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Artificial intelligence in geography fieldwork: pre-service teacher perspectives

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ABSTRACT

This study examines how pre-service geography teachers utilize artificial intelligence (AI) tools in fieldwork, by focusing selection criteria, usage patterns, and areas. A qualitative approach was employed, using open-ended questionnaires distributed to 31 final-year geography education (GE) students at Universiti Sains Malaysia. Participants had prior fieldwork experience across Malaysia, allowing them to share their experiences and perspectives on data collection, mapping, and geospatial analysis using AI. Findings show that AI is predominantly used for data analysis (90.3%), mapping (87.1%), and information searching (83.9%), with usability and relevance to field studies being primary consideration in tool selection. AI tools such as Google Earth Engine, GeoAI, and ChatGPT enhance geospatial analysis, automate large-scale data processing, and streamline literature reviews, thereby improving the accuracy of spatial assessments, reducing manual workload, and enabling more efficient decision-making in traditional fieldwork methods. Despite these advantages, several challenges have resulted in hindering the maximum usage of AI-generated data. The findings contribute to the broader field of AI integration in education and geography by demonstrating how AI enhances data collection, geospatial analysis, and digital fieldwork methods, while also highlighting the need for AI literacy and critical thinking to ensure effective and ethical implementation in GE.

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1. INTRODUCTION

Geography plays a crucial role as a fundamental educational field in preparing students to comprehend complex environmental and spatial relationships within their environments [1]. To effectively deliver content, courses such as geography education (GE) are designed to enhance student-teachers' spatial thinking abilities through compulsory practical fieldwork [1]–[3]. This practice is important as it can develop students' ability to think spatially, enabling them to analyze patterns, distributions, and relationships across various scales [4]. Besides, the GE itself is a body of knowledge that upholds environmental literacy as it fosters the understanding of natural systems, human-environment interactions and sustainability issues which are crucial for addressing global challenges. Fieldwork is considered an essential component of GE, as it allows students to directly experience and engage in the physical environment [5], [6]. Researchers have emphasized the effectiveness of inquiry-based approaches for fieldwork, where students are responsible for their own data collection in response to relevant research questions [7]. This approach can enhance students' geographical capabilities and develop resilience within society [8], [9].

The integration of modern technologies, including artificial intelligence (AI), has significantly transformed geography fieldwork [10]‒[12]. AI technologies in GE can be rule-based, following predefined algorithms to process data, or adaptive, learning from data to improve performance over time [13]. Rule-based AI operates on predefined instructions and is commonly used for structured tasks such as automated mapping and retrieving standard geographic datasets [14]. In contrast, adaptive AI learns from user inputs and evolving datasets, making it ideal for applications like pattern recognition in geospatial analysis, predictive modeling and personalized learning experiences [14], [15]. This study explores both types of AI and their integration with human oversight to ensure effective and ethical outcomes. AI has enhanced the efficiency and effectiveness of fieldwork by enabling students to collect and analyze data from remote locations, improving their data collection and spatial analysis skills [3], [14], [16], [17]. Recent research has demonstrated the significant role of machine learning (ML) in automating feature recognition in geographic data [18] particularly in tasks such as land cover classification, object detection in satellite imagery, and spatial pattern recognition. These applications not only improve the accuracy of geospatial analysis but also reduce manual processing time, enabling faster decision-making in both urban and environmental contexts [19]. At the same time, scholars have emphasized the importance of geospatial AI ethics in addressing complex challenges such as data privacy, algorithmic transparency, digital surveillance, and fair representation of marginalized populations in spatial datasets [20], [21]. As AI tools become increasingly embedded in geographic research and education, integrating ethical safeguards has become essential to prevent reinforcing spatial injustices and to promote responsible use of location-based technologies.

2. LITERATURE REVIEW

In recent years, AI technologies such as ML, deep learning, natural language processing (NLP) and computer vision have revolutionized students' experiences while they are conducting their fieldwork [12], [22]. ML enables analyzing large datasets, identifying patterns and trends that help students understand spatial relationships and environmental changes which improved accuracy [14]. Ifenthaler and Schumacher [23], emphasized that ML is linked to systems like recommender systems that support learners when the amount of data exceeds an individual's ability to process it, providing relevant content, courses, or optimal learning sequences. Study by Liao and Zheng [24] has shown that the use of ML and data analytics has effectively facilitated the development of an online learning management system, enhanced students' digital skills and supported the creation of new enterprises within the domain of AI. It is like Al-Zahrani [25] which found that ML and NLP are able to improve pedagogical methods, adapt to students' needs, and create new learning opportunities. For example, AI-driven 3D modeling and virtual reality (VR) technologies can enable student-teachers to explore geographical concepts and landscapes in immersive environments to visualize the historical context and potential future scenarios of an area [1], [26]. The study by Leininger-Frézal and Sprenger [11] discusses the use of virtual field trips in exploring distant spaces, foreign issues, and learning opportunities. This can be discussed as a real-world example of how virtual technologies can be integrated into educational settings to support geographical learning and promote sustainability. The results indicate that virtual field trips can enhance geographical learning by providing access to distant spaces and promoting sustainability. Besides, NLP-powered tools such as ChatGPT and Google Bard, assist in information retrieval, report structuring and automated feedback, thereby streamlining the research and documentation process [17]. It can facilitate real-time data collection, allowing student-teachers to gather and analyze geographical data in the field which promotes hands-on learning experiences [1], [27]. Additionally, AI-driven computer vision technologies allow for the automated analysis of satellite imagery and geospatial data, improving the precision of mapping and environmental assessments [13]. AI facilitates the processing of vast amounts of geographical data which enables students to identify patterns and trends that were previously difficult to discern might be due to limitations of previous technology [14].

