Received: 12/09/2025
Revised: 08/11/2025
Revised: 25/02/2026
Accepted: 28/02/2026
Published: 06/02/2026

Special Issue:
Teaching Geography for a World in Transition - Powerful Teaching in Uncertain Times

Teaching Geography for a World in Transition

DOI: 10.48088/ejg.m.bue.17.2.034.048
ISSN: 1792-1341
E-ISSN: 2410-7433

Research Article

Generative AI in Geography Education: Content Creation and Conversational AI-Supported Learning to Promote Environmental Awareness

María Bueno-Picazo [1] & **Sergio Tirado-Olivares** [1]✉

[1] University of Castilla-La Mancha, Spain

✉ Correspondence: sergio.tirado@uclm.es

Abstract: Fostering critical awareness of contemporary global challenges—such as those addressed by Sustainable Development Goals—has become a key educational priority. In this context, the emergence of generative artificial intelligence (AI) opens new opportunities to support this aim in schools, while also underscoring the need to promote critical thinking regarding the information encountered. This study explores the integration of generative AI in primary education, comparing conversational AI-supported learning with traditional web searches as a means to foster geographical thinking and environmental awareness concerning a recent real-world environmental phenomenon and its societal impact. A quasi-experimental and quantitative study was conducted in Spain with 45 5th-grade students enrolled in primary education, divided into two groups: the experimental group engaged in conversational AI-supported learning using ChatGPT, while the control group relied on traditional web searches (Google) to analyze the same AI-generated content. The results show significant improvements in geographical knowledge and the application of geographical thinking, particularly among students in the conversational AI-supported learning condition. Nevertheless, students' overall perceptions of conversational AI-supported learning remained generally neutral. These findings suggest that generative AI, when used with a clear educational purpose, can enrich geography instruction by connecting curricular content to real-world issues, fostering deeper reflection, and highlighting the need for further AI-mediated interventions in the classroom.

Keywords: artificial intelligence; geographical thinking; environmental awareness; primary education; critical digital literacy

Highlights:

- AI boosts geographical thinking in 5th graders through guided inquiry.
- Conversational AI-supported learning outperformed Google in geography knowledge tasks.
- Students reported largely neutral perceptions of conversational AI-supported learning.

1. Introduction

Social Sciences share a distinctive characteristic: the subject and the object of study are the same (Souto, 2018). Within this field, geography can foster skills such as geographical thinking, which is closely linked to critical thinking and awareness of current global challenges, particularly those related to the Sustainable Development Goals (SDGs) of the 21st century (Bendl et al., 2024; Souto González, 2024). However, geography is often perceived as encyclopedic knowledge with little relevance to everyday life (Tirado-Olivares et al., 2024). Therefore, the teaching of geographical content should shift from a descriptive model to a more reflective approach that helps students understand their environment and the dynamics within it (Brooks et al., 2017).

In recent decades, human relationships with space have changed substantially, having shifted from living in a local, closed world to a global, open one (De Miguel González, 2015). This drastic and rapid transformation has been driven by technology, which has revolutionized various domains, including teaching and learning processes (Robert et al., 2025). Within this context, Artificial Intelligence (hereafter AI), now widely recognized, has begun to impact all spheres of life, reshaping the way we interact with the world around us—and, consequently, the way we access information (Chang & Kidman, 2023).

This study aims to address the need for methodological renewal in the training of responsible and informed citizens who are aware of the issues affecting their environment. To this end, it examines the educational potential of generative AI, as a specific application of artificial intelligence, in primary geography education by evaluating an intervention designed to support students' ability to search for and critically assess reliable information. Specifically, the study compares conversational AI-supported learning using ChatGPT with traditional web searches using Google, in order to investigate their respective effects on students' geographical knowledge and their ability to apply geographical thinking when analyzing AI-generated news related to a recent extreme weather event and its social consequences. In addition, the study explores the students' perceptions of conversational AI-supported learning following their participation in the intervention.

2. Literature Review

Traditionally, geography was responsible for helping students understand their immediate surroundings (Karimova, 2023). However, today's students can access vast amounts of information in seconds and establish instant connections with distant parts of the world (Chang & Kidman, 2023; De Miguel González, 2021). None of this lies outside the scope of geographical education, which not only describes aspects of the environment, but also examines human relationships with those environments (Brooks et al., 2017; Souto, 2018). De Miguel González (2021) defines geography as the science of "where," enabling inquiry into how the places we inhabit affect life and social relations. It seeks to identify key issues, analyze their impact in both the present and the future, propose possible solutions, and encourage actions aimed at preserving the environment.

It is essential for children to learn, among other things, how to interpret the environment in which their daily actions take place, so they become aware of the need for a more sustainable world (Wals, 2021). This is how they can truly develop critical thinking about current issues, such as those related to natural disasters or geopolitical conflicts (Brooks et al., 2017; Roberts, 2014). However, as Tirado-Olivares et al. (2024) warns, the study of geographical content currently generates widespread disinterest among students, largely due to the persistence of traditional, lecture-based methodologies focused on memorizing basic theoretical information. As a result, geography cannot be engaging for students if they are not encouraged to connect the content to their everyday lives. Without this connection, one of today's core educational goals is also overlooked: forming citizens who are aware of their place in the world and equipped with the skills needed to participate actively in it (Lambert, 2011; OECD, 2025).

In this engagement with their environment, students must adopt a critical stance and recognize the various issues that affect their quality of life, in order to improve it (Robert et al., 2025; Souto González, 2024). This perspective aligns with one of the current trends in geographical education: fostering geographical thinking (Brooks et al., 2017), which promotes a deeper understanding of the world and a meaningful relationship with it. As Souto González (2024) points out, this could be defined as a way of acquiring geographical knowledge that, in turn, allows for a reasoned explanation of the social problems that occur in a territory. Interest in geographical thinking has grown in recent decades, particularly in response to global challenges such as climate change (Brooks et al., 2017; Roberts, 2014). However, there is still no clear consensus regarding how to incorporate it effectively into classroom practice. Developing it requires more than the acquisition of isolated concepts, it also involves understanding how these concepts are interrelated (Bendl et al., 2021). This idea is reflected in Lambert's (2011) analogy of "vocabulary" and "grammar." While vocabulary consists of the basic terms we use to describe the world (e.g., rivers, climates, cities), grammar refers to the underlying structure that allows us to make sense of how these elements interact, for example, how climate influences urban life and, in turn, the experiences of those who inhabit those spaces.

