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A proposed AI-based educational program for developing geographic virtual tour design skills and technological engagement among education faculty students

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Abstract

Geographic education faces significant challenges in engaging contemporary students and integrating emerging technologies effectively. This study aimed to evaluate the effectiveness of an AI-based educational program designed to develop geographic virtual tour design skills and enhance technological engagement. A quasi-experimental design with pre-test and post-test measurements was employed with 60 fourth-year geography students from Al-Azhar University. The AI-based educational program was developed using the ADDIE instructional design model. Participants' performance was assessed using three instruments: Geographic Virtual Tour Design Skills Achievement Test (GVTDS-AT), Geographic Virtual Tour Design Skills Performance Observation (GVTDS-PO), and a Technological Engagement Scale. Results revealed statistically significant improvements ($p < 0.01$) across all measured variables, with very large effect sizes ranging from 3.30 to 17.32. Theoretical knowledge scores increased from 19.88 to 59.18 (Cohen's d = 7.20), while practical performance improved from 27.91 to 99.78 (Cohen's d = 9.41). All technological engagement dimensions showed substantial improvements, with the total engagement score increasing from 74.51 to 173.23 (Cohen's d = 17.32). These findings demonstrate that AI-based educational programs can effectively enhance both geographic virtual tour design competencies and technological engagement, modernizing geographic education and preparing future educators with essential digital skills.

Keywords: Artificial intelligence, Geographic education, Teacher preparation, Technological engagement, Virtual tour design.

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1. Introduction

Geographic education in higher education institutions is experiencing significant transformation driven by technological advancement and institutional diversification. While the discipline has expanded globally, with countries like China producing approximately 30,000 Geographic Information Systems (GIS) undergraduates annually [1] it faces challenges in maintaining disciplinary identity and ensuring equitable access [2]. The digitalization of geographic education is rapidly advancing through GIS integration and emerging technologies like virtual reality (VR) and augmented reality (AR) [3] though implementation remains uneven across institutions. Regional disparities persist, with geographic proximity significantly affecting student access and completion rates [4, 5]. These developments necessitate updated curricula and enhanced teacher training to effectively integrate digital skills and maintain the discipline's relevance in contemporary higher education.

The integration of digital technology has fundamentally transformed geographic learning and teaching methodologies by introducing innovative tools that enhance student engagement and spatial analysis capabilities. GIS, VR, and AR have revolutionized how students visualize and interact with complex spatial data, making abstract geographic concepts more tangible and accessible [6, 7]. These technologies facilitate experiential learning through virtual field trips and simulations, reducing costs while expanding access to diverse geographical environments [8]. Furthermore, digital platforms support the development of critical thinking and spatial reasoning skills through interactive mapping and story mapping tools [9, 10]. The integration of online collaborative platforms and mobile learning applications has also enabled more flexible, self-paced learning experiences that accommodate diverse learning styles and geographical constraints.

Among the various digital innovations in geographic education, virtual tours have emerged as transformative tools that provide immersive and interactive experiences, significantly enhancing student learning and engagement [11, 12]. These digital platforms effectively address accessibility barriers and equity concerns by offering safe alternatives to traditional fieldwork, particularly for students facing financial, physical, or environmental constraints [13]. Furthermore, virtual tours foster the development of critical spatial thinking skills, analytical abilities, and collaborative learning opportunities while maintaining high levels of student motivation and curiosity [14, 15].

Despite these technological advances, geography departments face an urgent need for innovative educational approaches as traditional teaching methods prove insufficient for engaging contemporary students and addressing rapidly evolving societal demands. Current research indicates that many students demonstrate neutral or declining interest in geography, suggesting that conventional pedagogical approaches lack the engagement necessary for effective learning outcomes [16]. The accelerating pace of technological and societal change requires geography education to adapt continuously, incorporating digital tools and interdisciplinary knowledge to remain relevant [17, 18]. Furthermore, innovative methods such as GIS, VR, and blended learning are essential for developing critical thinking, spatial reasoning, and digital literacy skills 7highly valued in modern workplaces [7]. Recent research has demonstrated that innovative pedagogical approaches can significantly enhance student teachers' sense of efficacy and passion for teaching [19] suggesting that technology-enhanced methods may be particularly effective for teacher preparation programs.

