technology and pedagogical principles ensures that the solution is tailored to effectively enhance students' empathy. This stage addresses how the platform can be structured to meet the educational objectives related to GeoCapabilities.

The third stage was implementation and testing. This stage involved deploying the D-Learning platform in a real-world classroom setting and collecting data through pre- and post-tests to measure its impact on students' empathy. By implementing and testing the platform in a real-world setting, the study gathers empirical evidence on its effectiveness. This stage directly answers the research question by showing how the platform influences students' GeoCapabilities, specifically their social-environmental empathy, through measurable changes in their empathy levels.

The last stage was reflection and evaluation. This stage involved analyzing the outcomes to refine the D-Learning platform further and evaluate its effectiveness based on design principles. Reflection and evaluation ensure that the D-Learning platform is continually improved based on feedback and data. The stages of development are shown in **Figure 2**.

FINDINGS AND DISCUSSION

The Analysis of Practical Problems

To initiate the development of D-Learning platform, designed in alignment with pedagogical content knowledge (PCK) concerning disaster mitigation, the first step undertaken by the researchers was to conduct a needs analysis to understand the specific requirements and gaps in the current educational practices. This stage involves evaluating the necessity for digital technology in the learning system by examining the characteristics of geography education related to the empathy dimension applied by teachers and identifying students' learning styles. This comprehensive evaluation ensures that the product development is tailored to the specific needs of both teachers and students. The analysis phase directs the development of the product, focusing on three aspects:

(1) product type,

(2) concept, and

(3) product characteristics.

Regarding the product type, the development of the product type stemmed from the outcomes of a media needs analysis questionnaire that evaluated the current utilization of D-Learning tools. The survey disclosed that 88.24% of students rarely interact with digital learning during their classroom sessions. Furthermore, educators noted the absence of prior implementation of disaster education through D-Learning, contributing to students' limited grasp of disaster concepts.

Regarding the product concept, the analysis determined that the instructional approaches used by educators to foster socio-environmental empathy in geography classes are inadequate. Specifically, the data showed that 45.16% of students expressed uncertainty, while 39.16% disagreed with the assertion that

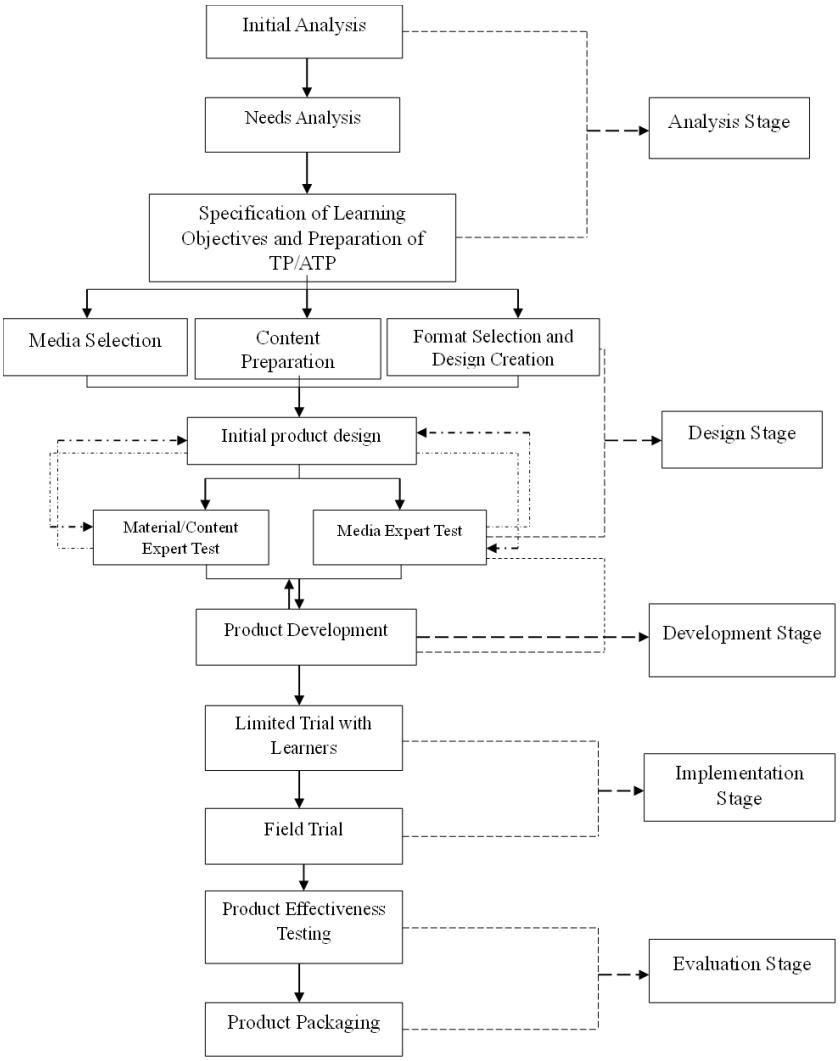

Figure 2. Product development framework (Source: Authors)

teachers effectively imparted these skills. This underscores the necessity for innovative teaching methodologies that can more effectively incorporate empathy into geography education.

Regarding the product characteristics, the development of D-Learning was guided by a survey that identified students' preferred learning styles, revealing that 73% favor visual learning methods. This finding ensures that the platform is tailored to accommodate the predominant learning preferences of students, thereby enhancing its effectiveness and appeal. The initial data analysis indicates that students' empathy in disaster mitigation remains relatively low. To address this, researchers have developed a D-Learning resource accessible to both teachers and students via all types of digital devices, at any time and from any location.

To determine the pedagogical content of the D-Learning platform, an investigation into students' disaster knowledge and mitigation strategies was conducted. The results from a questionnaire administered to 72 students at a public senior high school revealed a significant need to enhance disaster knowledge through more comprehensive disaster mitigation content. Consequently, the D-Learning platform incorporates PCK on disaster mitigation, presented in a more detailed and practical manner.

These data highlight several critical points. Firstly, the limited interaction with digital learning tools suggests a significant opportunity for the integration of D-Learning in geography education, particularly in disaster mitigation. This gap indicates a need for enhancing digital engagement in educational practices. Secondly, the considerable percentage of students expressing uncertainty or disagreement with the effectiveness of their teachers in fostering empathy through current instructional approaches points to the necessity for innovative teaching strategies. This gap underscores the potential for D-Learning platforms to address these deficiencies by providing more engaging and effective instructional content. The last, the