Fostering geographical thinking through this relational approach supports education for sustainability and prepares students to address the complex demands of the 21st century and the SDGs (Piotrowska , 2025). This form of thinking is grounded in the interaction of three core dimensions: space, which helps us observe how elements are distributed across the Earth's surface; place, understood not merely as a location but as a space defined by both natural (e.g., climate, landforms) and human (e.g., buildings, economy, population) characteristics; and the environment, where people engage with the physical world, transforming and adapting it to meet their needs (Dai & Liu, 2024; De Miguel González, 2021). Beyond its conceptual dimension, geographical thinking also encompasses a procedural component. By recreating the process of geographical inquiry, or assuming the role of the geographer, students can develop higher-order thinking skills, such as formulating geographical questions and acquiring and analyzing spatial information (Bendl et al., 2021; Howell & Maddox, 2022). Through this process, they learn to conceptualize the world by critically connecting its elements (Solem, 2022). Along these lines, authors such as Mašterová (2023) highlight that inquiry-based approaches supported by digital technologies can strengthen geographical thinking by actively engaging students in the interpretation, evaluation, and critical use of information within disciplinary contexts. Similarly, Hindmarsh and Budke (2023) show that while geography students can engage in material-based and multi-perspective argumentation, they often experience difficulties in critically integrating information from multiple sources, highlighting the need for instructional approaches that explicitly support inquiry and critical reasoning. This skill set becomes even more relevant in today's context of rapid technological advancement. The abundance of accessible information makes it essential not only to obtain data, but to know how to search for, evaluate, and interpret it effectively (OECD, 2023). Therefore, the development of geographical thinking must also include a technological component that enables students to access accurate and reliable geographical information (Tirado-Olivares, 2024).

2.1. Integrating Artificial Intelligence into Geographical Thinking and Teaching

Initially, technologies were introduced into the classroom as a complementary element, serving as a novel support to paper-based or oral content delivery. However, events such as the COVID-19 health crisis demonstrated the need to incorporate them as a key component of teaching and learning processes (Housni et al., 2021). Today, their use brings multiple benefits, including fostering active and participatory learning (Robert et al., 2025; Martínez Garrido & Solarte Gómez, 2025). Given the lack of student motivation to engage with geographical content (Montero Reyes et al., 2025), technology-mediated, renewed approaches may offer a promising solution. In this regard, AlAli et al. (2024) found that students enjoy lessons that integrate technology, as they allow for more engaging and motivating activities. The use of technology should not be an end in itself, but rather a means to enhance teaching and learning (Martínez Garrido & Solarte Gómez, 2025).

Open access to information also entails easier access to less reliable sources and, consequently, a greater risk of misinformation (Sebastian & Sebastian, 2024; UNESCO, 2024). This paradigm has intensified with the rise of AI. As Martínez Garrido and Solarte Gómez (2025) point out, information search and analysis skills are therefore essential to educate future citizens. This concern has prompted institutions such as the European Commission (2022) to publish guidelines ensuring its ethical and responsible use. Although AI may appear to be a recent development, it was in 1950 when Turing posed the now-famous question: "Can machines think?" (Turing, 1950). Shortly thereafter, in 1956, the term "Artificial Intelligence" began to be used, introduced by John McCarthy (McCarthy et al., 2006). Since then, various definitions have emerged, most of which agree that it refers to technology capable of executing tasks and processes that require a certain degree of intelligence (Luckin & Cukurova, 2022). Given its growing relevance, it is worth asking how AI can be incorporated into our domain of knowledge, as the promotion of both civic and digital competence takes on a new dimension with its integration. This is due, among other factors, to AI's ability to adapt content to students' needs and to support the development of diverse teaching methodologies, as highlighted in international reports such as the latest edition of the EDUCAUSE Horizon Report (Robert et al., 2025).

Among the various branches of AI, one of the most widely known, and the focus of the present study, is generative AI, which can produce content—such as text or images—based on large volumes of data and user prompts (Lim et al., 2023). This particular type of AI is not limited to retrieving information; it also requires interaction with the tool itself to generate output, making the user's ability to analyze and critically reflect on the responses an essential part of the process (Finlayson, 2017). As noted by Jacobsen and Weber (2025), the educational usefulness of AI-generated responses is highly dependent on the nature of users' interactions with the AI tool. Generative AI includes applications such as ChatGPT, which was launched in late 2022 and reached over one million users in less than a week (Schäfer, 2023). This rapid mass adoption generated uncertainty within the educational sphere, raising concerns about how to address the challenges posed by such tools. In some cases, it even led to efforts to suppress their use. However, as Finlayson et al. (2017) state, this strategy can backfire, increasing students' curiosity and desire to use these technologies. Generative AI relies on Large Language Models (LLMs)—systems trained on vast datasets (Hughes, 2023; Yu & Guo,

https://doi.org/10.48088/ejg.m.bue.17.2.034.048

2023) that enable fluid and coherent conversations (OECD, 2023). While these models are not intelligent in the human sense, their training allows them to perform tasks such as understanding, reasoning, and problem-solving (Lim et al., 2023). Nevertheless, despite its potential, generative AI also presents risks that must be considered. On the one hand, since these systems are trained on large datasets, they may exhibit limitations or biases when contextualizing information (Qiu et al., 2022). On the other hand, without precise contextualization, users may struggle to grasp nuances or emotions (Korteling et al., 2021), which can hinder accurate understanding of the content presented. For this reason, international institutions such as UNESCO (2024) have already developed competency frameworks that highlight the need to foster literacy for the appropriate and responsible use of these tools.