In response to these challenges, artificial intelligence (AI) has emerged as a promising solution for enhancing educational effectiveness and student engagement. AI-based tools significantly enhance students' technical skills development through personalized learning pathways, hands-on practice opportunities, and immediate feedback mechanisms. These tools provide adaptive learning experiences that cater to individual student needs while promoting higher-order thinking skills [20]. Interactive platforms facilitate creative application and technical proficiency in areas such as multimedia design and programming [21]. Furthermore, AI-powered systems offer automated assessment and self-evaluation capabilities that support continuous skill improvement [22-24].

However, the successful implementation of AI technologies in educational settings depends heavily on students' technological engagement, which is influenced by multiple interconnected factors that shape learning experiences and outcomes. Research indicates that cognitive and emotional factors, including students' intrinsic motivation, readiness, confidence, and anxiety levels regarding AI systems, significantly impact their perceived usefulness and ease of use [25]. Additionally, digital literacy and AI literacy serve as crucial moderators, with higher proficiency levels enabling students to better benefit from adaptive and interactive AI tools [26]. Trust in AI technology, institutional credibility, and perceived system reliability further influence engagement, as students demonstrate greater willingness to interact with AI systems they perceive as secure, transparent, and ethically sound [27, 28]. Moreover, ethical decision-making processes play a crucial mediating role in how students engage with generative AI technologies, influencing their behavioral intentions and actual usage patterns.

The importance of technological engagement extends beyond individual student preferences, as it serves as a fundamental catalyst for the successful implementation of technology-enhanced learning (TEL) by directly influencing teaching performance, participation, and academic outcomes [29, 30]. High levels of engagement with digital tools correlate with improved learning performance, as engaged students are more likely to access materials and participate in interactive activities [31]. Furthermore, engagement mediates TEL effectiveness, with active learning activities facilitated by technology leading to greater cognitive gains than passive use [32]. Students' digital skills are closely related to their engagement levels, suggesting that fostering both technological competence and engagement maximizes learning benefits [33].

Given the critical need for innovative approaches in geographic education and the promising potential of AI technologies, there is a pressing need to develop and evaluate educational programs that integrate AI tools with geographic virtual tour design skills. Such programs could address the current challenges in geographic education while preparing education faculty students with the necessary skills to effectively utilize modern technologies in their future teaching practices. The development of these skills is particularly important for education faculty students who will become the next generation of geography educators, as they will need to be proficient in both content knowledge and technological applications to meet the demands of contemporary education.

Therefore, this study aims to propose and evaluate an AI-based educational program specifically designed to develop geographic virtual tour design skills and enhance technological engagement among education faculty students. By employing a quasi-experimental research design with pre-test and post-test measurements, this research seeks to investigate the effectiveness of the proposed AI-based educational program as an independent variable on the dependent variables of geographic virtual tour design skills and technological engagement, contributing to the growing body of knowledge on technology-enhanced geographic education.

2. Method

2.1. Research Design

This study employed a quasi-experimental research design with a single-group pre-test and post-test design to investigate the effectiveness of an AI-based educational program on developing geographic virtual tour design skills and technological engagement among education faculty students. The research design allowed for the examination of changes in participants' performance before and after exposure to the AI-based educational intervention.

2.2. Participants

The study participants consisted of 60 fourth-year students from the Geography Department at Al-Azhar University's Faculty of Education in Dakahlia. Participants ranged in age from 21 to 23 years (M = 21.96, SD = 0.65), with 36 students from rural areas and 24 from urban areas. All participants were enrolled in their final year of the geography education program, ensuring they possessed foundational knowledge in geographic concepts and pedagogical principles necessary for understanding virtual tour design applications.

2.3. Instruments

2.3.1. Geographic Virtual Tour Design Skills Achievement Test (GVTDS-AT)

A cognitive achievement test was developed to assess participants' theoretical knowledge of geographic virtual tour design skills. The test development process followed established psychometric procedures, beginning with the creation of a content specification table that outlined the educational topics covered and distributed learning objectives across different cognitive levels according to their relative importance.

