**ANAS Transactions** **Earth Sciences** **Special Issue / 2026**

http://www.journalesgia.com

# VIRTUAL FIELD PRACTICAL TRAINING ON CLIMATE CHANGE: ARTIFICIAL INTELLIGENCE-BASED PEDAGOGICAL MODELS

**Şahin S.[1]*, Jafarov S.Sh[2*], Huseynov H.J.[3], Babashova S.O.[4], Mirzabayov A.Z.[5]**

*[1]Gazi University, Ankara, Türkiye,*
*6/1 Bandırma Street, Emniyet District, Yenimahalle, Ankara 06560*
*[2]Institute of Geography, Ministry of Science and Education of the Republic of Azerbaijan*
*117, H. Javid Ave., Baku, AZ1073*
*[3]Institute of Physics, Ministry of Science and Education of the Republic of Azerbaijan*
*131, H. Javid Ave., Baku, AZ1073*
*[4]Guba Branch of Azerbaijan State Pedagogical University, Azerbaijan*
*4, Lutfi Zadeh Street, Guba, AZ4000*
*[5]Mingachevir State University, Azerbaijan*
*21, D. Aliyeva street, Mingachevir, AZ4500*
**Corresponding authors: ssahin@gazi.edu.tr, sarxan.cafarov@geo.edu.az*

***Keywords:*** *climate change education, AI-supported virtual fieldwork, geographic inquiry, spatial thinking, pedagogical design framework*

***Summary.*** Climate change has become a global educational priority that requires learners to interpret scientific evidence, understand spatial relationships, and develop sustainable solutions. In this context, geography education plays a key role in fostering climate literacy, spatial thinking, and geographic inquiry. However, traditional fieldwork is constrained by limitations related to time, cost, accessibility, and safety. Although advances in virtual fieldwork and generative artificial intelligence (AI) provide new opportunities to address these challenges, systematic pedagogical approaches for integrating AI into virtual fieldwork remain limited. This study aims to develop a pedagogically grounded framework for AI-supported virtual fieldwork in climate change education and to demonstrate its application through representative learning activities. The study adopts a conceptual design based on a synthesis of contemporary literature on climate change education, geography education, virtual fieldwork, artificial intelligence, spatial thinking, and educational technologies. The proposed framework is structured around seven pedagogical design principles: beginning with authentic climate change problems, promoting spatial evidence-based learning, positioning AI as a cognitive learning partner, placing geographic inquiry at the centre of learning, fostering solution-oriented learning, employing process-oriented assessment, and ensuring the ethical and responsible use of AI. To illustrate the framework, three representative virtual fieldwork activities focusing on glacier retreat, drought, and urban heat islands were developed. The proposed framework provides a pedagogical foundation for strengthening climate literacy, spatial thinking, geographic inquiry, critical thinking, and AI literacy in geography education.

© 2026 Earth Science Division, Azerbaijan National Academy of Sciences. All rights reserved.

## Introduction

Climate change is one of the defining challenges of the twenty-first century, reaching far beyond environmental systems to touch economic development, social wellbeing, and education policy alike. As climate-related hazards grow more frequent and more severe, it becomes increasingly important for people to understand climate processes, weigh scientific evidence critically, and imagine workable, sustainable solutions. Contemporary climate change education reflects this shift: rather than simply transmitting facts, it aims to build climate literacy, critical thinking, evidence-based decision-making, and genuine engagement with sustainability (IPCC, 2023; UNESCO, 2021). Systematic reviews of the field point in the same direction, showing that effective climate change education needs to be student-centred, inquiry-driven, and oriented toward action rather than passive learning (Monroe et al., 2019).

Geography education has a particularly important role to play here, precisely because climate change is not a uniform, placeless phenomenon — its causes, impacts, and possible solutions look different from one place, region, and scale to another. Making sense of processes such as retreating glaciers, rising sea levels, drought, wildfires, or urban heat islands requires students to ask where these things are happening, why, and how they connect to both natural and human systems. This is why geography education leans so heavily on maps, satellite imagery, Geographic Information Systems (GIS), remote sensing data, and direct field observation: these tools are what turn spatial thinking and evidence-based reasoning from abstract skills into something students can actually practice (National Research Council, 2006; Bednarz et al., 2013).

Fieldwork has long been considered one of geography education's most powerful pedagogical tools. By giving students the chance to observe environmental processes firsthand and connect theoretical knowledge to the real world, fieldwork strengthens observation, inquiry, problem-solving, and experiential learning in ways that classroom instruction alone rarely can (Kent et al., 1997; Fuller et al., 2006). Yet traditional fieldwork comes with real constraints — cost, time, accessibility, safety, and weather, among others — and these constraints are often felt most acutely in climate change education specifically, where the very phenomena being studied (glaciers, droughts, extreme heat) can make field visits impractical or even hazardous. This is precisely the gap that virtual fieldwork has come to fill. Using satellite imagery, digital maps, GIS, and 3D visualization, virtual fieldwork allows students to compare different geographic environments and examine environmental change across a range of spatial and temporal scales that would be difficult, if not impossible, to access in person (Stainfield et al., 2000; Cliffe, 2017). Hybrid approaches, in particular, have been shown to widen access while preserving much of fieldwork's pedagogical value (France & Haigh, 2018).