Therefore, it is crucial for educators to stay informed about emerging technologies and their potential applications in GE. It ensures that their teaching methodologies remain relevant, engaging, and aligned with the evolving needs of students and the broader society [14]. Looking into the lens of criteria lookup by users in use for their education highlighted the necessity for user-friendly and intuitive tools that allow teachers to use them effectively without extensive training or technical expertise [24]. This is further supported by Al-Abdullatif and Alsubaie [28], who found that perceived ease of use significantly correlates with the intention to use AI tools like ChatGPT, indicating that tools which are easy to navigate are highly valued by pre-service teachers. The usefulness of technology for conducting field studies and reports is emphasized by Al-Abdullatif and Alsubaie [28], who found that perceived usefulness was significantly correlated with the intention to use ChatGPT. This suggests that tools supporting the fieldwork process, from data collection to analysis and report writing, are highly valued. Research by Fargher [2], Feng *et al.* [29] also supports this by discussing the use of WebGIS in creating geography curriculum artefacts and supporting enquiry-based learning, indicating that accuracy, while valued, is not as critical as ease of use and usefulness for field studies. The ability of a technological tool to function without an internet connection is deemed less essential. Research by Leininger-Frézal and Sprenger [11] highlights the use of virtual field trips, suggesting that most pre-service teachers are comfortable using tools that require an internet connection, as long as they are reliable and efficient. Data sharing capability is valued by pre-service teachers, as highlighted by Al-Zahrani [25] who discusses the use of AI in improving pedagogical methods and creating new learning opportunities. This indicates that while data sharing is beneficial, it is not a top priority for all pre-service teachers. Embracing these AI-driven innovations can make them envision more dynamic, interactive, and effective learning environments to provide the knowledge of GE to their future students. It can enhance the quality of education and equip student-teachers with digital literacy skills. These gained momentum as critical components for developing future-ready educators who can effectively prepare students for the complexities of the GE. The technological pedagogical content knowledge framework has stated that in an era of technological advancement, it is imperative that student-teachers not only use technology in the classroom but also integrate it effectively with appropriate content and pedagogy to ensure effective delivery of lessons. Research by Ruan *et al.* [3] further emphasized that with proper exposure, student-teachers can engage with geographical data in ways that enhance their learning experience and retention. The adoption of AI in fieldwork requires training and resource allocation which may cause financial challenges because it depends heavily on student-teachers' ability to integrate these technologies. This may create a gap particularly for underprivileged financial student-teachers [30].

In the context of the digital age, the integration of technology in educational settings, particularly in geography fieldwork, has become increasingly important. However, the effective integration of these technologies into educational practices remains a challenge [3]. Despite the potential benefits of technology and AI in education, there is a lack of comprehensive understanding of how student-teachers perceive and utilize these tools in their teaching practices [14], [31]. For instance, the studies by Feng *et al.* [29] highlights the digital divide as a component of information inequality, which has a technological nature and presupposes unequal opportunities for access, use, and production of information and knowledge or new technologies for their effective use in practice. Additionally, the study by Watted [31], Wang and Na [32] discuss the challenges of integrating advanced technology in education, including the uneven levels of multimedia literacy among teachers and the lack of clarity on the significance of integrating multimedia technology in educational practices. This gap in knowledge hinders the effective implementation of technology and AI tools in educational settings, particularly in geography fieldwork. While previous studies such as Ruan *et al.* [3], Sitohang *et al.* [5] have explored AI applications in education, limited research has examined AI's specific roles in enhancing practical geography field-based learning. Addressing this problem is crucial for enhancing the quality of education and preparing future educators to leverage AI technologies effectively. Understanding the perceptions and utilization of AI among pre-service teachers can inform the development of training programs and curricula that better integrate AI tools [33], [34]. Therefore, it can be assumed that there are multifaceted criteria valued by student-teachers in technology tools for conducting their fieldwork and the pattern of AI and technology integration