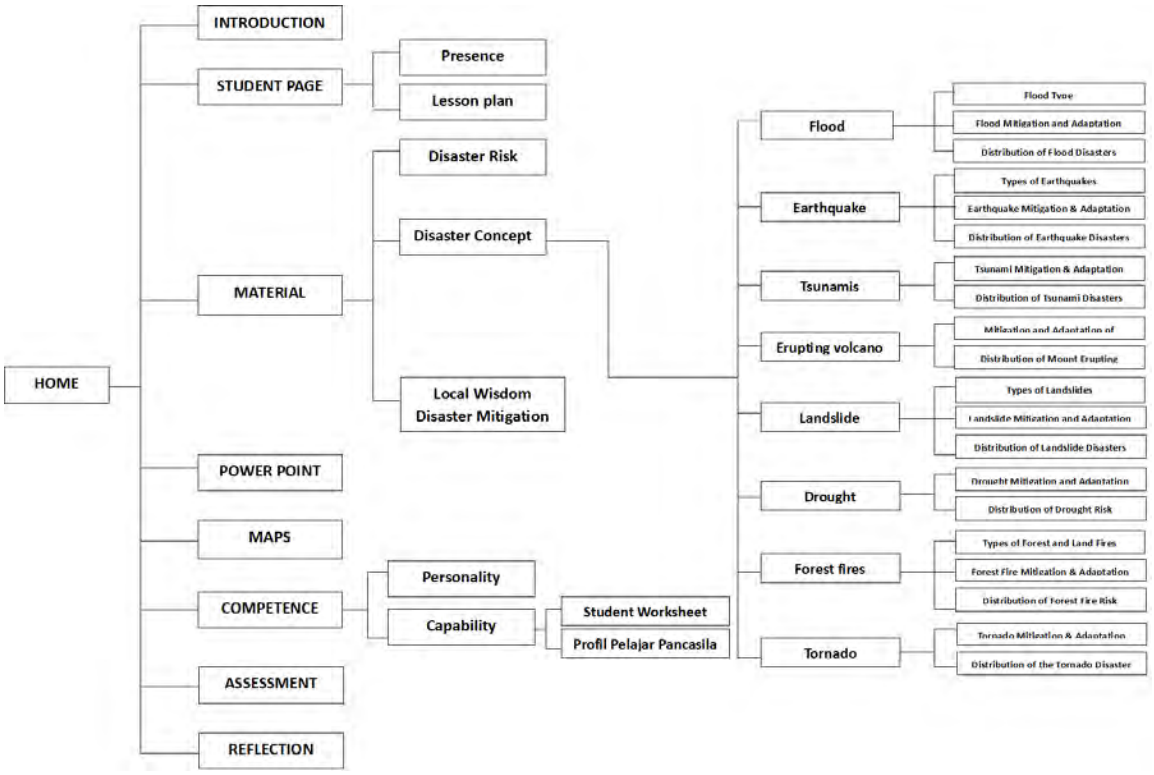

Figure 3. D-Learning design and structure (Source: Authors)

preference for visual learning methods among 73% of students indicates that the D-Learning platform should heavily incorporate visual elements to cater to these preferences, thereby enhancing learning outcomes and student engagement.

The development of a D-Learning platform aligns with the contemporary shift in education towards digital and interactive learning environments. According to Tursinbaevna et al. (2023), the use of digital learning platforms in education significantly improves student engagement and understanding of complex subjects. Similarly, Lian et al. (2022) emphasize that visual learning tools are essential in making abstract concepts more tangible and understandable for students. Furthermore, the importance of empathy in education, particularly in socio-environmental contexts, is well-documented. Rach (2024) suggests that teaching empathy through innovative digital platforms can significantly enhance students' socio-environmental awareness and responsiveness. This finding underscores the necessity of the D-Learning platform's focus on fostering empathy through disaster mitigation education.

The Development of Alternative Solutions

The primary outcome of this study is the formulation of a D-Learning platform, meticulously crafted to align with PCK related to disaster mitigation, with the aim of augmenting students' socio-environmental empathy. The development of the D-Learning platform commences with a rigorous analysis phase, evaluating factors such as geographical location, natural environmental conditions, and the socio-cultural context of the community. The pedagogical content integrates disaster mitigation materials focused on comprehending disaster issues, formulating action plans, enhancing internal locus of control, cultivating appropriate attitudes, and nurturing a sense of individual responsibility towards the social environment.

Subsequent to the needs analysis, the researchers progressed to the stages of design and product development. The D-Learning resources were designed to encompass rich content comprising images, videos, spatial data, digital maps, modules, learner worksheets, assessments, and reflective exercises. The comprehensive design and structure of the D-Learning platform ensure it meets identified requirements and effectively supports the enhancement of students' knowledge in disaster mitigation and socio-environmental empathy. **Figure 3** illustrates the detailed design and structure of the D-Learning platform.

Figure 4. Opening page view (Source: Authors)

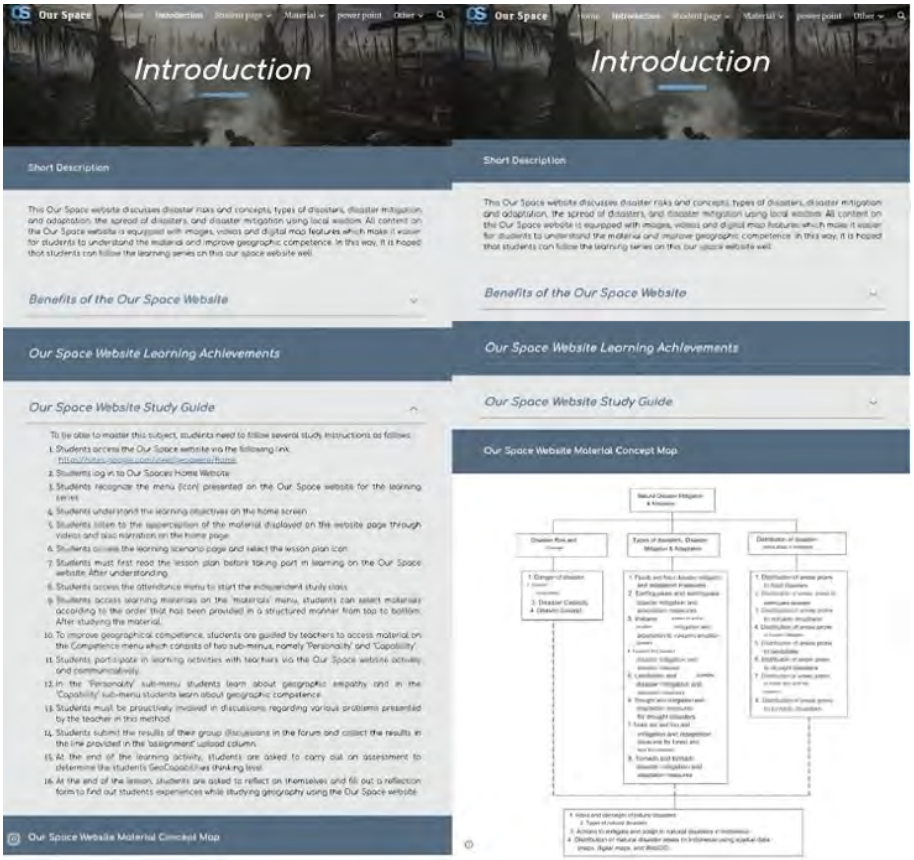

Figure 5. Introduction (Source: Authors)

The flowchart design, integrated into the D-Learning structure, embodies the design stage within the product development process. This initial design evolves into the D-Learning platform, slated for expert and user testing during its development phase.

The outcomes of this product development effort are showcased in **Figures 4–8**.

Figure 6. D-Learning pedagogical content on flood studies (Source: Authors)

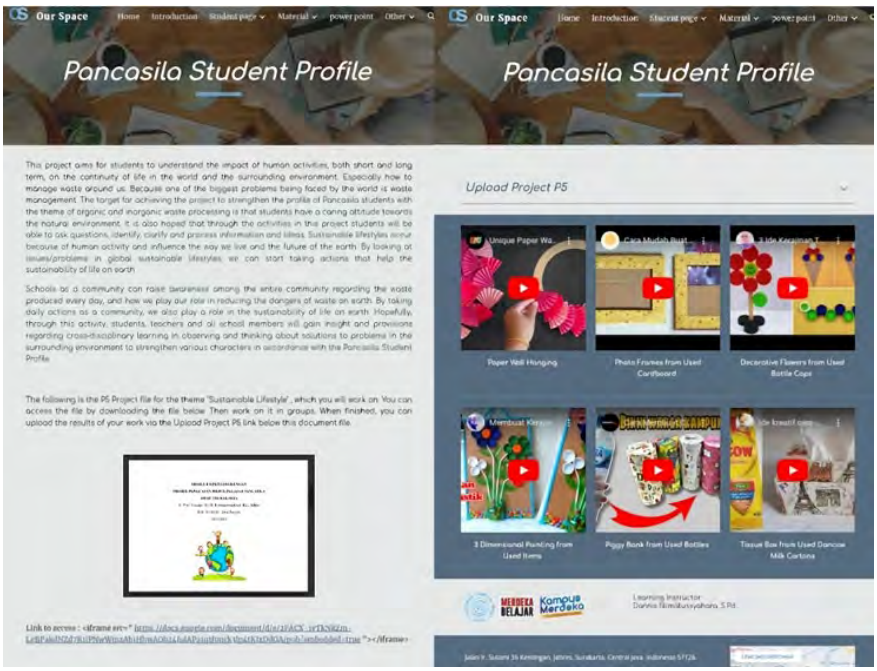

Figure 7. Modules, individual, and group activity sheets to train empathy (Source: Authors)