More recently, advances in digital technology — and generative artificial intelligence in particular — have begun to change what virtual fieldwork can actually be. Rather than functioning as static repositories of digital content, AI-enhanced virtual fieldwork environments can become interactive, adaptive learning spaces. Artificial intelligence can help generate inquiry questions, support the interpretation of spatial data, and offer adaptive feedback tailored to individual learners. When grounded in sound pedagogical principles, AI need not replace the teacher's role at all; instead, it can act as a cognitive learning partner that supports inquiry and critical thinking rather than substituting for it (Holmes et al., 2019; UNESCO, 2023). Even so, the literature currently offers little in the way of a coherent framework for how AI-supported virtual fieldwork should actually be designed and pedagogically structured within climate change education specifically. The present study responds to this gap: it proposes a set of pedagogical design principles for AI-supported virtual fieldwork in climate change education, illustrates how these principles can be translated into practice through sample activities, and considers what this approach might offer geography education more broadly.

*Purpose of the study*

This study aims to develop a pedagogically grounded framework for integrating artificial intelligence into virtual fieldwork for climate change education. The framework positions AI as a cognitive learning partner that supports, rather than replaces, geographic inquiry, spatial evidence interpretation, critical thinking, and human judgement. It brings together climate change education, geography education, virtual fieldwork, and generative AI within a coherent instructional approach.

Based on a synthesis of relevant literature, the study proposes seven interrelated pedagogical design principles and demonstrates their application through three illustrative virtual fieldwork activities focusing on glacier retreat, drought, and urban heat islands. The study is conceptual and design-oriented; therefore, the proposed framework and activities are presented as a foundation for subsequent expert validation, classroom implementation, and empirical research.

*Research questions*

Climate change education, virtual fieldwork, and artificial intelligence have each generated a substantial body of research in recent years. What's still missing, though, is work that brings these three areas together within geography education through a coherent, pedagogically grounded approach. Virtual fieldwork is widely recognized as an effective way to support geographic learning, and generative AI is understood to have real potential for inquiry-based, interactive, and adaptive learning — yet there is still no systematic design approach for how these two things might be combined in service of climate change education specifically. To the best of the authors' knowledge, no existing study has integrated generative AI, virtual fieldwork, and climate change education within geography education through a unified set of pedagogical design principles. This gap is what motivates the present study.

Within this framework, the study sets out to identify the pedagogical principles that should guide the design of AI-supported virtual fieldwork, and to show how those principles can be reflected in learning activities for climate change education. To that end, the study addresses the following research questions:

RQ1. How can artificial intelligence be integrated into virtual fieldwork for climate change education in a pedagogically meaningful and effective way?

RQ2. What pedagogical design principles should guide the design and implementation of AI-supported virtual fieldwork?

RQ3. How can the proposed pedagogical design principles be translated into sample learning activities for AI-supported virtual fieldwork?

RQ4. What learning outcomes can theoretically be supported through AI-supported virtual fieldwork in climate change education?

**Literature review**

The proposed framework draws on four interconnected areas of scholarship: climate change education, geography education, virtual fieldwork, and artificial intelligence in education. Climate change education emphasizes climate literacy, sustainability awareness, inquiry, and action-oriented learning (Monroe et al., 2019; UNESCO, 2021), while virtual fieldwork supports accessibility, experiential learning, and the development of spatial understanding (Cliffe, 2017; France & Haigh, 2018). Research on generative AI highlights its potential for personalized learning, adaptive support, inquiry, and learning analytics, while also emphasizing the importance of pedagogically responsible integration (Kasneci et al., 2023; UNESCO, 2023). Bringing these strands together provides the theoretical basis for developing a pedagogically grounded approach to AI-supported virtual fieldwork in climate change education.

*Climate change education*

Climate change education extends beyond the transmission of scientific knowledge by developing learners' climate literacy, critical evaluation of evidence, informed decision-making, and capacity to engage with adaptation and mitigation challenges (UNESCO, 2021; IPCC, 2023). Effective approaches are increasingly student-centred, inquiry-based, and action-oriented, encouraging learners to connect scientific understanding with meaningful responses to environmental problems (Monroe et al., 2019).

Geography education provides a particularly relevant context for these goals because climate change is inherently spatial and varies across places and scales. Maps, GIS, remote sensing, and satellite imagery enable students to investigate environmental change through spatial evidence and strengthen geographic reasoning and spatial thinking (National Research Council, 2006; Bednarz et al., 2013). These characteristics make climate change education well suited to virtual fieldwork environments in which learners can examine spatial and temporal patterns that may be difficult to observe directly.

*Virtual fieldwork in Geography education*

Virtual fieldwork enables students to explore geographic environments through digital maps, satellite imagery, GIS, remote sensing data, and 3D visualization, reducing constraints associated with location, time, accessibility, and cost. Rather than functioning merely as virtual tours, well-designed virtual field experiences can support spatial thinking, geographic inquiry, and the analysis of environmental processes (Stainfield et al., 2000; Cliffe, 2017).

Virtual fieldwork is particularly valuable for examining environmental change across spatial and temporal scales that are difficult to observe directly, including glacier retreat, drought, and urban transformation. However, it should generally complement rather than replace direct field experience, since virtual environments cannot fully reproduce observation and interaction in real-world settings (Kent et al., 1997; France & Haigh, 2018). This complementary role provides a useful foundation for integrating AI as an additional form of inquiry and learning support.

*Artificial Intelligence in Geography Education*

Generative AI offers new opportunities for personalized learning, inquiry support, formative feedback, and higher-order thinking, but its educational value depends on alignment with clear pedagogical objectives rather than technological capability alone (Kasneci et al., 2023; UNESCO, 2023; OECD, 2024). In geography education, AI can support students in formulating questions, comparing explanations, and interpreting maps, GIS, remote sensing, and other spatial evidence, while responsibility for evaluation and decision-making remains with the learner and teacher.