Focusing on geography, recent bibliometric analyses show that research at the intersection of artificial intelligence and geography has grown substantially over the last decade, with an increasing diversification of methodological approaches and research foci, as well as the emergence of ethical and technical challenges associated with the use of AI tools (Oğlakcı & Uzun, 2025). In particular, generative AI functionalities can support students in learning subject-related content (Chang & Kidman, 2023). Students interact with the tool by carefully formulating prompts in order to receive immediate feedback. For this reason, it has been described as simulating tutoring functions (Robert et al., 2025), provided that the accuracy of the generated information is critically assessed. When applied to geographical thinking, generative AI cannot replace students' reasoning abilities; rather, it should assist in developing analytical skills and critical evaluation of the information it provides. Teachers can encourage students to integrate generative AI as an ally in their learning processes. However, many educators' apprehension about this technology limits their ability to fully harness its potential (Cao & Dede, 2023). Generative AI can contribute to the creation of innovative and engaging teaching materials (Robert et al., 2025; UNESCO, 2023). Among these, visual resources, such as images, are particularly valuable, as visual analysis helps students relate spatial elements to human actions carried out within them (Souto González, 2024). Such images may intentionally or unintentionally include errors, thereby encouraging reflection closely linked to geographical thinking (Yu & Guo, 2023). It is also possible to generate artificially created fake news, allowing educators to address the broader issue of misinformation (Sebastian & Sebastian, 2024). In all these examples, students play an active role by critically engaging with the textual or visual information presented to them (Tapalova & Zhiyenbayeva, 2022). This approach is consistent with the development of skills associated with geographical thinking (Howell & Maddox, 2022). Generative AI can therefore be used in two main ways: to generate information—whether accurate or misleading—and to act as a personalized tutor. Nevertheless, there is still a lack of robust research regarding how to implement such educational practices (Chang & Kidman, 2023; Luckin & Cukurova, 2022), highlighting the need for further investigation.

Considering the above, the present study explores how geographical thinking can be fostered in primary education through the analysis of AI-generated information and the search for reliable data related to a social and environmental issue relevant to students' immediate context: an Isolated High-Level Depression (DANA), as referred to in the geographical setting where the study was conducted. In line with this aim, the study is guided by the following research questions:

- RQ1. To what extent does conversational AI-supported learning, compared to traditional web searches (Google), influence primary education students' geographical thinking and knowledge when analyzing AI-generated content related to a DANA?
- RQ2. What perceptions do primary education students hold regarding conversational AI-supported learning as a tool to acquire geographical knowledge?

These research questions are grounded in the assumption that different modes of interaction with information may shape students' learning processes in distinct ways. In particular, conversational AI-supported learning may offer affordances that differ from those of traditional web searches, such as iterative dialogue, on-demand reformulation, and immediate clarification of content, which can support inquiry-based learning and sustained engagement with complex geographical phenomena.

3. Materials and Methods

3.1. Design

To address the research questions posed, this study follows a quantitative research approach, based on the collection and analysis of numerical data, and adopts a quasi-experimental design involving pre-test and post-test measures

https://doi.org/10.48088/ejg.m.bue.17.2.034.048

under two experimental conditions. The choice of this methodology and design is justified by the intention to generalize the results as far as possible, and by the fact that the students were not randomly assigned. Instead, existing class groups were maintained, thereby preserving the integrity of the participants.

3.2. Sample

The study was conducted with students from a primary school in Spain. All participants were between 10 and 11 years old and enrolled in 5th grade, which corresponds to primary education within the Spanish educational system. This ensured homogeneity in terms of instructional conditions and cognitive development. A total of 45 students took part in the study. These students were divided into two groups. The first group consisted of 22 students (7 girls and 15 boys) and was randomly selected to serve as the control group (hereafter, CG). This group used Google as the primary tool for searching and analyzing AI-generated information. The second group, made up of 23 students (8 girls and 15 boys), was designated as the experimental group (hereafter, EG). These students worked with the same sources, but used ChatGPT for the information search process. All the sessions with the students were conducted by the research team, ensuring that the working conditions described in this manuscript were consistently maintained. This also accounts for the sample size reported.

To ensure ethical compliance, the study was approved by the Social Research Ethics Committee of the University of Castilla-La Mancha (Ref. CEIS-2025-95582). Participation required prior distribution of an information sheet and the signing of informed consent by the students' legal guardians, explicitly authorizing their participation and the collection of academic data for research purposes.

3.3. Procedure

The development of the study was divided into four phases:

3.3.1. Phase 1: Preparation of teaching materials

The first step involved reviewing the curricular content that participating students were expected to learn. Based on the textbook used at the school, relevant content focused on water and rivers—particularly their relationship with erosion and soil degradation—was identified. This thematic connection led to the selection of a case study on a DANA, using the recent event in Valencia as a spatial reference. This real-world example provided an optimal scenario not only for addressing the required curriculum, but also for fostering geographical thinking through the analysis of a local environmental phenomenon with tangible social impact (Roberts, 2014; Souto González, 2024).