This study provides a novel approach to understanding AI's role in enhancing geography fieldwork, specifically for pre-service teachers. Although prior research has predominantly focused on AI's contribution to lesson planning and virtual instruction, its application in practical field-based tasks such as spatial data collection, georeferencing, and analysis remains underexplored. In the context of geospatial education, emerging tools like geospatial ML and intelligent mapping systems are beginning to redefine how fieldwork is conducted and understanding how spatial knowledge is constructed [35], [36]. Even though many studies have examined the technical aspects of AI integration, only few have investigated the perspectives of the pre-service teachers and their live experiences. Current study fills that gap by exploring how AI tools are selected and used during fieldwork, identifying challenges such as access, literacy, and algorithmic bias. In doing so, it offers actionable insights for curriculum design in teacher education programs that aim to integrate AI effectively and ethically into geography instruction. Therefore, this study suggests that while AI offers significant potential to revolutionize fieldwork in GE, it requires the actual experiences faced by student-teachers to evaluate its potential. Thus, study aims to fully harness AI's capabilities in geography fieldwork by understanding the specific needs and preferences of student-teachers regarding AI applications. With that, the objective of this study is as follows:

- To identify essential criteria valued by student-teachers in technology tools for conducting geography fieldwork.
- To identify the pattern of integration of AI and other forms of technology in geographic fieldwork.
- To explore the aspect of fieldwork where student-teachers perceive a need for AI assistance.

3. METHOD

A qualitative approach was chosen to provide in-depth insights into participant's experiences, preferences and challenges related to AI adoption in field-based learning.

3.1. Respondents

The study utilized purposive sampling to select 31 student-teachers of third- and fourth-years study that enrolled in a GE program who were more likely to have fieldwork exposure and basic technological literacy. The selection of the entire student cohort as respondents were chosen because they are in their formative stages when AI is actively influencing their learning methods. This approach also enables an understanding of how AI might shape their future teaching strategies once they enter the profession.

3.2. Instrumentations

Data was prepared based on two sections in which the first section focused on demographic data such as age, academic year, and gender. The second section then focuses on three aspects which are; i) the criteria they look up for when they choose to use AI for their learning; ii) the actual AI usage for their learning; and iii) the patterns of AI technologies specifically for GE. All of the items undergo content validity by two experts in AI and GE. and items were amended based on the comments given. The purpose of the validity process is that the items structured are able to be understood by the respondent and able to provide valid data.

3.3. Data collections

This research has utilized an open-ended questionnaire due to its ease of distribution, data extraction capabilities in various file formats, and accessibility across multiple devices such as tablets, laptops, and smartphones. Preliminary information regarding volunteer participation, including the right to refuse or withdraw, was provided in the introduction to the instrument. The researcher functioned solely as a data collection administrator, facilitating the distribution of the survey without direct involvement in the response process. Additionally, the AI tools examined in this study include both rule-based systems, which follow specific algorithms for data analysis, and adaptive systems, which use ML to improve student-teachers' performance based on the data they processed.

3.4. Data analysis

This study employed mixed methods of data analysis which are qualitative and quantitative. The first section focused on demographic data; it was analyzed using descriptive analysis particularly its frequency and percentage. For the second part, data were coded by using open coding followed by axial coding into subthemes and categorized into themes. This procedure was adapted and improved from research by Abdekhodaie *et al.* [37] and Şen *et al.* [38]. Both open coding and axial coding were performed by two researchers, who engaged in several cycles of coding and comparison to ensure consistency and depth in the analysis. Axial coding was used to cluster related codes into subthemes, which were then synthesized into overarching themes. This involved coding responses to categorize data under predefined themes related to AI's role such as in data collection, mapping, simulations, and report writing. After completing the coding process, the macro function in Microsoft Word was utilized to extract all comments, facilitating the identification of the final themes. Key themes were identified based on the frequency and prominence of specific points mentioned by the respondents. This structured and collaborative method ensured that the analysis was thorough and that the findings accurately captured participants' responses, contributing significantly to the research objectives. Henceforth, data for qualitative parts were analyzed using Microsoft Word and ChatGPT. Data was also presented in frequencies and percentages to illustrate the prevalence of each feature and tool among the participants. All the descriptive statistical data were calculated using Statistical Package for the Social Sciences (SPSS) version 26.

3.5. Ethical considerations

All ethical protocols were adhered to, ensuring the protection of participants' rights and data privacy. Anonymization and depersonalization of responses were implemented to maintain strict compliance with legal and ethical standards [39]. Informed consent was obtained after clearly explaining the study's purpose, procedures, and voluntary nature, with participants assured of their right to withdraw at any stage without consequences. Confidentiality was maintained through anonymization and depersonalization of responses, ensuring no identifiable information was collected or reported. Data was securely stored on password-protected devices accessible only to the researchers, complying with institutional and legal data protection standards. Questions were carefully designed to avoid harm or discomfort, focusing solely on academic and professional experiences. These measures ensured the research upheld the highest standards of integrity, privacy, and respect for participants' rights.