Integrating AI with virtual fieldwork therefore has potential to strengthen geographic inquiry and evidence-based reasoning when it is grounded in appropriate pedagogical design. This approach is consistent with technology-integration frameworks such as TPACK and SAMR, which emphasize meaningful relationships among disciplinary knowledge, pedagogy, and technology (Mishra & Koehler, 2006; Puentedura, 2006). At the same time, responsible implementation requires attention to academic integrity, privacy, bias, and the critical verification of AI-generated information (UNESCO, 2023).

**Methodology**

This study employs a conceptual and design-oriented research approach to develop a pedagogical framework for AI-supported virtual fieldwork in climate change education. The methodological process was informed by the early analytical and design phases of educational design research, in which a practical educational problem is identified, relevant theoretical and empirical literature is synthesized, and theoretically grounded design principles are formulated for subsequent evaluation and refinement (Design-Based Research Collective, 2003; McKenney & Reeves, 2012). No classroom intervention or experimental evaluation was conducted at this stage; accordingly, the proposed framework should be understood as an initial design iteration rather than an empirically validated instructional model.

The theoretical foundation of the framework was developed through a narrative and purposive synthesis of literature on climate change education, geography education, virtual fieldwork, spatial thinking, and generative AI in education. Sources were selected for their conceptual relevance to the research questions and included both foundational scholarship and recent literature on AI-supported learning. This approach was chosen to support theoretical integration and framework development rather than exhaustive literature retrieval (Baumeister & Leary, 1997; Grant & Booth, 2009). Accordingly, the literature synthesis should not be interpreted as a systematic review.

The design principles were developed through a thematic synthesis of the selected literature. Recurring pedagogical concepts were identified across the reviewed sources, including inquiry-based learning, spatial evidence use, experiential learning, learner–AI interaction, solution-oriented learning, assessment, and responsible AI use. These concepts were grouped into broader themes and iteratively refined by examining their relevance to the four research questions. The resulting themes were also considered in relation to established technology-integration perspectives, particularly TPACK and SAMR (Mishra & Koehler, 2006; Puentedura, 2006). This process resulted in the seven interrelated pedagogical design principles presented in Section 4.

**Design principles for AI-Supported virtual fieldwork in climate change education**

Based on the synthesis described above, seven interrelated design principles are proposed for AI-supported virtual fieldwork in climate change education: (1) starting with authentic climate change problems, (2) supporting spatial evidence-based learning, (3) positioning AI as a cognitive learning partner, (4) centring geographic inquiry, (5) encouraging solution- and action-oriented learning, (6) using process-oriented assessment, and (7) ensuring the ethical and responsible use of AI. Together, these principles provide a pedagogically grounded but flexible guide for designing learning activities in which technology supports, rather than determines, geographic inquiry and climate change learning.

*Principle 1. Start with real climate change problems*

AI-supported virtual fieldwork should be organized around authentic climate change problems that connect learning with real-world environmental challenges. Problem-based learning provides a meaningful context for investigating environmental issues, evaluating scientific evidence, and developing possible solutions (Bransford et al., 2000; Monroe et al., 2019). Issues such as glacier retreat, drought, wildfires, sea-level rise, and urban heat islands can provide relevant contexts for inquiry, while AI can support the process through adaptive questions, alternative scenarios, and prompts for evidence-based discussion.

*Principle 2. Support spatial evidence-based learning*

Learning activities should require students to construct explanations from reliable spatial evidence rather than rely on AI-generated responses alone. Satellite imagery, GIS, remote sensing products, digital elevation models, and thematic maps provide important evidence for examining environmental change (National Research Council, 2006). AI can assist students in identifying patterns, comparing interpretations, and questioning relationships within spatial data, but conclusions should remain grounded in geographic evidence.

*Principle 3. Position AI as a Cognitive Learning Partner*

AI should support students' reasoning rather than replace it. Its role can include prompting questions, supporting hypothesis formation, suggesting alternative explanations, and providing formative feedback during inquiry (Luckin, 2018; UNESCO, 2023). Students should remain responsible for evaluating AI-generated information, interpreting evidence, and making decisions, thereby maintaining human judgement at the centre of the learning process.

*Principle 4. Put Geographic inquiry at the centre of learning*

Geographic inquiry should provide the organizing structure for AI-supported virtual fieldwork. Students can investigate environmental phenomena through questions such as: Where is it occurring? Why there? How is it changing? What might happen next? What responses are possible? (Lambert & Morgan, 2010; Maude, 2016). AI can support this inquiry by generating prompts, suggesting additional data sources, and facilitating

comparisons across places and scales, while students remain responsible for evidence-based interpretation and conclusions.

*Principle 5. Encourage solution- and action-oriented learning*

Climate change education should enable students not only to understand environmental problems but also to consider possible adaptation and mitigation responses (UNESCO, 2021; Monroe et al., 2019). Within virtual fieldwork, students can compare alternative strategies, examine their potential consequences, and develop evidence-based recommendations. AI can support this process by helping generate scenarios and alternative courses of action that students subsequently evaluate against scientific and geographic evidence.

*Principle 6. Use process-oriented assessment*

Assessment should address the inquiry process as well as the final product, including how students formulate questions, interpret spatial evidence, evaluate AI-generated information, justify conclusions, and reflect on their learning (Bransford et al., 2000; Kolb, 2015). AI may provide formative prompts and opportunities for self-assessment, but responsibility for evaluating student learning should remain with the teacher.