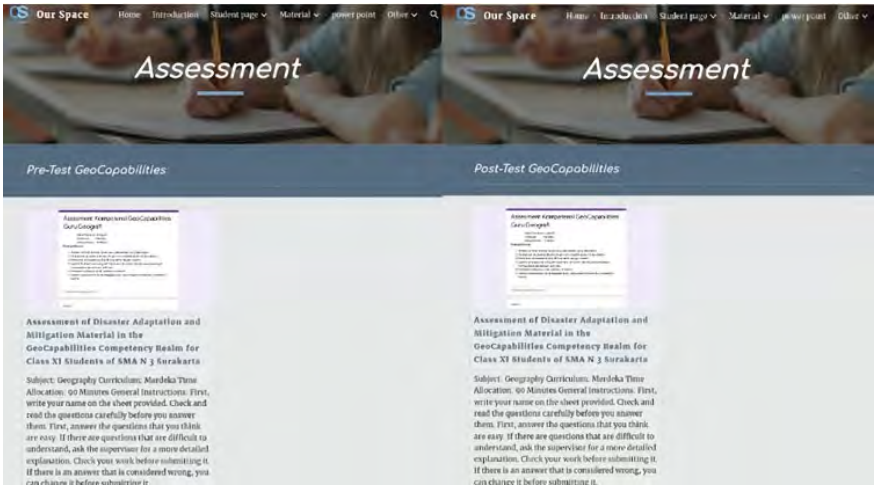

Figure 8. Evaluation view in D-Learning (Source: Authors)

Table 2. Media expert validation

Assessment components	Assessment criteria/scale					Total	Average score
	Very less (1)	Not enough (2)	Enough (3)	Good (4)	Very good (5)		
Website introduction	0	0	0	2	1	13	4.30
User control	0	0	0	3	0	12	4.00
Website appearance	0	0	0	13	7	87	4.35
Multimedia design principles	0	0	0	3	2	22	4.40
F	0	0	0	21	10	134	4.42
%	0	0	0	67.74	32.26	**88.4%**	
Category						**Very worth it**	

Table 3. Material expert validation

Assessment components	Assessment criteria/scale					Total	Average score
	Very less (1)	Not enough (2)	Enough (3)	Good (4)	Very good (5)		
Introductory aspects	0	0	0	3	1	17	4.25
Content aspect	0	0	0	8	3	47	4.27
Evaluation aspect	0	0	2	1	2	20	4.00
Empathy aspect	0	0	0	5	0	20	4.00
F	0	0	2	17	6	104	4.16
%	0	0	8	68	24	**83.2%**	
Category						**Very worth it**	

Table 4. User validation

No	Assessment items	Website criteria	Number of questions	Percentage (%)	Category
1	Media	Ease of website operation	7	81.6	Very worthy
		Website appearance design	15	79.6	Worthy
2	Material	Ease of website for studying its content	9	85.4	Very worthy
Average eligibility				**82.2**	**Very worthy**

As a foundation for guiding revisions to the D-Learning product, the validity criteria for percentage analysis, adapted from Arikunto (2010), are outlined in **Table 1**.

Prior to the implementation of the D-Learning platform for end-users, a comprehensive feasibility assessment was conducted through product validation by both material and media experts. The feasibility assessment involved geography education specialists, who possess extensive expertise in content development, as well as media development experts. This dual-faceted evaluation aimed to ensure the robustness and educational efficacy of the D-Learning platform. The validation process was executed offline, utilizing the Our Space website as the access point for the assessment. The results from the expert validation process are detailed, as follows.

Based on data from **Tables 1–4**, varying perceptions on D-Learning's feasibility emerged from expert and user validations.

The consistency test showed an average score of 84.4%, indicating strong support for its "very feasible" application. This validates D-Learning's potential to enhance socio-environmental empathy in disaster mitigation among students.

Expert endorsement emphasized educational efficacy and content integrity, while user feedback highlighted practical usability and engagement. The platform's multimedia resources, and interactive modules cater to diverse learning styles, ensuring comprehensive disaster education. These insights affirm D-Learning's readiness for implementation, bridging educational gaps and fostering proactive attitudes towards environmental challenges.

Learners exhibited positive and enthusiastic responses to the D-Learning approach, attributed to several key factors: comprehensive material on disaster topics within D-Learning; availability of modules and activity sheets for both individual and group work; inclusion of relevant images and videos related to disasters in Indonesia; provision of evaluations designed to assess the development of learners' socio-environmental empathy; and a socio-technical scenario-based design of D-Learning that enhances empathy learning.

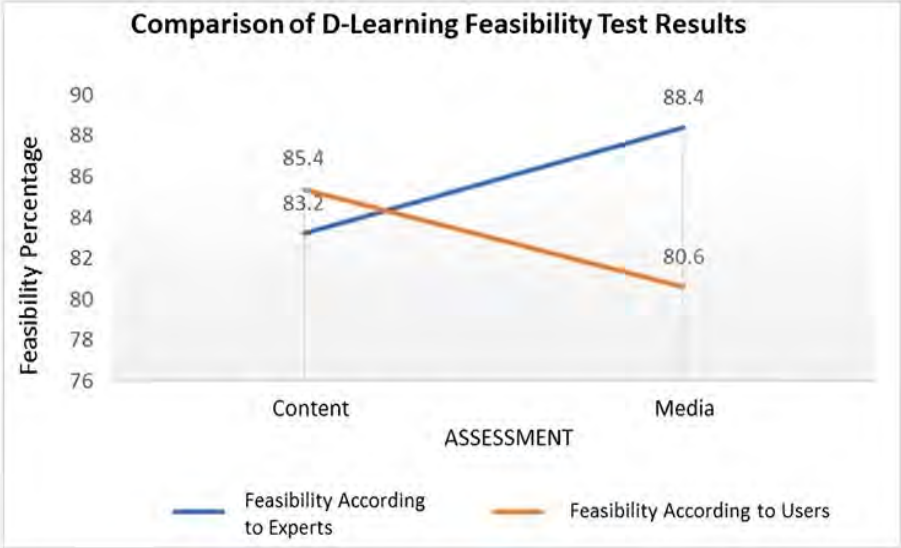

Figure 9. D-Learning feasibility graph (Source: Authors)

The primary outcome of this study was the successful development of a D-Learning platform aimed at enhancing students' socio-environmental empathy, particularly in disaster mitigation contexts. The analysis phase revealed a significant gap in the use of digital learning tools, with 88.24% of students rarely engaging in such activities, and a substantial portion perceiving that current teaching methods inadequately addressed socio-environmental empathy. To bridge this gap, the D-Learning platform incorporated comprehensive pedagogical content focused on disaster mitigation. The platform's design, shaped by students' preference for visual learning methods, included a variety of multimedia resources such as images, videos, digital maps, and interactive modules. This approach aligns with Abdulrahaman et al. (2020), who highlight the effectiveness of multimedia in enhancing learning outcomes and providing unrestricted access to quality education.