4. RESULTS AND DISCUSSION
4.1. Respondents profile
The age distribution shows two main age groups: 23 and 24 years old. A total of 17 pre-service teachers are 23 years old, making up 54.8% of the sample, while 14 participants are 24 years old, representing 45.2%. This indicates a relatively balanced distribution, although there is a slight majority among the 23-year-old participants. This age range aligns with the typical age of students in the later years of university study, providing context for the participants' maturity level and life stage. In terms of academic year, participants are either in their third or fourth year of study. Nineteen pre-service teachers, or 61.3% of the sample, are in their third year, while 12 participants, representing 38.7%, are in their fourth year. This indicates a higher number of third-year students, which may influence the study results, as these students may have different academic priorities or experiences compared to those in their final year.

4.2. Essential criteria in technology tools for pre-service teachers
Table 1 highlights the key characteristics that pre-service teachers prioritize when selecting technology for field studies and research. One of the most important features is ease of use, with 29 out of 31 respondents (93.5%) indicating that it is essential. This underscores the need for technology tools that are user-friendly and intuitive, allowing teachers to use them effectively without requiring extensive training or technical expertise [3], [7]. A straightforward interface enables pre-service teachers to focus on their tasks and research rather than struggling with complex technology [3], [38].

The second most valued feature is the usefulness of technology for conducting field studies and reports, with 30 out of 31 respondents (96.8%) identifying it as crucial, as shown in Table 1. This suggests that pre-service teachers highly value tools that can support them throughout the fieldwork process, from data collection to analysis and report writing. The ability to conduct field studies efficiently and produce comprehensive reports is viewed as an integral part of effective teaching and research, enhancing productivity and overall work quality [3], [7]. High accuracy is another significant feature, with 18 out of 31 pre-service teachers (58.1%) considering it important, as shown in Table 1. While accuracy is valued, it is not as critical as ease of use and usefulness for field studies. This indicates that some pre-service teachers may prioritize other features over perfect precision, suggesting that user-friendliness and functionality for fieldwork are more essential than absolute accuracy alone [4].

The ability of a technology tool to function without an internet connection was deemed essential by only 4 out of 31 respondents (12.9%), while 27 (87.1%) said it was not significant, as shown in Table 1. This suggests that most pre-service teachers are comfortable using tools that require an internet connection, if they are reliable and efficient. The need for offline functionality may be less critical when the primary work is conducted in environments with a stable internet connection [3]. Finally, data-sharing capability was valued by 22 out of 31 pre-service teachers (71.0%). This highlights the importance of collaborative work and the ability to share findings with peers, supporting teamwork and shared learning experiences. However, 9 respondents (29.0%) did not consider data sharing an essential feature, suggesting that while it is beneficial, it is not a top priority for all pre-service teachers [16], [30].

Table 1. Essential criteria in technology tools for pre-service teachers

Essential features in technology tools for pre-service teachers	Yes	No
Easy to use	29	2
Useful for conducting field studies and reports	30	1
High accuracy	18	13
Can function without internet connection	4	27
Data sharing capability	22	9

4.3. Integration of AI and other forms of technology in geographic fieldwork
The integration of AI into geography fieldwork and practice is predominantly observed in data collection, analysis, and visualization, with applications spanning both rule-based and adaptive AI technologies [12], [14]. Various AI tools and technologies have been developed, each catering to specific aspects of the discipline, enhancing efficiency and accuracy in geographical fieldwork [3], [17]. In the context of GE, AI implementation spans various domains. Table 2 shows that 48.8% of pre-service teachers stated that the integration of AI and technology in geographical fieldwork is primarily for data collection and analysis. The NLP powered tools such as ChatGPT, Julius AI, Google Scholar, and Google Bard, assist in information retrieval, report structuring and automated feedback, thereby streamlining the research and documentation process (Penuela 18. Statistical software like SPSS, even though not AI powered tools, is

essential for gathering, organizing, and interpreting large datasets. These technologies streamline the research process, enabling geographers to identify patterns and generate valuable insights efficiently [1], [14].

Another category is geographic mapping and visualization, as highlighted by 22.6% of pre-service teachers. This has shown that ML (adaptive AI) facilitates the identification of spatial trends, enabling students to interpret complex geographic distributions more effectively [14]. For instance, tools such as Google Earth Engine, digital mapping applications, and 3D modeling software are indispensable for effectively and accurately visualizing spatial data, which significantly reduces the time required for manual interpretation while improving accuracy [1]. These technologies enable researchers to create detailed, interactive, and realistic representations of geographical features, enhancing understanding and communication of complex spatial information.

In addition, 12.9% of pre-service teachers stated that they integrate the use of AI and technology for simulations, making it an increasingly important application in geographical research, as shown in Table 2. Technologies such as AI-driven augmented reality (AR) and VR enable realistic field simulations, allowing users to experience geographical environments virtually as if they were at the actual location [8], [26], [40]. With advanced visualization and interactive features, these technologies not only enhance understanding of geographical phenomena but also enable more accurate and detailed data collection [8]. The use of AR and VR is particularly effective in reducing the need for physical travel, saving time and costs, while minimizing risks, especially in hazardous or difficult-to-access environments [1]. This makes AI-based simulations an innovative and essential approach to strengthen field research and geographical education.