*Principle 7. Ensure the ethical and responsible use of AI*

AI-supported virtual fieldwork should be grounded in transparency, academic integrity, fairness, privacy, and critical use of technology. Students should verify AI-generated information against reliable scientific sources and geographic evidence rather than accept it uncritically (UNESCO, 2023; OECD, 2024). Attention should also be given to potential errors, bias, appropriate attribution, and data privacy, making responsible AI use an integral component of the learning process.

## The proposed AI-supported virtual fieldwork framework

The proposed framework integrates climate change education, geography education, virtual fieldwork, and artificial intelligence within a pedagogically coherent structure based on the seven design principles. Authentic climate change problems, spatial evidence, and geographic inquiry form the core of the framework, while AI functions as a supporting tool for inquiry, reflection, and evidence-based reasoning.

The framework is intentionally flexible rather than prescriptive. It is not tied to a specific AI platform, curriculum, educational level, or geographic topic and can therefore be adapted to different learning objectives, technological conditions, and climate-related phenomena.

### *Learning scenario and illustrative applications*

The framework is operationalized through six interconnected stages: (1) identifying an authentic climate change problem, (2) collecting relevant spatial evidence, (3) formulating geographic inquiry questions, (4) conducting AI-supported analysis, (5) constructing evidence-based explanations and possible solutions, and (6) reflecting on both the learning process and the use of AI. The stages provide a common structure for virtual fieldwork while allowing adaptation to different educational contexts.

Throughout the process, students work with relevant geographic evidence, such as satellite imagery, GIS data, thematic maps, remote sensing products, climate records, drought indices, and land-use data. AI may provide guiding questions, alternative explanations, and formative feedback, while students remain responsible for verifying information, interpreting evidence, and developing conclusions.

Three illustrative activities demonstrate how the framework can be applied at different geographic scales: glacier retreat at the global scale, drought at the regional scale, and urban heat islands at the local scale. Although the activities differ in topic and spatial scale, each follows the same inquiry-oriented structure and requires students to analyse spatial evidence and critically evaluate AI-supported interpretations. The activities are illustrative applications of the framework rather than empirically validated lesson plans.

## Expected educational outcomes and practical implications

The framework has the potential to support spatial thinking, geographic inquiry, and evidence-based decision-making through the use of satellite imagery, GIS, and remote sensing data (National Research Council, 2006; Bednarz et al., 2013). It may also contribute to climate literacy and AI literacy by encouraging students to examine climate-related problems across geographic scales while critically evaluating the reliability and limitations of AI-generated information.

Because the framework is not tied to a specific curriculum, grade level, geographic topic, or AI platform, it may provide a flexible reference for teachers, curriculum developers, and researchers. However, these outcomes are theoretically expected rather than empirically demonstrated. Future research should evaluate the framework through expert review, classroom implementation, and empirical studies examining student learning, teacher experience, feasibility, and the ethical dimensions of AI-supported virtual fieldwork.

**AI-supported virtual fieldwork for climate change education: three sample activities**

The activities below are built directly on the seven pedagogical design principles outlined earlier. The three illustrative activities summarized here — glacier retreat, drought, and urban heat islands — have been turned into short, focused lesson plans intended as adaptable starting points for high-school-level instruction, pending classroom piloting and teacher feedback.

Each one includes a learning objective, materials, the role AI plays, a step-by-step learning sequence, sample prompts, inquiry questions, and brief reflection prompts for process-oriented assessment. All three are designed to fit within a single 40-minute class period and can be adjusted depending on what a given school has available.

**Activity 1:** Glacier Retreat

| | |
|---|---|
| Level | High school |
| Duration | 40 minutes |
| Geographic scale | Global |
| Group structure | Groups of 3–4 |
| Technology needed | Computer/tablet, internet access; an AI chat tool (teacher-supervised) |

*1. Climate Change Context*

Students examine glacier retreat in a selected mountain region (e.g., the Alps, Kilimanjaro, Mount Ararat) using real satellite imagery, and explore how it connects to rising global temperatures, glacial mass loss, and the regional and global consequences that follow.

*2. Learning Objective and Outcomes*

The goal is for students to compare multi-temporal satellite images and, with AI support, build evidence-based explanations of glacier retreat as an indicator of climate change.

By the end of the activity, students should be able to:

- explain glacier retreat using scientific evidence,
- critically evaluate AI-generated information and verify it against independent sources,
- propose an evidence-based adaptation or mitigation strategy for glacier loss.

*3. Digital Resources and Materials*

- Google Earth (Timelapse) or Sentinel Hub EO Browser — satellite imagery from different years
- NASA Worldview / Global Ice Viewer — glacier time-series visuals
- Publicly available temperature data (e.g., NASA GISS) and a comparison worksheet

*4. The Role of AI*

Here, AI is a learning partner that accompanies inquiry rather than handing out answers: it suggests observation criteria, offers alternative explanations, and gives feedback. Interpretation and drawing conclusions stay with the student, and every claim needs to be checked against spatial evidence.

*Sample AI Prompts (for students to use)*

"Connect the three main reasons the [region name] glacier is shrinking to clues I could look for in a satellite image."

"Suggest two alternative scenarios for how glacier loss could affect water resources — what evidence should I check for each one?"

*5. Step-by-Step Learning Process*

Stage 1: Identifying the Problem and Gathering Evidence (15 min)

- The teacher opens with a current image or news story and the question "Why is this glacier shrinking?"; groups pick a glacier region to study.
- Groups compare satellite images from at least two different years and note changes in the glacier boundary on their worksheet.
- "Suggest three observation criteria I can use to compare the glacier front's position in these two images."