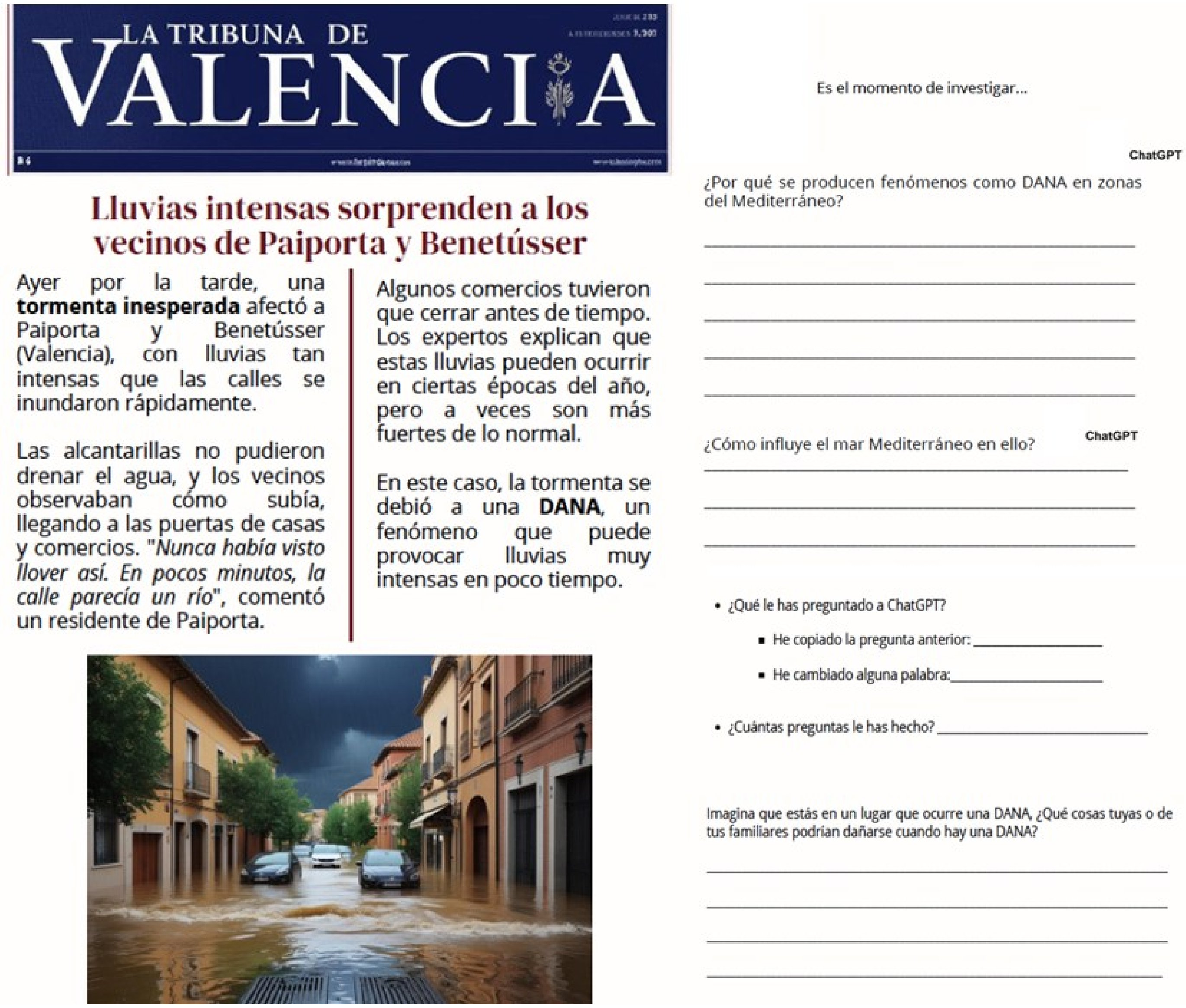
Once the central theme was defined, work began on designing the student materials. These consisted of workbooks styled as newspapers, which included AI-generated news articles and guiding questions to support information-seeking tasks. All textual content (headlines and body text) was generated using ChatGPT, while the images were created with DreamLab. To foster the students' critical thinking, the images included intentionally—but carefully—introduced errors (see Figure 1). The purpose was to encourage skills such as observation, reflection, and the ability to detect spatial inconsistencies. Therefore, the images were not treated as decorative elements, but as a key component to achieve the intended learning objectives.

As shown in Figure 1, the news articles were accompanied by questions designed to promote inquiry in line with the theoretical framework presented. These questions were intended to help students connect theoretical content with their everyday experiences. By providing AI-generated news articles, the aim was to offer a contextualized and "real" starting point that would spark the students' curiosity and engagement. In addition, the intentional errors embedded in the images encouraged careful observation and critical thinking. As a result, the students were not passive recipients of information, but actively constructed their understanding by identifying inconsistencies and formulating appropriate questions autonomously (Finlayson, 2017). Finally, it is worth noting that the news articles did not present isolated events related to the DANA. Instead, they followed a chronological sequence (see Figure 2), allowing the students to progressively explore the phenomenon—its emergence, consequences, and possible solutions.

3.3.2. Phase 2: Assessment of students' prior knowledge

https://doi.org/10.48088/ejg.m.bue.17.2.034.048

Before the intervention sessions, a pre-test was administered to assess the students' prior knowledge of the content to be covered. This test, described in detail in the Instruments section, was also administered after the intervention (phase 4). This test was carried out under conditions similar to those of a formal academic assessment: individually and without access to any sources of information or educational materials.



LA TRIBUNA DE VALENCIA

Lluvias intensas sorprenden a los vecinos de Paiporta y Benetússer

Ayer por la tarde, una **tormenta inesperada** afectó a Paiporta y Benetússer (Valencia), con lluvias tan intensas que las calles se inundaron rápidamente.

Las alcantarillas no pudieron drenar el agua, y los vecinos observaban cómo subía, llegando a las puertas de casas y comercios. "*Nunca había visto llover así. En pocos minutos, la calle parecía un río*", comentó un residente de Paiporta.

Algunos comercios tuvieron que cerrar antes de tiempo. Los expertos explican que estas lluvias pueden ocurrir en ciertas épocas del año, pero a veces son más fuertes de lo normal.

En este caso, la tormenta se debió a una **DANA**, un fenómeno que puede provocar lluvias muy intensas en poco tiempo.

Es el momento de investigar...

ChatGPT

¿Por qué se producen fenómenos como DANA en zonas del Mediterráneo?

____

ChatGPT

¿Cómo influye el mar Mediterráneo en ello?

____

- ¿Qué le has preguntado a ChatGPT?
  - He copiado la pregunta anterior: ________
  - He cambiado alguna palabra: ________
- ¿Cuántas preguntas le has hecho? ________

Imagina que estás en un lugar que ocurre una DANA, ¿Qué cosas tuyas o de tus familiares podrían dañarse cuando hay una DANA?