The use of AI for demographic and socio-economic analysis is another important category, as stated by 6.4% of pre-service teachers. Tools like GeoAI are specifically designed to analyze demographic and socio-economic patterns, leveraging advanced algorithms to help geographers identify relationships and trends in population data, such as migration patterns, urbanization, and social inequality [3]. Meanwhile, 9.6% of pre-service teachers stated that the integration of new AI and technology in geographic fieldwork is for geospatial data management and analysis [30]. Geographic information systems (GIS) serve as the backbone of this category, providing robust platforms for managing and analyzing spatial relationships [3], [41]. GIS enables researchers to integrate diverse datasets, model spatial phenomena, and support decision-making processes in areas such as environmental management and urban development. This technology allows for more effective evaluation and planning in addressing complex geospatial challenges [3], [14].

Henceforth, it can be assumed that the integration of AI in geography fieldwork is predominantly observed in data collection, analysis and visualization, which support by [15]. AI-based ML algorithms facilitate the identification of spatial trends, improving students' ability to interpret geographic distributions, supporting [3]. For instance, GIS powered by AI automates geospatial data analysis, reducing the time required for manual interpretation. NLP plays a crucial role in information searching and report writing, allowing students to efficiently synthesize large amounts of text-based data from academic sources. Furthermore, AI-driven AR and VR simulations create immersive fieldwork experiences, enabling students to explore and analyze geographical sites without physical presence. Meanwhile, rule-based AI is employed in administrative automation, streamlining logistics such as scheduling and resource allocation, thus improving the efficiency of organizing and conducting fieldwork, as aligned with [42]. These integrations underscore the potential of AI to not only improve technical data handling but also support interactive and adaptive learning strategies in GE. According to Orlando *et al.* [15], despite these advancements, human oversight remains critical in ensuring the accuracy, ethical applications and responsible use of AI-generated insights. Students must validate AI-assisted analyses, mitigate biases, and address ethical concerns such as data dependency, privacy risks, and equitable access to AI tools. These integrations highlight the transformative potential of AI in enhancing technical data handling while supporting interactive and adaptive learning strategies in GE.

Table 2. AI applications and technologies

Category	AI applications and technologies	Total	Percentage (%)
Data collection and analysis	ChatGPT, Julius AI, Google Scholar, Google Bard, SPSS	15	48.4
Geographic mapping and visualization	Google Earth Engine, applications for digital map sketching, and creating 3D models of geographical areas	7	22.6
Simulations	Use of AR/VR for field simulations	4	12.9
Demographic and socio-economic analysis	Applications like GeoAI that analyze demographic and social data	2	6.4
Geospatial data management and analysis	GIS that assists in managing and analyzing complex geospatial data	3	9.6
	Total	31	100

4.4. Aspects of geographic fieldwork in need of AI assistance

Five key areas of geographic fieldwork most requiring AI assistance are information searching, data collection, mapping, data analysis, and report writing. Table 3 presents the study findings, indicating that 83.9% of pre-service teachers (26 out of 31) utilize AI tools for information gathering. This substantial adoption suggests that AI has become essential in the initial stages of fieldwork, enhancing both the efficiency and depth of literature review and background research.

The data collection phase shows similarly strong AI integration, with 24 pre-service teachers (77.4%) employing AI technologies. This substantial adoption rate indicates that researchers are increasingly relying on AI-powered tools to gather field data, possibly through automated data collection systems, sensor technologies, or smart devices that enhance the accuracy and speed of data gathering processes. Mapping emerges as one of the most AI-integrated aspects, with 27 pre-service teachers (87.1%) reporting AI usage. This high adoption rate reflects the significant role of AI in geographical information systems (GIS), spatial analysis, and cartographic processes. The integration of AI in mapping suggests a transformation in how geographical data is visualized and interpreted. Data analysis shows the highest AI adoption rate among all aspects, with 28 pre-service teachers (90.3%) utilizing AI tools. This overwhelming majority indicates that AI has become almost indispensable in processing and analyzing geographic data, likely due to its capability to handle large datasets and identify patterns that might be difficult to detect through traditional analytical methods.

Interestingly, the report writing shows the lowest AI adoption rate, with only 11 pre-service teachers (35.5%) utilizing AI in this respect. This relatively low utilization suggests that researchers still prefer traditional methods for synthesizing and presenting their findings or perhaps indicates some reservation about using AI for creative and analytical writing tasks. The analysis also reveals interesting patterns in individual usage. Eight respondents demonstrated comprehensive AI integration, utilizing AI across all five aspects of their fieldwork. This group represents the forefront of AI adoption in geographic fieldwork, fully embracing technology throughout their research process. In contrast, two respondents exhibited minimal AI integration, using it only for data analysis, indicating a more cautious approach to adopting technology. These findings illustrate varying levels of AI integration across different aspects of geographic fieldwork. The higher adoption rates in technical areas (data analysis, mapping, and information searching) compared to creative tasks (report writing) suggest that researchers find AI most beneficial for data processing and analysis rather than for tasks that require human interpretation and creativity. Moreover, the pattern of adoption indicates a transformation in how geographic fieldwork is conducted, with AI tools becoming increasingly essential in certain areas while remaining supplementary in others. This selective integration demonstrates a thoughtful approach to adopting AI, where researchers leverage technology where it offers the most value while continuing to utilize traditional methods in areas where human expertise and judgment are considered crucial.