Stage 2: Inquiry and Verification (15 min)

- Groups formulate "Why, How, What might happen next?" questions and ask AI for alternative explanations.
- They check the explanation they receive against temperature data or a reliable source (IPCC/NASA), then write a short evidence report.

Stage 3: Proposing a Solution, Presenting, and Reflecting (10 min)

- Each group develops a brief adaptation or mitigation proposal for the region and shares it in 1–2 minutes.
- Students reflect briefly: how did I use AI, and what did I need to verify?

*6. Geographic Inquiry Questions*

Throughout the activity, students are expected to build evidence-based answers to:

- Where is glacier retreat happening, and to what extent?
- How has the glacier's area changed over time, and why?
- What adaptation or mitigation measures could be taken at the regional scale?

**Activity 2:** Assessing Drought

*Rainfall Variability and Land-Use Analysis*

| | |
|---|---|
| Level | High school |
| Duration | 40 minutes |
| Geographic scale | Regional |
| Group structure | Groups of 3–4 |
| Technology needed | Computer/tablet, internet access; an AI chat tool (teacher-supervised) |

*1. Climate Change Context*

Students examine a water-stressed region (e.g., Türkiye's Konya Closed Basin), looking at rainfall variability, drought indices, and land-use patterns, and investigate how natural (climatic) and human (over-extraction of water, land-use change) factors both contribute to drought.

*2. Learning Objective and Outcomes*

The goal is for students to analyse rainfall and drought data alongside land-use maps, and to build evidence-based explanations of drought's causes through AI-supported inquiry.

By the end of the activity, students should be able to:

- interpret the relationship between rainfall variability and drought indices,
- distinguish between natural and human factors and build a multi-causal explanation,
- propose an evidence-based, region-specific water management or drought-response strategy.

*3. Digital Resources and Materials*

- Rainfall map / time-series chart (e.g., from Türkiye's State Meteorological Service open data portal)
- Sample drought index map (SPI/PDSI) and an NDVI (vegetation cover) visual
- Land-use map and a comparison worksheet

*4. The Role of AI*

AI acts as a learning partner that helps students connect different data layers — rainfall, NDVI, land use — offering alternative scenarios involving natural and human causes and providing feedback. Students always check any proposed causal relationship against the actual data.

*Sample AI Prompts (for students to use),*

"List three things I should pay attention to when interpreting this graph showing a drop in SPI values." "Give examples of human factors — besides reduced rainfall — that could make drought worse. What data should I look at?"

*5. Step-by-Step Learning Process*

Stage 1: Introducing the Problem and Gathering Evidence (15 min)

- The teacher opens with a drought-related news story or image and the question "Why is this region drying out?"; groups select a sub-region or time period.
- Groups examine the rainfall chart and NDVI visual, and note the severity and distribution of drought on their worksheet.
- "What order should I follow to interpret the rainfall chart together with the NDVI map?"

Stage 2: Investigating Multiple Causes and Verification (15 min)

- Groups formulate "Why, How, What might happen next?" questions and ask AI for both natural and human explanations.
- They check the proposed causes against the land-use map and prepare a short cause-and-effect diagram.

Stage 3: Proposing a Solution, Presenting, and Reflecting (10 min)

- Each group develops 1–2 water management or drought-response proposals and shares them briefly.
- Individual reflection: why does it matter to distinguish between natural and human causes?

*6. Geographic Inquiry Questions*

Throughout the activity, students are expected to build evidence-based answers to:

- Where in this region is drought occurring, and how severe is it?
- What role do natural versus human factors play in causing it?
- What measures could help protect water resources?

**Activity 3:** Urban Heat Islands
*Thermal Satellite Imagery and Land Cover Analysis*

| | |
|---|---|
| Level | High school |
| Duration | 40 minutes |
| Geographic scale | Local (city/district level) |
| Group structure | Groups of 3–4 |
| Technology needed | Computer/tablet, internet access; an AI chat tool (teacher-supervised) |

*1. Climate Change Context*

Students examine the urban heat island effect in their own city using Landsat thermal bands and land cover maps, investigating why surface temperatures differ between densely built-up areas and green spaces or bodies of water, and how this connects to sustainable urban planning.

*2. Learning Objective and Outcomes*

The goal is for students to analyse thermal satellite imagery and land cover data to explain, through AI-supported inquiry, the spatial pattern and causes of the urban heat island effect, and to develop sustainable solutions.

By the end of the activity, students should be able to:

- interpret the distribution of urban surface temperature from thermal imagery,
- connect temperature differences to land cover (built-up areas, green space, water bodies),
- propose a practical cooling or planning strategy for their own environment.

*3. Digital Resources and Materials*

- Landsat thermal band imagery / a ready-made Land Surface Temperature (LST) map
- Land cover map (satellite imagery or an OpenStreetMap layer)
- Google Earth/Maps satellite view and a comparison worksheet

*4. The Role of AI*

AI acts as a learning partner that helps students interpret thermal imagery and land cover data together, offering alternative explanations for temperature differences (albedo, built-up density, human-generated heat). Students verify these explanations against map or observational evidence.

*Sample AI Prompts (for students to use)*

"What clues should I look for to compare the hottest and coolest areas on this thermal map?" "Why does surface temperature differ between a heavily paved area and a park? Explain using the concept of albedo."

*5. Step-by-Step Learning Process*

Stage 1: Introducing the Problem and Gathering Evidence (15 min)

- The teacher opens the lesson with data or a news story about the temperature difference between the city centre and its surroundings; groups pick a neighbourhood.
- Groups note the neighbourhood's temperature level on the LST map and its built-up/green space status on the land cover map.
- "What order should I follow when examining the thermal map together with the land cover map?"