Content validity was established through expert review by a panel of specialists in curriculum and instruction, and educational technology. The test was then administered to a pilot sample of 30 students to determine item characteristics. Item difficulty indices ranged from 0.20 to 0.80, while discrimination indices ranged from 0.42 to 0.50, indicating acceptable item quality. Internal consistency reliability was calculated using Cronbach's alpha, yielding a coefficient of 0.821, demonstrating high reliability.

2.3.2. Geographic Virtual Tour Design Skills Performance Observation (GVTDS-PO)

A structured observation card was developed to assess participants' practical performance of geographic virtual tour design skills before and after the AI-based educational program. The observation card was designed with specific procedural criteria, ensuring that skills were clearly defined, non-composite, precisely described, and logically sequenced.

Face validity was established through expert review by specialists in curriculum and instruction and educational technology to ensure clarity, logical sequencing, and observability of the skills. Reliability was assessed using Cronbach's alpha, resulting in a coefficient of 0.845, indicating high reliability and statistical significance.

2.3.3. Technological Engagement Scale

A technological engagement scale was developed to measure participants' acceptance and engagement with AI-based educational programs. The scale consisted of nine dimensions, each containing multiple items directly related to the construct being measured and appropriate for the target population. The scale dimensions included: (1) Expected Usefulness, (2) Ease of Use, (3) Information Quality, (4) Service Quality, (5) System Quality, (6) Trust, (7) Navigation Satisfaction, (8) Actual Usage and Continuance, and (9) Usage Motivation.

Content validity was established through expert review, and internal consistency was examined by calculating correlation coefficients between individual items and their respective dimensions. All correlation coefficients were statistically significant at $p < 0.05$, indicating adequate internal consistency. Additionally, correlation coefficients between each dimension and the total scale score ranged from 0.520 to 0.794, all significant at $p < 0.05$, supporting the scale's construct validity. Overall reliability was assessed using Cronbach's alpha, yielding a coefficient of 0.813, demonstrating high internal consistency.

2.3.4. AI-Based Educational Program Development

The experimental treatment consisted of an AI-based educational program designed to develop geographic virtual tour design skills. The program was developed following the ADDIE instructional design model (Analysis, Design, Development, Implementation, Evaluation), as outlined in Table 1.

Table 1.
ADDIE Model Implementation for AI-Based Educational Program Development.

Phase	Key Activities	Outcomes
Analysis	• Established instructional design criteria through literature review of electronic programs and AI-based applications. • Analyzed learner characteristics (fourth-year geography students). • Conducted educational needs assessment. • Identified learning prerequisites and constraints.	• Comprehensive understanding of target learners' similar age ranges, comparable prior knowledge levels, and existing motivation. • Identification of knowledge gaps in virtual tour design skills and technological engagement. • Foundation for program objectives established.
Design	• Identified learning objectives and skill lists through literature review. • Conducted informal interviews with students to understand actual needs. • Organized educational content into instructional modules. • Designed module structure with titles, objectives, content, activities, and assessments. • Planned interaction and communication tools.	• Comprehensive list of geographic virtual tour design skills. • Structured instructional modules with clear learning pathways. • Integration of multimedia elements (texts, images, graphics, videos, interactive links). • Communication framework including email, chat rooms, and discussion forums.
Development	• Translated design specifications into actual learning materials. • Gathered and produced multimedia elements using professional software. • Hosted program on online learning environment. • Integrated AI applications and tools. • Created student registration and tracking systems.	• Complete learning materials using Microsoft Word 2016, Adobe Photoshop CS6, Sound Forge 8, and Camtasia Studio 8. • Functional online learning environment with registration capabilities. • Integration of Intelligent Virtual Field Trips, Adaptive Learning Platforms, ChatGPT, and Gemini. • Comprehensive student tracking and reporting system.
Implementation	• Conducted alpha testing through expert review. • Performed beta testing with pilot sample (n=20). • Gathered feedback from specialists in educational technology and curriculum instruction. • Refined program based on pilot study results.	• Expert validation of program quality and appropriateness. • Confirmation of program suitability for target population. • Significant improvements in pre-post test scores ($p < 0.05$) demonstrating internal effectiveness. • Program ready for main experimental implementation.
Evaluation	• Implemented formative evaluation throughout development process. • Conducted summative evaluation through main experiment. • Administered pre-test and post-test measures. • Analyzed program effectiveness on learning outcomes	• Continuous improvement throughout development phases. • Comprehensive assessment of program impact on geographic virtual tour design skills and technological engagement. • Evidence-based conclusions about program effectiveness