Table 3. AI use across key aspects of geographic fieldwork

Fieldwork aspect	Number using AI (n=31)	Percentage (%)	AI integration
Information searching	26	83.9	AI is widely used to support literature review and background research
Data collection	24	77.4	AI supports data collection through automated systems, smart sensors, and mobile device
Mapping	27	87.1	AI is integrated into GIS, spatial analysis, and cartographic mapping, transforming data visualization
Data analysis	28	90.3	AI is essential for processing large datasets and detecting hidden patterns.
Report writing	11	35.5	Low usage of AI, suggesting continued reliance on traditional methods and the need for human creativity

5. CONCLUSION

The findings indicate a remarkable shift in geographic fieldwork practices using AI technology among pre-service teachers, with ML enhancing data analysis, NLP optimizing research and reporting and AR/VR simulations revolutionizing fieldwork experiences. They are increasingly applying AI for tasks requiring technical precision, such as data analysis and mapping, showcasing the technology's capability to manage large datasets, identify patterns, and effectively visualize spatial relationships. These applications not only enhance the accuracy and efficiency of geographic research, particularly during field studies, but also streamline time-intensive processes such as data analysis and information retrieval. The use of AI tools for information searching highlights its role in improving the efficiency and breadth of literature reviews and background research, which are fundamental to fieldwork. However, despite these advancements, the application of AI for creative and interpretative tasks, such as report writing, remains relatively limited. This trend reflects that respondents still value human capabilities in evaluation and creativity to synthesize findings and present research outcomes. It illustrates a cautious approach to fully integrating AI into tasks perceived as subjective or requiring deeper understanding. This pattern underscores the increasing reliance on AI for technical aspects while maintaining the importance of human expertise in interpretative tasks, highlighting a complementary relationship between technology and traditional methods in modern geographic fieldwork.

Furthermore, this study acknowledges several limitations in integrating AI into geography fieldwork. Data dependency poses a challenge, as AI tools require large and high-quality datasets, which may not always be available or representative of diverse geographical contexts. Biases in AI-generated outputs can lead to inaccuracies, particularly in spatial analysis and automated decision-making, potentially reinforcing existing misconceptions or errors. Scalability issues arise due to disparities in technological infrastructure and access, making it difficult to implement AI-based tools uniformly across different educational settings. Additionally, ethical concerns such as data privacy and security must be addressed, as AI tools often process sensitive geographical and personal data, necessitating strict protocols to ensure responsible use in educational contexts.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Therefore, authors state no conflict of interest. The authors ensure that the study is not influenced by any institution.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study. The distributed consent forms were being collected as the official agreement for participation. The participants were briefed on this matter before the study is conducted.

ETHICAL APPROVAL

No ethical approval is needed for this research. The authors understand that ethical approval is needed for some institutions. However, for this study. It does not require such approval.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article. Enough data was provided by the authors. The presented data in this article is ample for the readers to understand.

REFERENCES

[1] E. R. Hurrell *et al.*, "The role of virtual field trips in geography higher education: a perspective paper," *Area*, vol. 57, no. 3, 2025, doi: 10.1111/area.70011.

[2] M. Fargher, "WebGIS for geography education: towards a GeoCapabilities approach," *ISPRS International Journal of Geo-Information*, vol. 7, no. 3, pp. 1–15, 2018, doi: 10.3390/ijgi7030111.

[3] L. Ruan, Y. Long, L. Zhang, and G. Lv, "A platform and its applied modes for geography fieldwork in higher education based on location services," *ISPRS International Journal of Geo-Information*, vol. 10, no. 4, pp. 1–17, 2021, doi: 10.3390/ijgi10040225.

[4] J. Lee, "Designing an inquiry-based fieldwork project for students using mobile technology and its effects on students' experience," *Review of International Geographical Education Online*, vol. 10, no. 1, pp. 14–39, 2020, doi: 10.33403/rigeo.637666.

[5] L. L. Sitohang, B. Hariyanto, A. Kurniawati, S. P. Prasetya, E. Budiyanto, and N. H. Purnomo, "Head to the field: fieldwork as a direct experience learning tool in the integrated geography course," *Technium Social Sciences Journal*, vol. 50, pp. 71–78, 2023, doi: 10.47577/tssj.v50i1.9869.