The feasibility assessment conducted by material and media experts yielded positive outcomes, with the platform being rated as "very worthy" with an average score of 4.42 out of 5 (**Figure 9**). User validation also indicated high feasibility, with an average eligibility score of 82.2%, suggesting that users found the platform highly effective and engaging. The expert and user feedback underscored the platform's educational efficacy, practical usability, and engaging content. This is consistent with findings by researchers such as Tursinbaevna et al. (2023), who emphasize the importance of integrating digital tools in education to improve learner engagement and performance. The D-Learning platform's multimedia resources and interactive modules cater to diverse learning styles, ensuring comprehensive disaster education and fostering proactive attitudes towards environmental challenges. These insights affirm the platform's readiness for implementation, bridging educational gaps and enhancing socio-environmental empathy in students.

The Implementation and Testing of D-Learning for Disaster Mitigation

D-Learning was implemented between August and November 2023 with 72 eleventh-grade students at a Senior High School in Indonesia. The curriculum employed PjBL to impart disaster education and mitigation strategies. Topics covered included disaster concepts and analysis, types of disasters prevalent in Indonesia, disaster distribution patterns, and effective natural disaster mitigation strategies. Throughout the project, students focused on gaining comprehensive cognitive and emotional-affective understanding of specific local disasters. Group discussions were facilitated to encourage active student engagement and the exchange of ideas.

A comparison of pre- and post-test data between the experimental class, which utilized the D-Learning system, and the control class, which employed PowerPoint for learning purposes, is depicted in **Figure 10** and **Figure 11**.

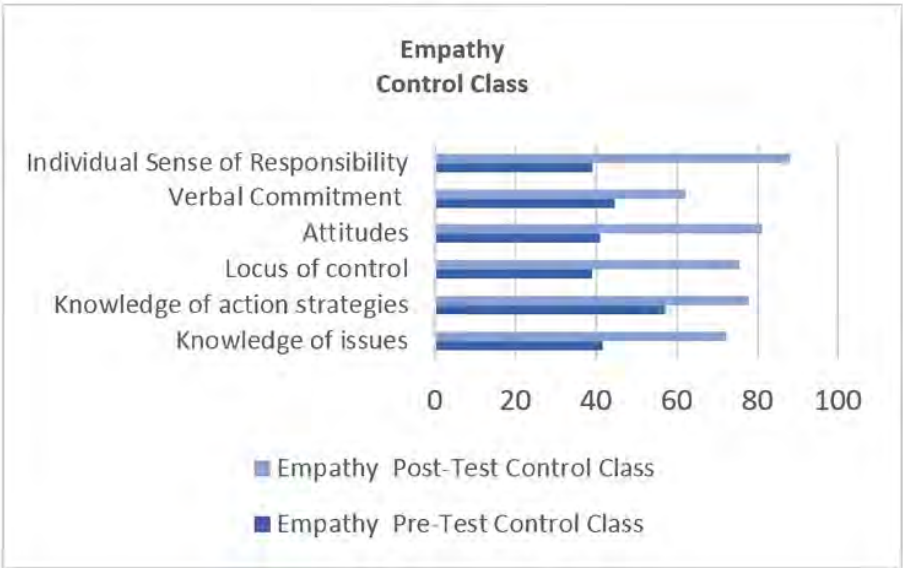

Figure 10. Students' empathy in control class (Source: Authors)

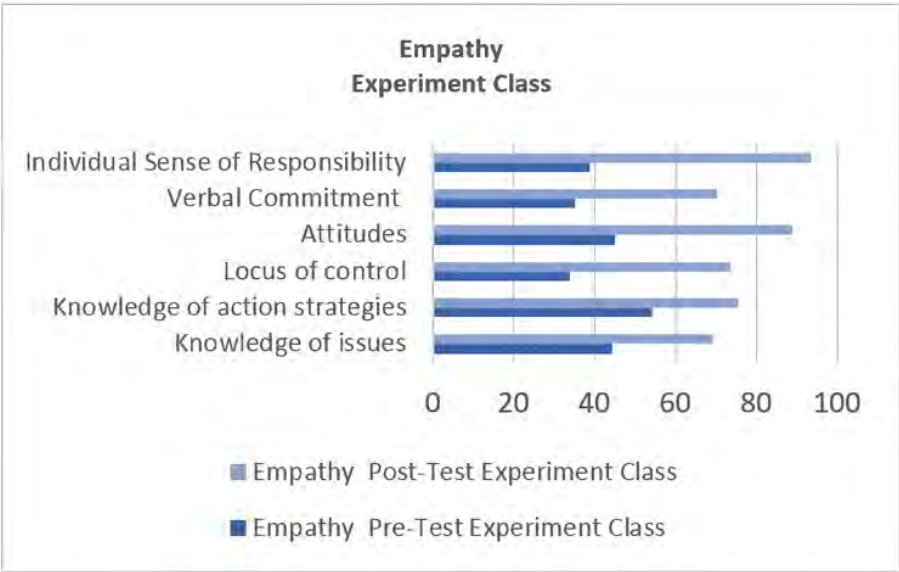

Figure 11. Students' empathy in experimental class (Source: Authors)

Based on the average scores from pre- and post-tests in both the experimental and control groups, it is evident that there was improvement in test results following the implementation of D-Learning (experimental group) and PowerPoint (control group) in the educational process. The experimental group showed the highest enhancement in empathy skills, with a notable increase of 46.58%, while the control group demonstrated a 42.71% improvement in empathy skills.

Throughout the D-Learning implementation phase, we evaluated students' empathy capabilities in disaster mitigation. The progress in students' empathy was assessed by comparing pre- and post-test data concerning their pedagogical and affective competencies before and after utilizing D-Learning. The evaluation of D-Learning's efficacy employed a quasi-experimental design on a limited scale, with data analysis conducted using IBM SPSS Statistics 22. Preliminary tests included parametric assessments of normality, homogeneity, and independent sample T-tests. The normality test utilized the Kolmogorov-Smirnov Z test with a significance level of 5% ($\alpha = 0.05$), detailed in **Table 5**.

Table 5. Tests of normality

Item	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistics	df	Sig.	Statistics	df	Sig.
Student disaster empathy	Pre-test control (PPT+PjBL)	.121	36	.200*	.978	36	.684
	Post-test control (PPT+PjBL)	.107	36	.200*	.961	36	.223
	Pre-test experiment (D-Learning+PjBL)	.122	36	.192	.947	36	.082
	Post-test experiment(D-Learning+PjBL)	.105	36	.200*	.970	36	.426

* This is a lower bound of the true significance

[a] Lilliefors significance correction

Table 6. Test of homogeneity of variances of student empathy capability

Levene statistics	df1	df2	Sig.
1.986	3	140	.119

Table 7. Independent sample t-test

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	MD	SED	95% CID	
									Lower	Upper
Student disaster empathy	Equal variances assumed	.287	.594	-2.896	70.000	.005	-6.361	2.197	-10.743	-1.980
	Equal variances are not assumed			-2.896	69.263	.005	-6.361	2.197	-10.743	-1.979

Note. MD: Mean difference; SED: Standard error difference; CID: Confidence interval of difference

The analysis indicates that D-Learning significantly enhances students' empathy towards disaster mitigation compared to conventional methods like PowerPoint. These findings underscore D-Learning's effectiveness in fostering socio-environmental empathy among students, emphasizing the integration of digital learning technologies in education to tackle complex social and environmental challenges.