Stage 2: Investigating Causes and Verification (15 min)

- Groups formulate "Why, How, What measures could be taken?" questions and ask AI for explanations grounded in albedo and built density.
- They verify the explanation against their own map observations (e.g., is the paved area really the hottest spot?) and write a short evidence report.

Stage 3: Proposing a Plan, Presenting, and Reflecting (10 min)

- Each group proposes 1–2 measures to reduce heat in the neighbourhood (tree planting, green roofs, light-coloured surfaces, etc.) and shares them briefly.
- Individual reflection: where in my own surroundings might I notice this effect?

*6. Geographic Inquiry Questions*

Throughout the activity, students are expected to build evidence-based answers to:

- Where are the highest and lowest surface temperatures found in the city?
- Why do these temperature differences occur?
- What measures could help reduce the heat island effect?

**Discussion**

This study brings climate change education, virtual fieldwork, and generative AI together within a pedagogically grounded framework centred on authentic environmental problems, spatial evidence, and geographic inquiry. The proposed principles are consistent with previous research emphasizing inquiry-based, experiential, and spatial approaches to geography education (Kent et al., 1997; Cliffe, 2017; France & Haigh, 2018), while extending this work by explicitly considering the pedagogical role of generative AI. Rather than treating AI as a source of ready-made answers, the framework positions it as a cognitive support for questioning, interpretation, feedback, and reflection, with students and teachers retaining responsibility for evaluating evidence and making decisions (UNESCO, 2023; Kasneci et al., 2023).

An important practical consideration is digital equity. Although virtual fieldwork can reduce some constraints associated with conventional fieldwork, meaningful implementation still depends on reliable connectivity, appropriate hardware, access to digital resources, teacher competence, and institutional support (Ahmed, 2024; OECD, 2024). Unequal access to these conditions may result in substantially different learning experiences across schools and regions, particularly when generative AI is introduced into already unequal educational environments (Holstein & Doroudi, 2021). The adaptability of the framework should therefore not be interpreted as a guarantee of equal implementation across educational contexts.

The study also has important methodological limitations. The proposed framework is conceptual and has not yet been empirically validated. Moreover, the three illustrative activities were developed as applications of the seven design principles rather than through expert review, teacher-panel evaluation, or classroom piloting. Their feasibility, age-appropriateness, instructional timing, and learning effects therefore remain to be established. Future research should subject the framework and activities to expert validation and classroom-based evaluation, including structured teacher panels or Delphi studies, followed by experimental, mixed-methods, or design-based research across different educational and technological contexts.

**Conclusion**

This study proposes a pedagogically grounded framework for AI-supported virtual fieldwork in climate change education. Based on seven interrelated design principles, the framework connects authentic climate change problems, spatial evidence, geographic inquiry, solution-oriented learning, process-based assessment, and responsible AI use. AI is positioned as a cognitive support for inquiry rather than a substitute for geographic evidence, student reasoning, or teacher judgement.

The framework provides a flexible basis for designing virtual fieldwork across different climate-related topics, geographic scales, educational levels, and technological contexts. The three illustrative activities demonstrate how its principles can be translated into instructional designs addressing glacier retreat, drought, and urban heat islands. However, these applications should be understood as conceptual examples rather than evidence of educational effectiveness.

Further research should therefore focus on expert validation, classroom implementation, and empirical evaluation of the framework. Particular attention should be given to its feasibility, effects on students' climate literacy, spatial reasoning and AI literacy, teachers' experiences, ethical considerations, and implementation across educational settings with different levels of technological access. Such evidence will be necessary to determine the educational value and practical applicability of AI-supported virtual fieldwork in climate change education.

**REFERENCES**

Ahmed, F. (2024). The digital divide and AI in education: Addressing equity and accessibility. *AI EDIFY Journal, 1*(2), 12–23.

Baumeister, R.F., & Leary, M.R. (1997). Writing narrative literature reviews. *Review of General Psychology, 1*(3), 311–320.

Bednarz, S. W., Heffron, S., & Huynh, N. T. (Eds.). (2013). *A road map for 21st century geography education: Geography education research*. National Geographic Society.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. National Academies Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Cliffe, A. D. (2017). A review of the benefits and drawbacks to virtual field guides in today's geoscience higher education environment. *International Journal of Educational Technology in Higher Education, 14*(1), Article 28. https://doi.org/10.1186/s41239-017-0066-x

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

France, D., & Haigh, M. (2018). Fieldwork@40: Fieldwork in geography higher education. *Journal of Geography in Higher Education, 42*(4), 498–514. https://doi.org/10.1080/03098265.2018.1515187

Fuller, I.C., Edmondson, S., France, D., Higgitt, D., & Ratinen, I. (2006). International perspectives on the effectiveness of geography fieldwork for learning. *Journal of Geography in Higher Education, 30*(1), 89–101. https://doi.org/10.1080/03098260500499667

Grant, M. J., & Booth, A. (2009). A typology of reviews. *Health Information & Libraries Journal, 26*(2), 91–108.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

Holstein, K., & Doroudi, S. (2021). *Equity and artificial intelligence in education: Will "AIEd" amplify or alleviate inequities in education?* arXiv. https://arxiv.org/abs/2104.12920

Ibrahimova, S.I., Jabarov, S.H., Aliyeva, N.A., & Aliyev, Y.I. (2021). Study vibrational and structural properties of $Cu_3SeTe$ by Raman spectroscopy and XRD. *International Journal of Modern Physics B, 35*(27), Article 2150271. https://doi.org/10.1142/S0217979221502714

Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*.