2.4. Procedure

Pre-test measures were administered including the cognitive achievement test, performance observation card, and technological engagement scale. Participants then engaged with the AI-based educational program, studying the content and completing activities. Following program completion, post-test measures were administered using the same instruments to assess changes in participants' geographic virtual tour design skills and technological engagement levels.

3. Results

The effectiveness of the AI-based educational program was evaluated through pre-test and post-test measurements using paired-samples t-tests. Cohen's d was calculated to determine effect sizes, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. The complete statistical results are presented in Table 2.

Table 2.
Pre-test and Post-test Comparison of Geographic Virtual Tour Design Skills and Technological Engagement (N= 60).

Variable	Mean		Mean Difference	SD	t-value	Cohen's d	Effect Size
	Pretest	Posttest					
GVTDS-AT	19.88	59.18	39.30	7.20	42.23**	7.20	Very Large
GVTDS-PO	27.91	99.78	71.86	9.41	59.09**	9.41	Very Large
Expected Usefulness	7.83	16.73	8.90	4.39	15.67**	4.39	Very Large
Ease of Use	8.66	22.26	13.60	4.38	24.04**	4.38	Very Large
Information Quality	8.06	20.43	12.36	3.86	24.77**	3.86	Very Large
Service Quality	7.11	15.23	8.11	3.39	18.51**	3.39	Very Large
System Quality	7.13	16.43	9.30	3.36	21.43**	3.36	Very Large
Trust	6.56	12.93	6.36	3.30	14.90**	3.30	Very Large
Navigation Satisfaction	10.18	25.50	15.31	3.67	32.32**	3.67	Very Large
Actual Usage and Continuance	7.68	16.33	8.65	3.93	17.00**	3.93	Very Large
Usage Motivation	11.26	27.36	16.10	5.22	23.84**	5.22	Very Large
Total Score	74.51	173.23	98.71	17.32	44.13**	17.32	Very Large

Note: ** $p < 0.01$, df = 59.

The analysis revealed significant improvements in participants' geographic virtual tour design skills. For theoretical knowledge (GVTDS-AT), participants' mean scores increased from 19.88 to 59.18, $t(59) = 42.23$, $p < 0.01$, Cohen's d = 7.20. Practical performance skills (GVTDS-PO) showed even greater improvement, with mean scores increasing from 27.91 to 99.78, $t(59) = 59.09$, $p < 0.01$, Cohen's d = 9.41.

All nine dimensions of the technological engagement scale showed significant improvements (see Table 2). The most substantial improvements were observed in Navigation Satisfaction (mean difference = 15.31, Cohen's d = 3.67) and Usage Motivation (mean difference = 16.10, Cohen's d = 5.22). Other notable improvements included Ease of Use (Cohen's d = 4.38), Information Quality (Cohen's d = 3.86), and Expected Usefulness (Cohen's d = 4.39). The overall technological engagement total score increased from 74.51 to 173.23, $t(59) = 44.13$, $p < 0.01$, Cohen's d = 17.32.

All measured variables showed statistically significant improvements at the $p < 0.01$ level, with effect sizes ranging from 3.30 to 17.32, all classified as very large effects. These results provide strong evidence for the effectiveness of the AI-based educational program in developing both geographic virtual tour design skills and technological engagement among education faculty students.

4. Discussion

The findings of this study provide compelling evidence for the effectiveness of AI-based educational programs in developing geographic virtual tour design skills and enhancing technological engagement among education faculty students. The substantial improvements observed across all measured variables demonstrate that artificial intelligence can serve as a powerful catalyst for transforming geographic education and preparing future educators with essential digital competencies. These results align with and extend the growing body of research on technology-enhanced learning in educational contexts, particularly supporting findings by Figueroa and Jung [34] who demonstrated that VR tours in online learning environments effectively increase learner motivation, with the novelty of technology and visually appealing scenery playing crucial roles in engagement.