Based on the findings presented in **Table 5**, the pre-test scores reflecting students' empathy capabilities exhibit normal distribution patterns, with significance values of 0.684 for the control group and 0.082 for the experimental group. Similarly, the post-test scores concerning students' empathy capabilities also demonstrate normal distribution, with significance values of 0.223 for the control group and 0.426 for the experimental group. These results indicate that both the initial and final assessments of students' empathy capabilities adhere to a normal distribution.

Subsequently, a homogeneity test was conducted to ascertain whether the sample data used in the study were homogeneous or heterogeneous. Levene's test for equality of variances, employing a significance level of 5% ($\alpha = 0.05$), was employed for this purpose. The outcomes of the homogeneity test are detailed in **Table 6**.

The homogeneity test yielded a value of 0.119 for students' empathy capabilities, which exceeds the significance level of 0.05. This indicates that both the pre- and post-test data concerning students' empathy capabilities in disaster mitigation exhibit homogeneous distribution. For the final implementation test, we utilized the Independent Sample t-test analysis method with a significance level of $\alpha = 0.05$. The detailed results of this analysis are provided in **Table 7**.

Based on the outcomes of the independent samples t-test, the statistical significance (Sig. [2-tailed]) is 0.005, with a corresponding t-value of -2.896. Analysis of the t-test data supports the conclusion that the significance level (Sig. [2-tailed]) of 0.005 is below the conventional threshold of 0.05. Moreover, the computed t-value of -2.896 exceeds the critical value derived from the t-distribution table, which is -2.030. These results suggest a notable disparity in mean test scores between students who engaged with D-Learning and those exposed to PowerPoint-based instruction.

Consequently, it is postulated that D-Learning demonstrates superior efficacy in fostering students' empathy capabilities for disaster mitigation, compared to conventional PowerPoint-based methods. Subsequently, an efficacy assessment was undertaken to appraise the impact of the Volcano Disaster Mitigation Module on enhancing students' disaster preparedness.

Table 8. D-Learning effectiveness test using Cohen's standards

Empathy indicator	Effect size	Category
Knowledge of issues	-0.30	Small
Knowledge of action strategies	0.22	Small
Locus of control	0.22	Small
Attitudes	0.82	Big
Verbal commitment	0.89	Big
Individual sense of responsibility	0.59	Currently

Based on Cohen's analysis, the average effect size derived from the D-Learning effectiveness test is 0.41, indicating a "medium" effect size. This suggests that while D-Learning positively impacts students' empathy capabilities, there remains significant potential for enhancing the quality of its educational content. Given this medium effect size, it is evident that the current pedagogical content of D-Learning does not fully encompass all facets of empathy capability. Therefore, further refinement and development of D-Learning content are imperative to comprehensively address all dimensions of empathy (**Table 8**).

Improving the pedagogical content holds promise for enhancing the effectiveness of D-Learning in cultivating deeper socio-environmental empathy among students, particularly in disaster mitigation education contexts. The analysis underscores that D-Learning notably enhances students' empathy towards disaster mitigation more effectively than traditional PowerPoint methods. The results of the Independent Samples t-test reveal a substantial disparity in empathy enhancement between the experimental and control groups, affirming the efficacy of D-Learning.

These findings align with those of Wahyuningtyas et al. (2021), who similarly demonstrated that their developed application for disaster mitigation education significantly enhanced attention, interactivity, presentation quality, feedback mechanisms, and overall learning experience compared to conventional PowerPoint approaches. Moreover, their study established that the application not only improved these educational aspects but also fostered students' empathy towards disaster mitigation.

Reflection and Evaluation of Students' Empathy Activities towards Neighborhood Disaster Mitigation

Environmental and social empathy refer to learners' comprehension of their ecological surroundings on the earth's surface, fostering a profound sense of accountability, empathy, and awareness as local, national, and global citizens with a holistic perspective. The D-Learning platform, which has been developed, incorporates educational resources meticulously crafted to cultivate learners' cognitive disposition towards environmental and social stewardship, often denoted as empathy capability.

D-Learning modules offer versatile approaches for disaster preparedness, combining virtual simulations with hands-on learning experiences. Students can engage in immersive activities, such as simulating disaster scenarios and participating in virtual practical exercises. These interactive tools not only deepen theoretical understanding but also cultivate practical skills essential for responding to real-world emergencies effectively. By integrating virtual and hands-on components, D-Learning enables students to develop comprehensive disaster mitigation strategies and enhances their readiness to tackle diverse challenges in emergency situations. The students' activities in hands-on activities can be seen in **Figure 12**.

This cognitive orientation towards environmental and social stewardship is underpinned by several key indicators: knowledge of pertinent issues, familiarity with actionable strategies, locus of control, attitudinal orientation, and individual sense of accountability. Educational content aimed at inculcating the concept of environmental and social empathy in learners is prominently featured on the platform's personality development page, encompassing aspects of social responsibility and behavioral conditioning.

Furthermore, initiatives geared towards nurturing and enhancing students' environmental and social empathy in a comprehensive and structured manner are prominently highlighted on the Pancasila Student Profile (a set of characteristics that embody the values and principles of Pancasila within the context of student development in Indonesia) page in the form of e-modules. These initiatives offer a methodical approach to fostering empathy through practical and experiential learning endeavors. Similar to

Figure 12. Students' environmental empathy activities (Source: Authors)

Kalogiannakis et al. (2018) who found that Hands-on activities in natural science enhance skills like problem-solving and teamwork, while interactive mobile applications can simulate real-world scenarios.

The empathy module engaged students in proposing solutions and taking tangible actions in real-life scenarios, specifically focusing on addressing the local issue of flood disasters. By using familiar and relevant challenges from their surroundings, the module aimed to stimulate critical thinking, proactive behavior, and problem-solving skills among learners.

The efficacy of this approach is evidenced by the practical projects undertaken by students. These initiatives empowered them to identify and implement specific measures for disaster mitigation, devise innovative solutions for environmental issues, demonstrate confidence in their ability to positively impact environmental conservation efforts, and make informed decisions reflecting environmental stewardship. These outcomes underscore how the empathy module enhanced both practical and cognitive skills among students, preparing them to engage effectively in meaningful environmental initiatives.

Through its emphasis on fostering a deep understanding of students' environments and cultivating a sense of responsibility, empathy, and global citizenship, the D-Learning platform contributes to shaping students' attitudes towards environmental and social responsibility. This aligns with findings from Sebastián-López and González (2020), who highlight the positive impact of digital learning in environmental education on students' attitudes and behaviors related to environmental and social care. The platform achieves this through a comprehensive curriculum that addresses issues, action strategies, locus of control, attitudes, and individual responsibility.

IMPLICATION AND SUGGESTION

The findings of this study have several implications for both theory and practice in the field of digital learning and geography education. Firstly, the identification of a significant gap in students' interaction with digital learning tools highlights a crucial opportunity for educational institutions and policymakers to enhance digital engagement in geography education, particularly in disaster mitigation contexts. By integrating the D-Learning platform developed in this study, which caters to students' visual learning preferences and incorporates comprehensive disaster content, educators can bridge this gap effectively. This not only addresses current deficiencies in disaster education but also prepares students more adequately to understand and respond to disaster scenarios.

Secondly, the study underscores the need for innovative teaching methodologies that foster socio-environmental empathy among students. The dissatisfaction expressed by a substantial percentage of students regarding the effectiveness of current instructional approaches in imparting empathy skills suggests

that traditional methods may be inadequate. The D-Learning platform, with its multimedia-rich content and interactive modules designed to enhance empathy through disaster education, offers a promising alternative. Educators can leverage these tools to create engaging learning experiences that cultivate not only knowledge but also attitudes and values crucial for responsible citizenship and environmental stewardship.