____

Figure 1. Screenshot of an AI-generated worksheet developed by the authors for the purposes of this study (text generated with ChatGPT and image created with DreamLab).

3.3.3. Phase 3: Implementation of the classroom intervention

After the pre-test was administered, three 45-minute sessions were conducted over the course of three consecutive weeks. In the first session, the AI-generated news article introduced the occurrence of heavy rainfall in areas near the Mediterranean Sea, presenting the meteorological phenomenon. It also explained the influence of the sea and the relationship between the causes of its origin and the time of year when it typically arises. The second session focused on the effects of the DANA on everyday life, highlighting both its social and material consequences, such as damage to homes and businesses, and the responses of emergency services. The questions in this session were designed to encourage the students to respond as if they themselves had been affected, thus fostering connections with real-life social issues, as recommended in the teaching of geographical thinking (Brooks et al., 2017). The third and final AI-generated news report addressed the topic of prevention in relation to this type of disaster, prompting the students to reflect on possible solutions applicable to real-world contexts.

Each session concluded with a set of final questions. The question “Is there anything in the image that seems strange or out of place?” was intended to help students critically analyze the visual information presented. In addition, in order to monitor how they were using the technological tools, the AI-generated resources included the following questions: “What did you ask ChatGPT/Google?”, “How many questions did you ask ChatGPT / how many websites did you consult?”. This information, along with direct observation by the research team, allowed the students’ interactions with the tools to be monitored.

The session structure remained consistent throughout the intervention. At the beginning, a brief explanation of the session’s topic was provided. Then, the AI-generated resources were distributed. The students worked individually, reading the news articles and responding to the questions using their assigned search engine (Google or ChatGPT). The final part of each session was dedicated to a whole-class discussion of the guiding questions and the geographical errors present in the images, in order to prevent students from assimilating incorrect information as valid.

3.3.4. Phase 4: Administration of the post-test and AI acceptance questionnaire

Following the intervention sessions, the students completed the post-test, which employed the same instrument as the pre-test. This allowed for an analysis of the intervention’s impact by comparing results related to the content covered (RQ1). In addition to the test, and in order to assess the students’ perceptions following their use of AI (RQ2), a purpose-specific questionnaire was administered to the experimental group (EG), as detailed in the following section. This phase was carried out under the same conditions as Phase 2. A summary of the procedure followed is presented in Figure 2.

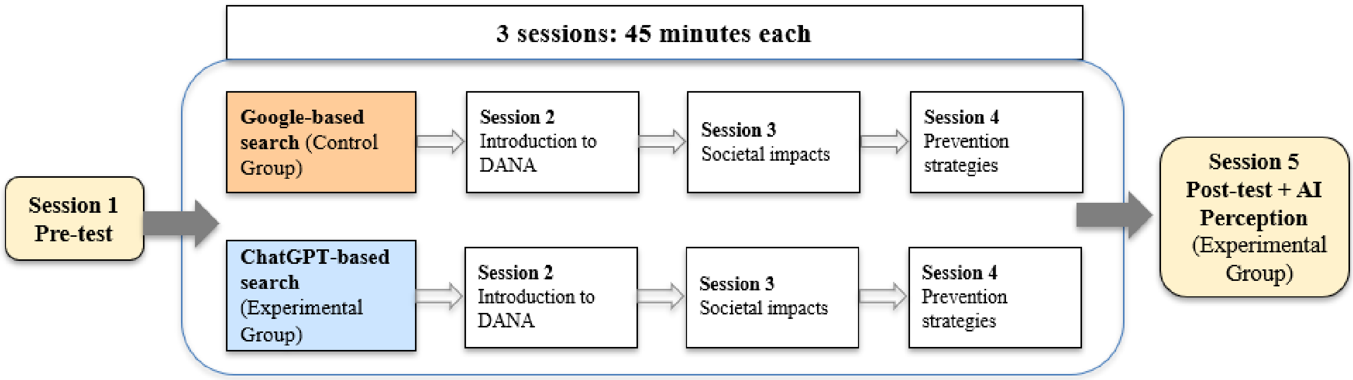


Figure 2. Overview of the research process carried out during the educational intervention.

3.4. Instruments

3.4.1. Instrument for measuring geographical thinking (RQ1)

This ad hoc instrument was specifically designed to assess knowledge acquired in relation to the DANA and its connection to the development of geographical thinking. It was based on the curricular content that students at this educational stage are expected to learn (Organic Law 3/2020). The test was divided into two parts. The first consisted of six multiple-choice questions covering basic aspects related to the DANA, including its definition, timing and typical locations, relevant geographical agents, and involved institutions and infrastructures (e.g., “What does the acronym DANA stand for?”, “What infrastructure can help reduce the damage caused by a DANA?” and “Which institution in Spain is responsible for issuing warnings about a possible DANA?”. The second part included four open-ended questions. These required the students not only to explain the phenomenon (its origin, causes, and links to climate change), but also to demonstrate their ability to reflect, reason, and propose solutions regarding the consequences of this climatic event (e.g., “How does a DANA form? Justify your answer”, “What problems can a DANA cause in cities? And in agriculture? In homes?” or, “Do you think climate change influences the formation of a DANA? How? Justify your answer”).

3.4.2. Instrument for exploring perceived potential of AI (RQ2)

In relation to the second research question—understanding the potential that students attribute to the use of conversational AI—the questionnaire developed by Al-Abdullatif (2023) was employed. This instrument is based on the Technology Acceptance Model (TAM) (Davis, 1985) and the Value-Based Adoption Model (VAM) (Kim et al., 2007). The questionnaire consists of 27 items organized into seven dimensions: perceived ease of use, perceived usefulness, perceived enjoyment, perceived risk, attitude, perceived value, and conversational AI acceptance. It uses a five-point Likert scale ranging from "strongly disagree" to "strongly agree".