[6] P. Couper, "Feeling rules and emotion work in geomorphology fieldwork," *Environment and Planning F*, vol. 3, no. 3, pp. 162–177, 2024, doi: 10.1177/26349825231226884.

[7] B. Archer-Kuhn, Y. Lee, J. Hewson, and V. Burns, "Growing together: cultivating inquiry-based learning in social work education," *Social Work Education*, vol. 41, no. 3, pp. 1–21, 2020, doi: 10.1080/02615479.2020.1839407.

[8] M. S. Jong, C. C. Tsai, H. Xie, and F. K. Wong, "Integrating interactive learner-immersed video-based virtual reality into learning and teaching of physical geography," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2064–2079, 2020, doi: 10.1111/bjet.12947.

[9] T. Wepener, "Namibian secondary-level school learners' lived experiences of physical geography," *The Journal of Geography Education in Africa*, vol. 5, pp. 49–76, 2022, doi: 10.46622/jogea.v5i1.3785.

[10] J. Lee *et al.*, "Transforming geography education: The role of generative AI in curriculum, pedagogy, assessment, and fieldwork," *International Research in Geographical and Environmental Education*, pp. 1–17, 2025, doi: 10.1080/10382046.2024.2323590.

[11] C. Leininger-Frézal and S. Sprenger, "Virtual field trips in binational collaborative teacher training: opportunities and challenges in the context of education for sustainable development," *Sustainability*, vol. 14, no. 19, pp. 1–16, 2022, doi: 10.3390/su141912933.

[12] T. Adiguzel, M. H. Kaya, and F. K. Cansu, "Revolutionizing education with AI: exploring the transformative potential of ChatGPT," *Contemporary Educational Technology*, vol. 15, no. 3, pp. 1–13, 2023, doi: 10.30935/cedtech/13152.

[13] W. Li and C. Y. Hsu, "GeoAI for large-scale image analysis and machine vision: recent progress of artificial intelligence in geography," *ISPRS International Journal of Geo-Information*, vol. 11, no. 7, pp. 1–44, 2022, doi: 10.3390/ijgi11070385.

[14] P. R. Rana and P. Bhambri, "Harnessing AI and machine learning for enhanced geospatial analysis," *Recent Trends in Geospatial AI*, pp. 27–72, 2025, doi: 10.4018/978-1-6684-9999-6.ch002.

[15] W. Orlando *et al.*, "Applications of artificial intelligence in the teaching of mathematical techniques for biology, mining, and environment," *Journal of Namibian Studies*, vol. 34, pp. 3181–3189, 2023, doi: 10.59670/jns.v33i.953.

[16] I. Himmetoğlu, M. Karagöz, A. Türker, and B. Aksoy, "Determination of high school students' awareness of geographical elements with fieldwork: a qualitative research," *Bulletin of Educational Studies*, vol. 2, no. 2, pp. 76–90, 2023, doi: 10.61326/bes.v2i2.137.

[17] R. Mussakhan, "Methods and techniques of remote organization of fieldwork in geography lessons," *Pedagogy and Psychology*, vol. 56, no. 3, pp. 56–64, 2023, doi: 10.51889/2960-1649.2023.15.3.006.

[18] S. Li, S. Dragicevic, and F. Anton, "Machine learning for the automated recognition of geographic features: a review," *ISPRS International Journal of Geo-Information*, vol. 9, no. 2, 2020, doi: 10.3390/ijgi9020112.

[19] X. X. Zhu *et al.*, "Deep learning in remote sensing: a comprehensive review and list of resources," *IEEE geoscience and remote sensing magazine*, vol. 9, no. 2, pp. 68–112, 2021, doi: 10.1109/MGRS.2021.3056207.

[20] C. Wang and M. F. Goodchild, "Geospatial artificial intelligence and the ethics of location data," *Computers, Environment and Urban Systems*, vol. 90, 2021, doi: 10.1016/j.compenvurbsys.2021.101708.

[21] A. Leszczynski, "Glitches in the matrix: AI, geography, and ethics," *Dialogues in Human Geography*, vol. 10, no. 1, pp. 3–6, 2020, doi: 10.1177/2043820619899619.

[22] A. Harry, "Role of AI in education," *Interdiciplinary Journal & Hummanity (INJURITY)*, vol. 2, no. 3, pp. 260–268, 2023, doi: 10.58631/injurity.v2i3.52.

[23] D. Ifenthaler and C. Schumacher, "Reciprocal issues of artificial and human intelligence in education," *Journal of Research on Technology in Education*, vol. 55, no. 1, pp. 1–6, 2023, doi: 10.1080/15391523.2022.2154511.

[24] J. Liao and Y. Zheng, "Integrating artificial intelligence into vocational education: case studies of AI pedagogical tools in technical schools," in *Proceedings of the International Conference on Education and AI*, pp. 112–120, 2025, doi: 10.1145/3745238.3745471.