Furthermore, the positive outcomes of the feasibility assessment, including high ratings from both material and media experts, affirm the readiness of the D-Learning platform for implementation in educational settings. The platform's robust validation underscores its potential to improve educational outcomes by providing accessible, engaging, and effective learning experiences. Moving forward, educational institutions can use these findings to guide the integration of digital technologies in curriculum development, ensuring that future generations are better equipped to address complex societal challenges like disaster mitigation.

Based on the findings and limitations identified, the study suggests several avenues for future research in digital learning for disaster mitigation education. These include longitudinal studies to assess long-term impacts, comparative research to evaluate different digital tools, and investigations into policy frameworks. These research directions aim to enhance understanding, effectiveness, and sustainability of digital learning interventions in preparing learners for disaster resilience, thereby advancing educational technology and disaster preparedness efforts.

Limitation and Future Work

This study on digital learning for disaster mitigation education has several limitations that should be acknowledged. Firstly, the research focused predominantly on a specific demographic group, potentially limiting the generalizability of findings across diverse populations. Secondly, the study's reliance on self-reported data and surveys may introduce response bias and affect the accuracy of results. Additionally, the time frame of the study might not capture long-term behavioral changes or impacts of digital interventions. Finally, technological constraints or variations in digital infrastructure across regions could influence the implementation and effectiveness of digital learning tools.

Future research in this area could address these limitations and further advance the field of digital learning for disaster mitigation education. Firstly, longitudinal studies could be conducted to explore sustained impacts and effectiveness over time. Secondly, comparative research across different demographic groups or geographic regions could provide insights into contextual variations and effectiveness of digital tools. Additionally, qualitative studies focusing on user experiences and perceptions could offer nuanced understanding of engagement and learning outcomes. Furthermore, interdisciplinary collaborations integrating education, technology, and disaster management fields could foster innovative approaches and tools. Lastly, policy-oriented research could investigate frameworks and strategies for integrating digital learning into formal education systems and disaster preparedness initiatives effectively.

CONCLUSION

This research aimed to explore the effectiveness of D-Learning in enhancing students' socio-environmental empathy, particularly in the context of disaster mitigation. The study investigated whether learners' knowledge, perception, behavior, and actions could influence their decision-making and lead to more relevant actions in developing social-environmental empathy. The results indicated that D-Learning positively impacts students' ability to process waste and reduce flood risks in their environment, thus fostering a greater sense of social-environmental empathy. Students demonstrated improved disaster preparedness and a more profound emotional and cognitive connection to nature, leading to more responsible environmental behaviors and attitudes. These findings suggest that integrating empathy-based digital learning tools can significantly enhance environmental stewardship and disaster preparedness among students. However, the study acknowledges limitations in the development of D-Learning, particularly in addressing all indicators of socio-environmental empathy. Future research should focus on refining these digital learning tools to cover a broader range of empathy indicators and further investigate their long-term impact on students' environmental actions and preparedness.

Author contributions: S: conceptualization, project administration, supervision, writing–original draft, & writing–review & editing; **CM:** formal analysis, methodology, writing–original draft, & writing–review & editing; **DN:** investigation, resources, visualization, writing–original draft, & writing–review & editing. All authors approved the final version of the article.

Funding: This article was supported by Universitas Sebelas Maret.

Acknowledgements: The authors would like to thank the promoters, validators, reviewers, and everyone else who contributed to and participated in this research.

Ethics declaration: The authors declared that the study was approved by the Institutional Review Board of Sebelas Maret University on September 5, 2023 (Approval code: 20748/UN27.02/PK.03.08/2023). Written informed consents were obtained from the participants.

Declaration of interest: The authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Abdulrahaman, M., Faruk, N., Oloyede, A., Surajudeen-Bakinde, N., Olawoyin, L., Mejabi, O., Imam-Fulani, Y., Fahm, A., & Azeez, A. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, *6*(11), Article e05312. https://doi.org/10.1016/j.heliyon.2020.e05312.

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Educational Technology & Society, 11*(4), 29-40.

Amri, A., Lassa, J. A., Tebe, Y., Hanifa, N. R., Kumar, J., & Sagala, S. (2022). Pathways to Disaster Risk Reduction Education integration in schools: Insights from SPAB evaluation in Indonesia. *International Journal of Disaster Risk Reduction*, *73*, Article 102860. https://doi.org/10.1016/j.ijdrr.2022.102860

Arikunto, S. (2010). *Prosedur penelitian suatu pendekatan praktik* [*Research procedures are a practical approach*] (Vol. 34). Rineka Cipta.

Ayuningtyas, D., Windiarti, S., Hadi, M. S., Fasrini, U. U., & Barinda, S. (2021). Disaster preparedness and mitigation in Indonesia: A narrative review. *Iranian Journal of Public Health*, *50*(8), 1536–1546. https://doi.org/10.18502/ijph.v50i8.6799

Babbie, E. (2010). *The practice of social research*. Wadsworth.

Bagoly-Simó, P., Hartmann, J., & Reinke, V. (2020). School geography under COVID-19: Geographical knowledge in the German formal education. *Tijdschrift Voor Economische En Sociale Geografie*, *111*(3), 224–238. https://doi.org/10.1111/tesg.12452

Banfield, J. C., & Dovidio, J. F. (2012). The role of empathy in responding to natural disasters: Comment on "who helps natural disaster victims?" *Analyses of Social Issues and Public Policy*, *12*(1), 276–279. https://doi.org/10.1111/j.1530-2415.2012.01285.x

Bereczki, E. O., & Kárpáti, A. (2021). Technology-enhanced creativity: A multiple case study of digital technology-integration expert teachers' beliefs and practices. *Thinking Skills and Creativity, 39*. https://doi.org/10.1016/j.tsc.2021.100791

Biddulph, M., Beneker, T., Mitchell, D., Hanus, M., Leininger-Frezal, C., Zwartjes, L., & Donert, K. (2020). Teaching powerful geographical knowledge – A matter of social justice: Initial findings from the GeoCapabilities 3 project. *International Research in Geographical and Environmental Education, 29*(3), 260-274. https://doi.org/10.1080/10382046.2020.1749756

Bladh, G. (2020). GeoCapabilities, *Didaktical* analysis and curriculum thinking – furthering the dialogue between *Didaktik* and curriculum. *International Research in Geographical and Environmental Education, 29*(3), 206-220. https://doi.org/10.1080/10382046.2020.1749766

Brown, K., Adger, W. N., Devine-Wright, P., Anderies, J. M., Barr, S., Bousquet, F., Butler, C., Evans, L., Marshall, N., & Quinn, T. (2019). Empathy, place and identity interactions for sustainability. *Global Environmental Change, 56,* 11-17. https://doi.org/10.1016/j.gloenvcha.2019.03.003

Bustin, R., Lambert, D., & Tani, S. (2020). The development of GeoCapabilities: Reflections, and the spread of an idea. *International Research in Geographical and Environmental Education, 29*(3), 201-205. https://doi.org/10.1080/10382046.2020.1749773

Cochrane, T., Galvin, K., Buskes, G., Lam, L., Rajagopal, V., Glasser, S., Osborne, M., Loveridge, B., Davey, C., John, S., Townsin, L., & Moss, T. (2023). Design-based research. *Proceedings of the 2023 ASCILITE Conference: People, Partnerships and Pedagogies*. https://doi.org/10.14742/apubs.2023.489

Collins, C., Page, H., Semple, P., & Innis, J. (2022). Interprofessional collaboration among first responder students in a simulated disaster exercise. *Journal of emergency management, 20*(3), 273-278. https://doi.org/10.5055/jem.0659