3.5. Data analysis

All data were anonymized, coded, and exported into a spreadsheet using Microsoft Excel. Firstly, to evaluate responses to the open-ended items, a quantitative scoring procedure based on qualitative criteria was applied. Specifically, students' open-ended responses were evaluated using a rubric based on García Monteagudo (2024), designed to assess progressive levels of geographical thinking through the integration of declarative knowledge and applied reasoning. The rubric comprised five formative levels of achievement, each associated with a score ranging from 0 to 1 point. Level 0 (Null / Not present; 0 points) corresponded to responses that did not demonstrate knowledge or understanding of the geographical environment and failed to identify relevant geographical elements or relationships. Level 1 (Basic Declarative / Null Applied; 0.25 points) described responses in which students were able to identify and explain basic geographical concepts and demonstrated an initial understanding of geographical thinking competences; however, their answers remained primarily descriptive and no solutions were proposed. Level 2 (Intermediate Declarative / Basic Applied; 0.5 points) included responses that identified and defined geographical characteristics with greater clarity and recognized basic problems, yet without articulating coherent or sufficiently developed solutions. Level 3 (High Declarative / Intermediate Applied; 0.75 points) referred to responses demonstrating more advanced disciplinary understanding, in which problems were identified and a solution was proposed, albeit in a limited or only partially developed manner. Finally, Level 4 (High Declarative / Complex Applied; 1 point) represented integrated geographical thinking, as students identified environments, defined complex characteristics, and proposed coherent and contextually grounded solutions to the specific problems addressed.

This progression reflects a developmental shift from descriptive recognition toward increasingly sophisticated applied geographical reasoning. The rubric enabled the systematic quantification of qualitative responses and ensured comparability across pre- and post-intervention measures. In cases where uncertainty arose during the coding process, responses were discussed among members of the research team. The resulting scores were subsequently used for statistical analysis.

After this, all the data were subjected to both descriptive (means and standard deviations) and inferential statistical analysis. Specifically, the Mann–Whitney U test was used to compare differences between groups, and the Wilcoxon signed-rank test was applied to compare pre-test and post-test scores, in order to determine whether there were statistically significant differences in the variables related to RQ1. Similarly, for RQ2—focused exclusively on the students in the experimental group—the results were analyzed by gender using the Mann–Whitney U test. Rosenthal's r was used as the measure of effect size in all cases. A 95% confidence interval was applied throughout, as is standard practice in social sciences research (Cohen, 1988).

4. Results

The results are organized according to the research questions.

4.1. Results related to academic achievement (RQ1)

The first analysis assesses the students' ability to apply geographical thinking while engaging with the content described above. Table 1 presents the results separately for the multiple-choice and open-ended questions, along with the overall mean score for each test and experimental condition.

https://doi.org/10.48088/ejg.m.bue.17.2.034.048

Table 1. Pre- and post-intervention results

		Pre-test		Post-test		Dffpre-post		
		Mean	SD	Mean	SD	Z	p	r
Multiple-choice questions	EG	7.01	2.06	7.97	1.66	-2.27	.023	.47
	CG	7.27	1.32	8.26	.81	-2.70	.007	.56
Open-ended questions	EG	3.07	.75	3.61	1.25	-2.33	.20	.49
	CG	4.03	.96	3.78	1.44	-0.45	.650	.10
Total score	EG	5.04	1.26	5.79	1.22	-2.70	.007	.56
	CG	5.65	.83	6.02	.81	-1.46	.145	.31

The results indicate that the EG demonstrated notable gains in both knowledge and the application of geographical thinking. Inferential analysis revealed that these differences were statistically significant in both the multiple-choice questions (Z=–2.27; p=.023; r=.47) and the open-ended questions (Z=–2.33; p=.020; r=.49), with effect sizes ranging from moderate to large (Cohen, 1988). As a result, the overall mean score also showed a significant improvement (Z=–2.70; p=.007; r=.56), indicating a large effect size. In contrast, in the CG, significant differences were only observed for the multiple-choice questions (Z=–2.70; p=.007; r=.57), with a large effect size. No significant improvements were found in the open-ended questions, where scores slightly decreased (Z=–0.45; p=.650; r=.10), nor in the overall mean (Z=–1.46; p=.145; r=.31).

When comparing the results between groups, the CG students started from a higher baseline. In fact, the difference between groups in the open-ended questions of the pre-test was statistically significant, with a medium-to-large effect size (U=113.5; p=.001; r=.48). These differences between both groups disappeared in the post-test, as no significant differences were found in the open-ended questions (U=236.5; p=.704; r=.06), the multiple-choice ones (U=239.0; p=.714; r=.06), or the overall score (U=238.5; p=.741; r=.05). Therefore, although the students in the EG started at a lower level, they achieved significant improvement, attaining performance levels comparable to those of the CG.

4.2. Students' perceptions of conversational AI use (RQ2)

Focusing on the students' perceptions regarding the educational use of conversational AI, the results are presented in Table 2, organized by gender.

Table 2. Results based on Al-Abdullatif's questionnaire (2023)

		Mean	SD	U	p	r
Ease of Use	Female	4.06	.37	25.5	.025	.50
	Male	3.25	.92			
Usefulness	Female	3.28	.74	54.5	.722	.08
	Male	3.15	.93			
Enjoyment	Female	3.04	.95	55.5	.770	.06
	Male	3.13	1.25			
Risk	Female	2.79	.75	54.0	.692	.08
	Male	2.97	.82			
Attitude	Female	2.90	.60	44.5	.311	.21
	Male	3.08	1.00			
Value	Female	3.38	.57	46.0	.363	.19
	Male	2.91	1.02			
Acceptance	Female	2.33	.84	42.5	.257	.24
	Male	2.77	1.08			

Overall, the students' perceptions across the different dimensions were generally balanced and neutral regarding conversational AI-supported learning. No statistically significant differences were found between genders, except in the ease-of-use dimension. This was the highest-rated dimension overall, and the only one where a significant difference emerged (U=25.5; p=.025; r=.50); the girls reported higher scores than the boys and a moderate-to-large effect size (Cohen, 1988). The students rated the usefulness and perceived value dimensions similarly across genders (U=54.5; p=.722; r=.08 and U=46.0; p=.363; r=.19, respectively). This general balance was also observed in the remaining dimensions, where the male students gave slightly higher ratings for enjoyment (U=55.5; p=.770; r=.06), attitude (U=44.5; p=.311; r=.21), acceptance (U=42.5; p=.257; r=.24), and perceived risk (U=54.0; p=.692; r=.08). These results suggest a neutral and largely homogeneous perception of AI use among the students, regardless of gender.