The dramatic improvements in both theoretical knowledge and practical performance of geographic virtual tour design skills underscore the transformative potential of AI-enhanced learning environments. The theoretical knowledge component showed remarkable growth, with participants' mean scores increasing nearly threefold from pre-test to post-test, achieving a very large effect size of 7.20. This substantial improvement suggests that AI-based educational programs can effectively address the knowledge gaps that traditionally challenge geography students when attempting to integrate digital technologies into their learning and future teaching practices. The structured, adaptive nature of AI systems appears particularly well-suited to delivering complex technical content in digestible, personalized formats that accommodate diverse learning styles and paces. These findings are consistent with research by Chou, et al. [35] who found that ICT self-efficacy and human-computer interaction experience significantly influence students' learning effectiveness of AI-based technology applications in educational settings.

Even more striking was the improvement in practical performance skills, which demonstrated the largest effect size observed in the study at 9.41. This finding is particularly significant because it indicates that AI-based programs can successfully bridge the often-problematic gap between theoretical understanding and practical application in educational technology. The ability of participants to translate their enhanced theoretical knowledge into actual virtual tour design capabilities suggests that the AI program effectively provided scaffolded learning experiences, immediate feedback, and iterative practice opportunities that are essential for skill development. This practical competency development is crucial for education faculty students who must not only understand these technologies conceptually but also implement them effectively in their future classrooms. The success in developing practical skills mirrors findings by Chen, et al. [36] who demonstrated that robot-assisted language learning effectively trains tour guides by increasing motivation, engagement, and providing active learning experiences that translate into practical communication skills.

The success in developing both theoretical and practical skills can be attributed to several key features of AI-enhanced learning environments. The adaptive learning pathways provided by AI systems allow students to progress at their own pace while receiving personalized feedback and support, addressing individual learning needs more effectively than traditional instructional methods. Furthermore, the interactive nature of AI tools enables students to engage with complex spatial concepts through hands-on experimentation and immediate error correction, fostering deeper understanding and retention of virtual tour design principles. This aligns with research by Sarshartehrani, et al. [37] who found that embodied AI tutors in immersive virtual environments significantly enhance user engagement and proficiency in educational contexts, with particular implications for distance learning and personalized educational adaptation.

The comprehensive improvements observed across all nine dimensions of technological engagement reveal the multifaceted benefits of AI integration in educational settings. The substantial increases in expected usefulness and ease of use suggest that AI-based programs can effectively address two of the most critical factors in technology acceptance theory. When students perceive AI tools as both useful and easy to use, they are more likely to embrace these technologies and integrate them into their learning processes. This finding is particularly important for education faculty students who will need to model positive technology attitudes and demonstrate competent technology use in their future teaching roles. The enhancement of perceived usefulness and ease of use supports the technology acceptance framework and is consistent with research demonstrating that these factors are fundamental predictors of technology adoption in educational contexts.

The significant improvements in information quality, service quality, and system quality dimensions indicate that AI-based educational programs can deliver high-quality learning experiences that meet or exceed student expectations. These improvements suggest that AI systems can provide accurate, relevant, and timely information while maintaining reliable performance standards. The enhancement of trust levels among participants is equally important, as it indicates that students developed confidence in AI technologies' reliability and ethical application in educational contexts. This trust development is crucial for sustainable technology adoption and continued engagement with AI-enhanced learning environments. These findings complement research by Latifah, et al. [38] who demonstrated that integrating AI chatbots with web-based virtual tours significantly improves user interaction and engagement, making educational experiences more engaging and informative for student orientation and learning purposes.

Navigation satisfaction and usage motivation showed particularly strong improvements, with effect sizes exceeding 3.5 and 5.2 respectively. These findings suggest that AI-based programs can create engaging, intuitive learning experiences that motivate continued use and exploration. The improved navigation satisfaction indicates that participants found the AI-enhanced learning environment user-friendly and logically organized, reducing cognitive load and allowing focus on content mastery rather than interface navigation. The substantial increase in usage motivation is particularly significant because it suggests that participants developed intrinsic motivation to continue using AI tools beyond the experimental period, indicating potential for long-term technology adoption and integration. This finding aligns with recent research demonstrating that AI tool usage, particularly ChatGPT, can enhance research motivation among postgraduate students through its mediating effect on self-efficacy, suggesting that AI-based educational programs may foster sustained academic engagement beyond immediate learning outcomes.