Iskandarov, E., Ismayilov, G., Ismayilova, F., & Myltykbaeva, L. (2026). Active boundary layer approach to laminar flow under high-pressure and entrance conditions. *Advanced Physical Research, 8*(1), 75–85. https://doi.org/10.62476/apr.8175

Jafarov, S. (2023). Synergetic and innovative approaches to education. Revista de Investigaciones Universidad del Quindío, 35(1), 415–430. https://doi.org/10.33975/riuq.vol35n1.1191

Jafarov, S. (2024). Internationalisation and cultural aspects of online learning, training, and research. *Pakistan Journal of Life and Social Sciences, 22*(2), 6437–6452. https://doi.org/10.57239/PJLSS-2024-22.2.00486

Jafarov, S. (2024). Education Policy of 3rd Generation Universities. *Revista De Gestão Social E Ambiental*, *18*(6), e05690. https://doi.org/10.24857/rgsa.v18n6-007

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeiffer, F., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences, 103*, Article 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kent, M., Gilbertson, D. D., & Hunt, C. O. (1997). Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education, 21*(3), 313–332. https://doi.org/10.1080/03098269708725439

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.

Lambert, D., & Morgan, J. (2010). *Teaching geography 11–18: A conceptual approach*. Open University Press.

Luckin, R. (2018). *Machine learning and human intelligence: The future of education for the 21st century*. UCL IOE Press.

Maude, A. (2016). What might powerful geographical knowledge look like? *Geography, 101*(2), 70–76. https://doi.org/10.1080/00167487.2016.12093987

McKenney, S., & Reeves, T. C. (2012). *Conducting educational design research*. Routledge.

Mirzayev, N.A., Filosofov, D., Mammadov, Kh., De Jésus, M., Karaivanov, D.V., Ponomarev, D., Rakhimov, A., Rozova, I., Rozov, S., & Temerbulatova, N. (2020). Low radioactive $NH_4Cl$ flux. *Journal of Instrumentation, 15*, Article T05004. https://doi.org/10.1088/1748-0221/15/05/T05004

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

Monroe, M.C., Plate, R.R., Oxarart, A., Bowers, A., & Chaves, W.A. (2019). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research, 25*(6), 791–812. https://doi.org/10.1080/13504622.2017.1360842

National Research Council. (2006). *Learning to think spatially*. National Academies Press.

OECD. (2024). *Artificial intelligence in education: Shaping the future of learning*.

OECD. (2024). *The potential impact of artificial intelligence on equity and inclusion in education*.

Puentedura, R.R. (2006). *Transformation, technology, and education: The SAMR model*. http://hippasus.com

Stainfield, J., Fisher, P., Ford, B., & Solem, M. (2000). International virtual field trips: A new direction? *Journal of Geography in Higher Education, 24*(2), 255–262. https://doi.org/10.1080/713677387

UNESCO. (2021). *Learn for our planet: A global review of how environmental issues are integrated in education.*

*UNESCO. (2023). Guidance for generative AI in education and research.*

*U.S. Global Change Research Program. (2009). Climate literacy: The essential principles of climate science.*

## ВИРТУАЛЬНЫЕ ПОЛЕВЫЕ ПРАКТИКУМЫ ПО ИЗМЕНЕНИЮ КЛИМАТА: ПЕДАГОГИЧЕСКИЕ МОДЕЛИ НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

**Шахин С.[1]*, Джафаров С.Ш.[2]*, Гусейнов Г.Дж.[3], Бабашова С.О.[4], Мирзабаев А.З.[5]**

*[1]Университет Гази, Турция*
*06560, Анкара, Йенимахалле, квартал Эмниет, ул. Бандырма, 6/1*
*[2]Институт географии Министерства науки и образования Азербайджанской Республики, Азербайджан*
*AZ1073, Баку, пр. Г. Джавида, 117*
*[3] Институт физики Министерства науки и образования Азербайджанской Республики*
*AZ1073, Баку, пр. Г. Джавида, 131*
*[4]Губинский филиал Азербайджанского государственного педагогического университета, Азербайджан*
*AZ4000, Губа, ул. Лютфи Заде, 4*
*[5]Мингячевирский государственный университет, Азербайджан*
*AZ4500, Мингячевир, ул. Д. Алиевой, 21*
**Авторы, отвечающие за переписку: ssahin@gazi.edu.tr, sarxan.cafarov@geo.edu.az*

***Резюме.*** Изменение климата стало глобальным образовательным приоритетом, требующим от обучающихся умения интерпретировать научные данные, понимать пространственные взаимосвязи и разрабатывать устойчивые решения. В данном контексте географическое образование играет ключевую роль в формировании климатической грамотности,

пространственного мышления и навыков географического исследования. Однако традиционные полевые исследования сталкиваются с ограничениями, связанными со временем, затратами, доступностью и безопасностью. Несмотря на то что развитие виртуальных полевых исследований и генеративного искусственного интеллекта (ИИ) открывает новые возможности для преодоления этих трудностей, систематические педагогические подходы к интеграции ИИ в виртуальные полевые исследования остаются недостаточно разработанными. Цель исследования заключается в разработке педагогически обоснованной концептуальной модели виртуальных полевых исследований с поддержкой искусственного интеллекта в образовании по вопросам изменения климата и демонстрации её применения посредством типовых учебных заданий. В исследовании используется концептуальный подход к проектированию, основанный на синтезе современной научной литературы по вопросам образования в области изменения климата, географического образования, виртуальных полевых исследований, искусственного интеллекта, пространственного мышления и образовательных технологий. Предлагаемая модель структурирована на основе семи принципов педагогического проектирования: использование реальных проблем изменения климата в качестве отправной точки, содействие обучению на основе пространственных данных, позиционирование искусственного интеллекта как когнитивного партнёра в обучении, постановка географического исследования в центр образовательного процесса, развитие обучения, ориентированного на поиск решений, применение процессно-ориентированного оценивания и обеспечение этичного и ответственного использования искусственного интеллекта. Для иллюстрации предлагаемой модели разработаны три типовых виртуальных полевых учебных задания, посвящённых отступанию ледников, засухе и городским островам тепла. Предлагаемая модель формирует педагогическую основу для развития климатической грамотности, пространственного мышления, навыков географического исследования, критического мышления и грамотности в области искусственного интеллекта в географическом образовании.