Di Fabio, A., & Kenny, M. E. (2021). Connectedness to nature, personality traits and empathy from a sustainability perspective. *Current Psychology*, *40*, 1095-1106. https://doi.org/10.1007/s12144-018-0031-4

Drumhiller, N. K., Wilkin, T. L., & Srba, K. V. (2021). Introduction to simulation learning in emergency and disaster management. In N. Drumhiller, T. Wilkin, & K. Srba (Eds.), *Simulation and game-based learning in emergency and disaster management* (pp. 1-26). IGI Global. https://doi.org/10.4018/978-1-7998-4087-9.ch001

Ellis, P. D. (2010). *The essential guide to effect sizes.* Cambridge University Press. https://doi.org/10.1017/cbo9780511761676

Fido, D., & Richardson, M. (2019). Empathy mediates the relationship between nature connectedness and both callous and uncaring traits. *Ecopsychology, 11*(2), 130-137. https://doi.org/10.1089/eco.2018.0071

Franklin, R., Delmelle, E. C., Andris, C., Cheng, T., Dodge, S., Franklin, J., Heppenstall, A., Kwan, M.-P., Li, W., McLaffetry, S., Miller, J. A., Munroe, D. K., Nelson, T., Öner, Ö., Pumain, D., Stewart, K., Tong, D., & Wentz, E. A. (2022). Making space in geographical analysis. *Geographical Analysis, 55*(2), 325-341. https://doi.org/10.1111/gean.12325

Goff, M., & Getenet, S. (2017). Design based research in doctoral studies: Adding a new dimension to doctoral research. *International Journal of Doctoral Studies, 12*, 107-121. https://doi.org/10.28945/3761

Granados-Sánchez, J. (2022). Levels of transformation in sustainable curricula: The case of geography education. *Sustainability*, *14*(8), Article 4481. https://doi.org/10.3390/su14084481

Gouramanis, C., & MoralesRamirez, C. A. (2020). Deep understanding of natural hazards based on the Sendai framework for disaster risk reduction in a higher education geography module in Singapore. *International Research in Geographical and Environmental Education, 30*(1), 4–23. https://doi.org/10.1080/10382046.2020.1751391

Hellín, C. J., Calles-Esteban, F., Valledor, A., Gómez, J., Otón-Tortosa, S., & Tayebi, A. (2023). Enhancing student motivation and engagement through a gamified learning environment. *Sustainability*, *15*(19), Article 14119. https://doi.org/10.3390/su151914119

Hoffmann, R., & Blecha, D. (2020). Education and disaster vulnerability in Southeast Asia: Evidence and policy implications. *Community, Environment and Disaster Risk Management, 21*, 17-37. https://doi.org/10.1108/S2040-726220200000021002

Hosseini, K. A., & Izadkhah, Y. O. (2020). From "Earthquake and safety" school drills to "safe school-resilient communities": A continuous attempt for promoting community-based disaster risk management in Iran. *International journal of disaster risk reduction*, *45*, Article 101512. https://doi.org/10.1016/j.ijdrr.2020.101512

Kamil, P. A., Utaya, S., Sumarmi, & Utomo, D. H. (2020). Improving disaster knowledge within high school students through geographic literacy. *International Journal of Disaster Risk Reduction*, *43*, Article 101411. https://doi.org/10.1016/j.ijdrr.2019.101411

Kalogiannakis, M., Ampartzaki, M., Papadakis, S., & Skaraki, E. (2018). Teaching natural science concepts to young children with mobile devices and hands-on activities. A case study. *International Journal of Teaching and Case Studies*, *9*(2), 171-183. https://doi.org/10.1504/IJTCS.2018.090965

Keengwe, J., & Georgina, D. (2012). Digital learning tools for disaster education: A review. *Computers & Education, 59*(3), 946-956. https://doi.org/10.1016/j.compedu.2012.04.013

Kerski, J. J. (2023). Teaching and learning geography with a Web GIS approach. In A. Klonari, M. L. De Lázaro y Torres, & A. Kizos (Eds.), *Re-visioning Geography. Key Challenges in Geography*. Springer, Cham. https://doi.org/10.1007/978-3-031-40747-5_7

Khanal, S., Medasetti, U. S., Mashal, M., Savage, B., & Khadka, R. (2022). Virtual and augmented reality in the disaster management technology: A literature review of the past 11 years. *Frontiers in Virtual Reality*, *3*, Article 843195. https://doi.org/10.3389/frvir.2022.843195

Krishna, R. N. (2021). *Child co-developed and delivered Disaster Resilience Education in Chennai, India* [PhD Thesis, Monash University]. https://doi.org/10.26180/14602881.V1

Labianca, M. (2021). Can GIS foster conscious and critical learning in geography? An application from students to a real case included in the national strategy for inner areas: Monti Dauni, Apulia (Italy). *Sustainability, 13*(16), Article 9246. https://doi.org/10.3390/su13169246

Lampropoulos, G., & Sidiropoulos, A. (2024). Impact of gamification on students' learning outcomes and academic performance: A longitudinal study comparing online, traditional, and gamified learning. *Education Sciences*, *14*(4), Article 367. https://doi.org/10.3390/educsci14040367

Lian, V., Varoy, E., & Giacaman, N. (2022). Learning object-oriented programming concepts through visual analogies. *IEEE Transactions on Learning Technologies*, *15*(1), 78–92. https://doi.org/10.1109/TLT.2022.3154805

Luzi, D., Di Maio, P., & de Lauretis, S. (2021). Realistic simulations and disaster response: Enhancing cognitive and practical skills. *International Journal of Disaster Risk Reduction, 59*, Article 102207. https://doi.org/10.1016/j.ijdrr.2021.102207

Maude, A. (2020). The role of geography's concepts and powerful knowledge in a future 3 curriculum. *International Research in Geographical and Environmental Education, 29*(3), 232-243. https://doi.org/10.1080/10382046.2020.1749771

Mitchell, D. (2022). GeoCapabilities 3—knowledge and values in education for the Anthropocene. *International Research in Geographical and Environmental Education, 31*(3), 265-281. https://doi.org/10.1080/10382046.2022.2133353

Mitchell, D. R., Hanus, M., Béneker, T., Biddulph, M., Leininger-Frézal, C., Zwartjes, L., & Donert, K. (2022). Enhancing teachers' expertise through curriculum leadership—Lessons from the GeoCapabilities 3 project. *Journal of Geography, 121*(2), 162-172. https://doi.org/10.1080/00221341.2022.2149838

Morel, G. M. (2021). Empathy in the shift to digital. *Educational Technology Research and Development, 69*(1), 71-72. https://doi.org/10.1007/s11423-021-09952-z

Nohrstedt, D., Parker, C. F., von Uexkull, N., Mard, J., Albrecht, F., Petrova, K., Nyberg, L., Göteman, M., Hileman, J., Messori, G., & Di Baldassarre, G. (2022). Disaster risk reduction and the limits of truisms: Improving the knowledge and practice interface. *International Journal of Disaster Risk Reduction, 67*, Article 102661. https://doi.org/10.1016/j.ijdrr.2021.102661

Perpiñá-Galvañ, J., Juliá-Sanchis, R., Olmos-Castelló, É., Mollá-Pérez, S., & Sanjuán-Quiles, Á. (2021). European educational programmes in health emergency and disaster management: An integrative review. *International Journal of Environmental Research and Public Health, 18*. https://doi.org/10.3390/ijerph18041905

Peter, C., & Sprenger, S. (2022). Digitalization and geography education – A curriculum analysis. *ERDKUNDE, 76*(1), 3-19. https://doi.org/10.3112/erdkunde.2022.01.01

Plomp, T., & Nieveen, N. M. (2010). Educational design research: An introduction. In *Proceedings of the Seminar Conducted at the East China Normal University*.