5. Discussion

This study aimed to explore the integration of one of the most relevant scientific-educational approaches currently gaining attention in the field of geography within primary education: geographical thinking (Souto González, 2024). As Brooks et al. (2017) point out, the development of geographical thinking is particularly relevant because it enables students to learn geography while simultaneously addressing real-world and environmental issues. This approach fosters critical and reflective awareness of the information they encounter and supports the transfer of learning to everyday life, particularly in areas such as civic awareness and sustainability (Meadows, 2020), thus giving theoretical knowledge a practical and meaningful dimension (Tapalova & Zhiyenbayeva, 2022). In this context, the emergence of AI presents new opportunities. It can serve both as a generator of pedagogical resources and as a guide throughout the learning process (Chang & Kidman, 2023; Luckin & Cukurova, 2022). This dual role is particularly valuable in fostering key competences and deepening understanding of complex, real-world issues, such as those related to the SDGs.

Despite the short duration of the intervention, the students in the experimental group (EG), who used the generative AI tool ChatGPT within a conversational AI-supported learning approach, increased their knowledge levels, thereby overcoming the initial gap with the control group (CG), who worked with the same sources but used Google to search for information. This finding aligns with the proposal by Martínez Garrido and Solarte Gómez (2025), who argue that the key is not merely to use technologies, but to embed them within a sound pedagogical framework. These findings should be interpreted in light of the well-documented limitations of generative AI systems, particularly with regard to the reliability of AI-generated information. Recent research has emphasized that critically engaging with AI outputs constitutes a core competence of AI literacy and highlights the need for further studies in authentic educational settings (Ng et al., 2021), in which the ways AI tools are pedagogically integrated are clearly specified (Weidlich et al., 2025). As noted by Long and Magerko (2020), fostering AI literacy involves creating educational environments in which students are required to critically reflect on and evaluate information generated by AI tools.

In our study, AI was used not only to create the resources employed in the sessions—both texts and images designed to promote reflection and critical thinking among the students, but also to support the development of the students' skills in interacting effectively with the tool (UNESCO, 2024). This educational approach is consistent with the perspective highlighted by authors such as Souto González (2024) and De Miguel González (2021), who emphasize that geographical thinking, as an essential competence in school geography courses, should not be reduced to the memorization of theoretical concepts. Rather, it should enable students, through active methodologies, to understand the relationship between humans, society, and nature, fostering civic awareness of relevant social issues and promoting environmental responsibility through inquiry-based, autonomous knowledge construction (Meadows, 2020).

This connection became particularly evident through the AI-generated news articles about the DANA event that occurred near the students' place of residence. These materials helped the students better understand their immediate environment, while encouraging them to critically evaluate the accuracy of the geographical information presented, helping to foster both geographical thinking and critical reflection (Piotrowska, 2025; UNESCO, 2024). This process of inquiry, also noted by authors such as Howell and Maddox (2022), was carried out throughout all the sessions that comprised the intervention phase. Through the guiding questions, it was observed that some students prompted ChatGPT with requests such as "Summarize this for me" or "Explain it in other words" in order to work with the information. This clearly illustrates the students' efforts to learn how to interact appropriately with AI (UNESCO, 2024) in the context of the learning task. Such examples highlight the potential of this technological tool to support personalized learning (Robert et al., 2025). Thus, the promotion of geographical thinking was built upon the process of information searching, making it simultaneously aligned with the educational challenges of the 21st century, in which learning how to access reliable information online is essential (OECD, 2023).

Regarding RQ2, the results reveal that the students' overall acceptance of AI use was relatively neutral and not influenced by gender. This pattern may partly be explained by the fact that the students are not yet familiar with the educational use of this tool and have not received specific training on how to use it, despite the widespread recognition of AI as one of the most impactful educational trends in the short to medium term (Robert et al., 2025). Additionally, it should be noted that both groups engaged in a novel learning activity, as the analysis of AI-generated resources was new for all the students. This shared novelty limits the extent to which group differences can be explained solely by initial exposure to ChatGPT. Along these lines, Othman (2023) found that although students often express enthusiasm for technologies, such as conversational AI, they frequently lack the skills required to use them effectively, which can lead to feelings of insecurity and/or mistrust. Similar findings emerged in this study, as evidenced by the students' responses to the Al-Abdullatif (2023) questionnaire. Additionally, Korteling et al. (2021) point out that AI-generated responses are not always fully understood by users and may lack contextual sensitivity to the issues being addressed. Taken together, these findings tentatively suggest that students may require more structured support to fully benefit from conversational AI in educational contexts, particularly with regard to understanding, evaluating, and contextualizing AI-generated information (UNESCO, 2024).

6. Conclusions

Exploring effective ways to apply AI in education requires targeted research that supports the effective integration of these tools into teaching-learning processes (Aravantinos et al., 2026; Weidlich et al., 2025). The present study aimed to contribute evidence on how generative AI can be applied in the field of geography, responding to the calls of authors such as Chang and Kidman (2023), who stress the need to investigate AI use in educational settings while fostering skills such as the ability to search for reliable information and promote geographical thinking in line with current trends in the discipline (Brooks et al., 2017).