***Ключевые слова:*** *обучение вопросам изменения климата, виртуальные полевые исследования с поддержкой искусственного интеллекта, географическое исследование, пространственное мышление, педагогическая модель проектирования*

## İQLİM DƏYİŞMƏLƏRİ ÜZRƏ VİRTUAL SAHƏ TƏCRÜBƏLƏRİ: SÜNİ İNTELLEKTƏ ƏSASLANAN PEDAQOJİ MODELLƏR

**Şahin S.[1]*, Cəfərov S.Ş.[2]*, Hüseynov H.C.[3], Babaşova S.O.[4], Mirzəbəyov A.Z.[5]**
*[1]Qazi Universiteti, Türkiyə*
*06560, Ankara, Yenimahalle, Emniyet məh., Bandırma küç. 6/1*
*[2]Azərbaycan Respublikası Elm və Təhsil Nazirliyi, Coğrafiya İnstitutu, Azərbaycan*
*AZ1073, Bakı, H. Cavid pr. 117*
*[3]Azərbaycan Respublikası Elm və Təhsil Nazirliyi, Fizika İnstitutu, Azərbaycan*
*AZ1073, Bakı, H. Cavid pr. 131*
*[4]Azərbaycan Dövlət Pedaqoji Universitetinin Quba filialı, Azərbaycan*
*AZ4000, Quba, Lütfi Zadə küç. 4*
*[5]Mingəçevir Dövlət Universiteti, Azərbaycan*
*AZ4500, Mingəçevir, D. Əliyeva küç. 21*
**Məsul müəlliflər: ssahin@gazi.edu.tr, sarxan.cafarov@geo.edu.az*

***Xülasə.*** İqlim dəyişikliyi təhsilalanlardan elmi sübutları şərh etməyi, məkan əlaqələrini anlamağı və dayanıqlı həll yolları hazırlamağı tələb edən qlobal təhsil prioritetinə çevrilmişdir. Bu kontekstdə coğrafiya təhsili iqlim savadlılığının, məkan təfəkkürünün və coğrafi tədqiqat bacarıqlarının formalaşdırılmasında mühüm rol oynayır. Bununla belə, ənənəvi çöl tədqiqatları vaxt, xərc, əlçatanlıq və təhlükəsizliklə bağlı məhdudiyyətlərlə üzləşir. Virtual çöl tədqiqatları və generativ süni intellekt (Sİİ) sahəsindəki irəliləyişlər bu çətinliklərin aradan qaldırılması üçün yeni imkanlar yaratsa da, süni intellektin virtual çöl tədqiqatlarına inteqrasiyası üzrə sistemli pedaqoji yanaşmalar hələ də məhduddur. Tədqiqatın məqsədi iqlim dəyişikliyi təhsilində süni intellektlə dəstəklənən virtual çöl tədqiqatları üçün pedaqoji cəhətdən əsaslandırılmış çərçivə hazırlamaq və onun tətbiqini nümunəvi təlim fəaliyyətləri vasitəsilə nümayiş etdirməkdir. Tədqiqatda iqlim dəyişikliyi təhsili, coğrafiya təhsili, virtual çöl tədqiqatları, süni intellekt, məkan təfəkkürü və təhsil texnologiyaları üzrə müasir elmi ədəbiyyatın sintezinə əsaslanan konseptual layihələndirmə yanaşması tətbiq edilmişdir. Təklif olunan çərçivə yeddi pedaqoji layihələndirmə prinsipi əsasında qurulmuşdur: real iqlim dəyişikliyi problemlərindən başlamaq, məkan sübutlarına əsaslanan öyrənməni təşviq etmək, süni intellekti koqnitiv təlim tərəfdaşı kimi mövqeləndirmək, coğrafi tədqiqatı təlim prosesinin mərkəzinə yerləşdirmək, həll yönümlü öyrənməni inkişaf etdirmək, prosesyönümlü qiymətləndirmə tətbiq etmək və süni intellektdən etik və məsuliyyətli istifadəni təmin etmək. Təklif olunan çərçivəni nümayiş etdirmək məqsədilə buzlaqların geri çəkilməsi, quraqlıq və şəhər istilik adaları mövzularına yönəlmiş üç nümunəvi virtual çöl tədqiqatı fəaliyyəti hazırlanmışdır. Təklif edilən çərçivə coğrafiya təhsilində iqlim savadlılığının, məkan təfəkkürünün, coğrafi tədqiqat bacarıqlarının, tənqidi təfəkkürün və süni intellekt savadlılığının gücləndirilməsi üçün pedaqoji əsas yaradır.

***Açar sözlər:*** *iqlim dəyişikliyi təhsili, süni intellekt dəstəkli virtual çöl tədqiqatı, coğrafi araşdırma, məkan təfəkkürü, pedaqoji layihələndirmə çərçivəsi*