Prawoto, E., & Octavia, L. (2021). Disaster storytelling: Extending the memory of the community toward disaster preparedness from myth, scientific explanation, and popular culture. *Journal of Disaster Research*, *16*(2), 228–233. https://doi.org/10.20965/jdr.2021.p0228

Rach, H. (2024). Exploring the geographical lens and the spatial perspective in *Welcome to the New World*. *The Geography Teacher*, *21*(2), 98–100. https://doi.org/10.1080/19338341.2024.2355484

Røe, Y., Wojniusz, S., & Hessen Bjerke, A. (2022). The digital transformation of higher education teaching: Four pedagogical prescriptions to move active learning pedagogy forward. *Frontiers in Education, 6.* https://doi.org/10.3389/feduc.2021.784701

Ryan, A., & Aasetre, J. (2020). Digital storytelling, student engagement and deep learning in geography. *Journal of Geography in Higher Education, 45,* 380-396. https://doi.org/10.1080/03098265.2020.1833319

Sakurai, M., & Shaw, R. (2022). The potential of digitally enabled disaster education for sustainable development goals. *Sustainability*, *14*(11), Article 6568. https://doi.org/10.3390/su14116568

Saleem, A. N., Noori, N. M., & Ozdamli, F. (2021). Gamification applications in e-learning: A literature review. *Technology, Knowledge and Learning*, *27*, 139-159. https://doi.org/10.1007/s10758-020-09487-x

Satchwell, C., Walley, B., Dodding, J., & Lagi, M. D. A. (2024). Conversations across international divides: Children learning through empathy about climate change. *Geographical Research*. https://doi.org/10.1111/1745-5871.12638

Sebastián-López, M., & González, R. (2020). Mobile learning for sustainable development and environmental teacher education. *Sustainability*, *12*(22), Article 9757. https://doi.org/10.3390/su12229757

Şeremet, M., Haigh, M., & Cihangir, E. (2021). Fostering constructive thinking about the 'wicked problems' of team-work and decision-making in tourism and geography. *Journal of Geography in Higher Education, 45*(4), 517-537. https://doi.org/10.1080/03098265.2020.1869924

Sheppard, E. (2022). Geography and the present conjuncture. *Environment and Planning, 1*, 14-25. https://doi.org/10.1177/26349825221082164

Shi, P., Ye, T., Wang, Y., Zhou, T., Xu, W., Du, J., Wang, J., Li, N., Huang, C., Liu, L., Chen, B., Su, Y., Fang, W., Wang, M., Hu, X., Wu, J., He, C., Zhang, Q., Ye, Q., ..., & Okada, N. (2020). Disaster risk science: A geographical perspective and a research framework. *International Journal of Disaster Risk Science, 11*(4), 426-440. https://doi.org/10.1007/s13753-020-00296-5

Shulga, M. (2023). What does digital learning teach? *International Journal of Interactive Mobile Technologies*, *17*(9), 31–43. https://doi.org/10.3991/ijim.v17i09.38313

Siddiqua, A., Akhter, N., & Islam, T. (2022). The GeoCapabilities framework within the dimension of social-environmental empathy encompasses knowledge of issues, knowledge of action strategies, locus of control, attitudes, and a sense of individual responsibility. *Journal of Environmental Education, 33*(2), 145-160. https://doi.org/10.1080/10382046.2022.2133353

Sim, D., Boyle, E., Leith, M., Williams, A., Jimoyiannis, A., & Tsiotakis, P. (2020). Learning about Europe through educational gaming. *Journal of Geography in Higher Education, 45*, 155-161. https://doi.org/10.1080/03098265.2020.1803816

Skarstein, F., & Wolff, L. A. (2020). An issue of scale: The challenge of time, space and multitude in sustainability and geography education. *Education Sciences, 10*(2), Article 28. https://doi.org/10.3390/educsci10020028

Song, J., Yamauchi, H., Oguchi, T., Ogura, T., Nakamura, Y., & Wang, J. (2023). Effects of web geographic information system (GIS) technology and curriculum approaches on education for disaster risk reduction. *Natural Hazards and Earth System Sciences*, *23*(11), 3617–3634. https://doi.org/10.5194/nhess-23-3617-2023

Sonrum, P., & Worapun, W. (2023). Enhancing grade 5 student geography skills and learning achievement: A problem-based learning approach. *Journal of Education and Learning, 12*(5), 188-196. https://doi.org/10.5539/jel.v12n5p188

Su, Y. (2014). Self-directed, genuine graduate attributes: The person-based approach. *Higher Education Research & Development, 33*(6), 1208-1220. https://doi.org/10.1080/07294360.2014.911255

Thouret, J.-C., Wavelet, E., Taillandier, M., Tjahjono, B., Jenkins, S. F., Azzaoui, N., & Santoni, O. (2022). Defining population socio-economic characteristics, hazard knowledge and risk perception: The adaptive capacity to persistent volcanic threats from Semeru, Indonesia. *International Journal of Disaster Risk Reduction, 77*, Article 103064. https://doi.org/10.1016/j.ijdrr.2022.103064

Tkachuck, M. A., Schulenberg, S. E., & Lair, E. C. (2018). Natural disaster preparedness in college students: Implications for institutions of higher learning. *Journal of American College Health*, *66*(4), 269–279. https://doi.org/10.1080/07448481.2018.1431897

Tracey, M. W., & Hutchinson, A. (2019). Empathic design: Imagining the cognitive and emotional learner experience. *Educational Technology Research and Development, 67*(5), 1259-1272. https://doi.org/10.1007/s11423-019-09683-2

Tursinbaevna, G., Muzapparovna, T., & Turganbaevna, K. (2023). The implementation of innovative technologies in teaching geography. *International Journal of Pedagogics*, *3*(10), 53–56. https://doi.org/10.37547/ijp/volume03issue10-10

Uhlenwinkel, A., Beneker, T., Bladh, G., Tani, S., & Lambert, D. (2017). GeoCapabilities and curriculum leadership: Balancing the priorities of aim-based and knowledge-led curriculum thinking in schools. *International Research in Geographical and Environmental Education, 26*(4), 327-341. https://doi.org/10.1080/10382046.2016.1262603

Vega, A. (2022). A proposal for geography competence assessment in geography fieldtrips for sustainable education. *Sustainability, 14*(3), Article 1429. https://doi.org/10.3390/su14031429

Wahyuningtyas, N., Ruja, I. N., Yahya, M. H., Wijaya, D. N., & Ibrahim, M. H. (2021). Developing of a learning media for smartphones for disaster mitigation education. I*nternational Journal of Emerging Technologies in Learning, 16*(7), 4-18. https://doi.org/10.3991/ijet.v16i07.21195

Walker, G., & Venker Weidenbenner, J. (2019). Social and emotional learning in the age of virtual play: Technology, empathy, and learning. *Journal of Research in Innovative Teaching & Learning, 12*(2), 116-132. https://doi.org/10.1108/JRIT-03-2019-0046

Walkington, H., Dyer, S., Solem, M., Haigh, M., & Waddington, S. (2018). A capabilities approach to higher education: Geocapabilities and implications for geography curricula. *Journal of Geography in Higher Education*, *42*(1), 7-24. https://doi.org/10.1080/03098265.2017.1379060

Wu, L., Kim, M., & Markauskaite, L. (2020). Developing young children's empathic perception through digitally mediated interpersonal experience: Principles for a hybrid design of empathy games. *British Journal of Educational Technology, 51*(4), 1168-1187. https://doi.org/10.1111/bjet.12918