These results provide strong empirical support for the integration of AI technologies in geographic education and contribute to the growing body of literature on technology-enhanced learning. The findings align with and extend previous research on digital tool integration in geography education, demonstrating that AI-based approaches can achieve significantly larger effect sizes than traditional technology integration methods reported in the literature. The comprehensive nature of the improvements observed across multiple skill domains and engagement dimensions suggests that AI-enhanced learning environments can address the complex, multifaceted challenges facing contemporary geographic education. This comprehensive effectiveness is supported by research from del Rocío León-Ortiz and León [39] who found that combining on-site and virtual tours effectively develops geographic skills, fostering practical abilities and enhancing map interpretation and geospatial navigation capabilities. Furthermore, the comprehensive improvements in engagement dimensions suggest that AI-based programs may enhance students' academic buoyancy and psychological flow, psychological states that are crucial for sustained academic performance and resilience in higher education contexts [40].

The study findings contribute to technology acceptance theory by demonstrating that well-designed AI educational programs can simultaneously improve multiple factors that influence technology adoption and continued use. The improvements in perceived usefulness, ease of use, trust, and motivation suggest that AI-based programs can create positive feedback loops that enhance both learning outcomes and technology engagement. This finding has important implications for educational technology design and implementation, suggesting that AI integration should focus on creating holistic learning experiences rather than simply adding technological features to existing curricula. The holistic approach to technology integration is further supported by research on virtual patient educational tools and AI-powered interactive virtual tutors, which demonstrate that comprehensive AI integration can significantly improve student engagement, satisfaction, and academic performance through personalized guidance and interventions.

For curriculum designers and educational technology specialists, these findings suggest that AI-based educational programs should be considered as viable alternatives to traditional instruction methods, particularly for complex technical skills that require both theoretical understanding and practical application. The success of the ADDIE-based development approach employed in this study provides a replicable framework for creating effective AI-enhanced learning experiences in geographic education and related disciplines. The systematic approach to AI integration demonstrated in this study supports broader research on AI-based curriculum development, which suggests that artificial intelligence can revolutionize education by delivering personalized, adaptable, and engaging learning experiences when properly implemented and ethically managed.

While these findings are encouraging, several limitations should be acknowledged that provide directions for future research. The single-group pre-test post-test design, while appropriate for initial program evaluation, limits the ability to establish causal relationships and control for potential confounding variables. Future research should employ randomized controlled trial designs with control groups to provide stronger evidence for AI program effectiveness and isolate the specific contributions of AI technologies versus other instructional factors. Additionally, the study was conducted with a relatively homogeneous population of fourth-year geography students from a single institution, which may limit the generalizability of findings to other populations, educational levels, and cultural contexts.

The study focus on immediate post-test outcomes also raises questions about the long-term retention of skills and sustained technological engagement that warrant further investigation. Longitudinal follow-up studies would provide valuable insights into the durability of AI-enhanced learning effects and the extent to which participants continue to use and develop their virtual tour design skills in their professional practice. Furthermore, future research should investigate the optimal balance between AI-mediated and human-mediated instruction to maximize learning outcomes while maintaining the social and collaborative aspects of learning that are essential for educator preparation. Such research would help determine how AI technologies can best complement rather than replace human instruction in educational settings.

The findings of this study demonstrate that AI-based educational programs can significantly enhance both geographic virtual tour design skills and technological engagement among education faculty students. The substantial improvements observed across all measured variables provide strong evidence for the potential of AI technologies to transform geographic education and prepare future educators with essential digital competencies. These results suggest that AI integration should be seriously considered by geography departments and teacher preparation programs seeking to modernize their curricula and improve student outcomes in an increasingly digital educational landscape. The success of this AI-based educational program offers a promising model for addressing the challenges facing contemporary geographic education while preparing students for the technological demands of their future teaching careers, contributing to the broader movement toward technology-enhanced learning that is reshaping educational practice across disciplines.

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