[25] A. M. Al-Zahrani, "Exploring the impact of artificial intelligence on higher education: opportunities and challenges," *Humanities and Social Sciences Communications*, vol. 11, 2024, doi: 10.1057/s41599-024-03432-4.

[26] M. Zafari, J. S. Bazargani, A. Sadeghi-Niaraki, and S. M. Choi, "Artificial intelligence applications in K-12 education: a systematic literature review," *IEEE Access*, vol. 10, pp. 61905–61921, 2022, doi: 10.1109/ACCESS.2022.3179356.

[27] C.-H. Chang *et al.*, "Lessons from learner experiences in a field-based inquiry in geography using mobile devices," *International Research in Geographical and Environmental Education*, vol. 21, no. 1, pp. 41–58, 2012, doi: 10.1080/10382046.2012.639155.

[28] A. M. Al-Abdullatif and M. A. Alsubaie, "ChatGPT in learning: assessing students' use intentions and perceived value," *Behavioral Sciences*, vol. 14, no. 9, 2024, doi: 10.3390/bs14090845.

[29] J. Feng, B. Yu, W. H. Tan, Z. Dai, and Z. Li, "Key factors influencing educational technology adoption in higher education: a systematic review," *PLOS Digital Health*, vol. 4, no. 4, 2025, doi: 10.1371/journal.pdig.0000764.

[30] H. Rakuasa, "Integration of artificial intelligence in geography learning: challenges and opportunities," *Sinergi International Journal of Education*, vol. 1, no. 2, pp. 75–83, 2023, doi: 10.61194/education.v1i2.71.

[31] A. Watted, "Teachers' perceptions and intentions toward AI integration in education: insights from the UTAUT model," *Power System Technology Journal*, vol. 49, no. 2, pp. 164–183, 2025.

[32] Z. Wang and H. Na, "Multimedia technology based interactive translation learning for students," in *ACM Transactions on Asian and Low-Resource Language Information Processing*, 2023, doi: 10.1145/3588569.

[33] M. A. Ayanwale, O. P. Adelana, R. R. Molefi, O. Adeeko, and A. M. Ishola, "Examining artificial intelligence literacy among pre-service teachers for future classrooms," *Computers and education open*, vol. 6, pp. 1–15, 2024, doi: 10.1016/j.caeo.2024.100179.

[34] M. Gatlin, "Assessing pre-service teachers' attitudes and perceptions of using artificial intelligence in the classroom," *Texas Educator Preparation*, vol. 7, no. 2, pp. 1–8, 2023, doi: 10.59719/txep.v7i2.35.

[35] K. Janowicz, S. Gao, G. McKenzie, B. B. Y. Hu, and T. E. Chow, "GeoAI: Spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond," *International Journal of Geographical Information Science*, vol. 34, no. 4, pp. 625–645, 2020, doi: 10.1080/13658816.2019.1684500.

[36] P. P. Roy, M. S. Abdullah, and I. M. Siddique, "Machine learning empowered geographic information systems: advancing spatial analysis and decision making," *World Journal of Advanced Research and Reviews*, vol. 22, no. 1, pp. 1387–1397, 2024, doi: 10.30574/wjarr.2024.22.1.1200.

[37] E. Abdekhodaie, J. Hatami, H. B. Ehsan, and R. Kormi-Nouri, "WordCommentsAnalyzer: a Windows software tool for qualitative research," *F1000Research*, vol. 7, pp. 1–17, 2018, doi: 10.12688/f1000research.14819.1.

[38] M. Şen, Ş. N. Şen, and T. G. Şahin, "A new era for data analysis in qualitative research: ChatGPT!," *Shanlax International Journal of Education*, vol. 11, no. 1, pp. 1–15, 2023, doi: 10.34293/education.v11is1-oct.6683.

[39] E. Kang and H. J. Hwang, "Ethical conducts in qualitative research methodology: participant observation and interview process," *Journal of Research and Publication Ethics*, vol. 2, no. 2, pp. 5–10, 2021, doi: 10.15722/jrpe.2.2.202109.5.

[40] J. S. G. Al Balushi, M. I. A. Al Jabri, S. Palarimath, P. Maran, K. Thenmozhi, and C. Balakumar, "Incorporating artificial intelligence powered immersive realities to improve learning using virtual reality (VR) and augmented reality (AR) technology," in *International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, 2024, pp. 760–765, doi: 10.1109/ICAAIC60154.2024.10386279.

[41] R. Liu, R. Greene, X. Li, T. Wang, M. Lu, and Y. Xu, "Comparing geoinformation and geography students' spatial thinking skills with a human-geography pedagogical approach in a Chinese context," *Sustainability*, vol. 11, no. 20, pp. 1–21, 2019, doi: 10.3390/su11205573.

[42] S. Ahmad, S. Umirzakova, G. Mujtaba, M. S. Amin, and T. Whangbo, "Education 5.0: requirements, enabling technologies, and future directions," *arXiv preprint*, pp. 1–24, 2023, doi: 10.48550/arXiv.2307.15846.

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