From this perspective, recent research has emphasized the triadic nature of AI literacy, highlighting the central role of teachers as mediators who frame, guide, and contextualize students' interactions with generative AI tools (Prilop et al., 2025). This mediating role is particularly relevant in educational contexts where critical evaluation of AI-generated information is required. This study explored the integration of generative AI both as part of a conversational AI-supported learning approach (Robert et al., 2025) and as a tool to create educational resources (UNESCO, 2024). The participants who engaged with AI during the intervention, compared to their peers who accessed the same content using Google, started from a lower baseline, but reached comparable levels after three sessions. This finding suggests that the educational value of generative AI lies not only in its ability to produce content, but also in its role as a mediator of learning within instructional sequences that allow for greater personalization (Grace et al., 2023; Robert et al., 2025). In this regard, and considering the growing importance of accessing reliable information (Sebastian & Sebastian, 2024; UNESCO, 2023), interventions such as the one presented might contribute to fostering students' AI literacy (Long & Magerko, 2020). The educational value of generative AI in primary geography education lies not in its use as a factual information source, but in its integration within carefully designed inquiry-based activities that promote critical evaluation and reflective discussion. This aligns with the broader aim of cultivating a critically informed and digitally literate citizenry (Martínez Garrido and Solarte Gómez, 2025). However, achieving this objective requires promoting a culture of critical questioning toward the information generated by such tools (Chang & Kidman, 2023). The predominantly neutral responses observed regarding AI's potential and usefulness suggest that instructional sequences may need to more explicitly support both learning about AI and learning through its use. From this perspective, AI should not be regarded merely as a tool to deliver answers, but rather as a catalyst for critical thinking; encouraging students to assess the reliability, accuracy, and contextual relevance of the information it provides (Luckin & Cukurova, 2022).

There is evidence that not all information generated by AI is accurate (Cui & Zhang, 2025); a limitation that also became apparent during the creation of the materials used in this study. Therefore, training students in the ethical and informed use of AI represents one of the key challenges currently facing educational contexts (Grace et al., 2023). Given the limited evidence available in the scientific literature, particularly within the field of geography (Chang & Kidman, 2023), this study highlights the need for educational interventions in which teachers not only use AI to generate instructional resources, but also to actively support students in critically analyzing and questioning AI-generated content. Such an approach may help address the often-reported lack of motivation and perceived irrelevance of geography among students (Tirado-Olivares et al., 2024). In doing so, it not only aligns with contemporary pedagogical approaches to geography education, but also fosters the development of students' digital competence in response to the educational demands of the 21st century.

6.1. Limitations and Future Directions

During the development of this study, new ideas and hypotheses emerged that may inform future lines of research. First, given the relatively small sample size, increasing the number of participants would be advisable in order to enhance the generalizability of the findings. As a consequence, it was not possible to calculate formal interrater reliability coefficients for the coding of the open-ended responses. Considering these constraints, expanding the intervention to include a larger number of student groups, and additional educational levels, as well as increasing the number of instructional sessions, would allow for more robust comparisons across contexts and variables.

Moreover, future studies should consider incorporating qualitative data through techniques such as interviews, in order to capture the opinions, perceptions, and engagement of both the students and teachers involved in AI-supported educational interventions. This approach would make it possible to explore in greater depth the factors underlying students' perceptions, including the extent to which motivation or engagement may be influenced by the novelty of the learning activity itself. Given that both groups in the present study were exposed for the first time to the analysis of AI-generated texts and images, qualitative evidence could help disentangle the relative contribution of novelty-related factors and interactional dynamics to students' perceptions. In addition, administering perception instruments to all participant groups could provide further insight into how students experience different modes of information interaction. Adopting a mixed-methods design could therefore enrich the interpretation of results and provide a more comprehensive understanding of the role of conversational AI-supported learning in the development of geographical thinking. This line of future research would also allow researchers to explore how instructional design and pedagogical mediation may influence learning gains and student motivation in AI-supported teaching–learning processes (Fan et al., 2025).

Additionally, although the students' use of ChatGPT and Google was monitored through in-class observation and guiding questions embedded in the learning materials, the study did not include systematic logging or analysis of the students' prompts or search queries. Consequently, the specific interactional strategies employed by the students—such as prompt formulation or reformulation—could not be examined in depth. Future research could therefore be explicitly designed to analyze students' interaction patterns with generative AI tools, including prompt engineering strategies, which recent studies have conceptualized as an emerging and increasingly relevant educational competence (Federiakin et al., 2024). Such analyses may yield complementary insights and allow the findings of the present study to be further examined and contrasted.

Funding: This research was funded by the University of Castilla-La Mancha and the European Regional Development Fund (ERDF) under grant 2025-GRIN38341, and by the European Union through the ERDF and the Regional Government of Castilla-La Mancha through INNOCAM under project SBPLY/24/180225/000132.

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data presented in this study are available upon request to the corresponding author as they are part of a research project in which other variables external to this study may be evaluated

Acknowledgments: This article forms part of the Special Issue (SI_TGEO), Teaching Geography for a World in Transition. Powerful Teaching in Uncertain Times, published in the European Journal of Geography. The Special Issue draws inspiration from the 2026 EUROGEO Conference, held in Tilburg, The Netherlands, 21 to 22 May 2026. The collection brings together research on geography education and geographical inquiry, with a focus on powerful geographical knowledge, spatial thinking, and critical, future oriented pedagogies. Contributions address key transformations shaping contemporary geography, including deglobalisation, multipolar world orders, postcolonial critique, contested knowledge and places, and the integration of artificial intelligence in educational practice and research. The Special Issue is edited by **Dr. Neli Heidari**, University of Bremen, Germany, **Dr. Uwe Krause**, Fontys University of Applied Sciences, The Netherlands, **Dr. Susan Caldis**, Macquarie University, Australia, **Prof. Tine Beneker**, Utrecht University, The Netherlands, and **Dr.**

SI_TGEO
Teaching Geography
for a World in Transition

Alexandros Bartzokas-Tsiompras, National Technical University of Athens, Greece, & Associate Editor of the European Journal of Geography.

Contribution to the Special Issue Topics: This study contributes to the Special Issue by exploring how generative AI can support powerful geographical knowledge and spatial thinking in primary education within a world in transition. By engaging students in the critical analysis of a real environmental event, it demonstrates how AI-mediated inquiry can foster environmental awareness, critical digital literacy, and future-oriented geographical learning in a digitally transforming world.

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