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Integrating Project-Based Learning and Artificial Intelligence in High School Geography: A Case Study of Coastal Tourism Planning

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Abstract: The rapid development of artificial intelligence and its gradual adoption in modern education have created new possibilities for integrating AI with Project-based Learning (PBL) in high school geography instructional innovation. This study designed and implemented a two-month geography PBL project integrating multiple AI tools at an international high school in Shenzhen, China. Adopting a single case study design, the research conducted a thematic analysis of 20 participating students' self-reflections. The findings indicate that integrating AI and PBL in high school geography education is highly feasible and generates positive teaching outcomes. From the students' perspective, AI tools significantly enhanced information retrieval and learning efficiency, promoted critical thinking, and helped students initially form AI literacy. All 20 students reported a renewed understanding of geography's disciplinary value. From the teacher's perspective, project implementation entailed multiple challenges, including tool selection, student role assignment, and collaboration and progress coordination. These challenges provided practical experience for future implementation. The study has limitations: the small sample size from a single school limits generalizability, and the qualitative method may involve subjectivity and insider bias from researcher-participants. In summary, effective AI-integrated PBL requires teachers to possess comprehensive competencies in instructional design, tool selection, process management, and team coordination, alongside corresponding school support in time and resources.

Keywords: artificial intelligence; project-based learning; geography education; case study; ai literacy

1. Introduction

Project-based Learning (PBL) is a teaching method widely adopted across educational levels and subjects. A growing body of research has demonstrated its effectiveness in fostering students' critical thinking, problem-solving abilities, and teamwork skills. PBL also cultivates students' self-regulated learning skills and intrinsic motivation, shifting them from passive recipients to active inquirers. Although PBL is already a well-established approach, the integration of artificial intelligence—exemplified by large language models developed and deployed in China—is gaining traction in education. AI can alleviate teacher workload and improve instructional efficiency, enabling educators to prioritize higher-order pedagogical tasks. At the same time, its interactive and adaptive capabilities can stimulate student interest and deepen engagement, thereby reinforcing learning motivation. In mainland China, geography education in most public high schools is constrained by tight curriculum schedules and the overriding demand for gaokao preparation, making it difficult to implement long-term PBL projects on a regular basis. However, the international high school that serves as the site of this study operates under a different educational context. Its curriculum system—such as the Advanced Placement (AP) program—emphasizes formative assessment and encourages teachers to organize a wide range of extracurricular activities,

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which in turn support students' extracurricular profiles for overseas university applications [1]. This unique educational ecosystem provides a rare 'testing ground'—rarely available in regular public schools—to experiment with the integration of PBL and AI. Consequently, teachers at this international school have greater flexibility in instructional design and are strongly motivated to explore emerging technologies, with the aim of enhancing their courses' attractiveness and competitiveness for students. As a result, they have proactively embraced AI in their teaching, leveraging its capacity to offer personalized learning support and real-time feedback, and employing it as a scaffold in instructional design.

While the application of PBL in physical geography—such as field-based water quality monitoring and ecological literacy—has been widely acknowledged, research on AI-integrated geography PBL remains significantly under-researched, particularly regarding empirical cases that deeply embed AI tools into geography project work. To address this gap, this study examines an AI-integrated PBL project implemented at an international high school, analyzing participating students' self-reflections to explore the actual effects of combining AI with geography PBL [2]. To fill this research gap, the present study aims to answer the following research questions: How do students perceive the practicality and reliability of AI-generated information in a geography PBL project? How does an AI-integrated geography PBL project influence students' understanding of geography as a discipline?

2. Literature Review

2.1. Project-Based Learning: Theoretical Foundations

Project-based Learning (PBL) emerged in the early 20th century as a pedagogical approach centered on purposeful, socially embedded activities, where students engage deeply with meaningful projects. Subsequent scholarly work has consolidated its core characteristics into six interrelated dimensions: learning through active doing, addressing authentic real-world challenges, structured teacher facilitation, integration across subject areas, collaborative group engagement, and the creation of tangible, shareable outcomes. These features reflect an emphasis on intrinsic motivation and relevance to learners' lived experiences [3]. At its foundation, PBL organizes learning around a central theme or inquiry, fostering not only collaborative and investigative capacities but also the ability to produce work intended for broader audiences. Students typically work in teams, respond to complex problem scenarios, and identify their own learning needs throughout the process. This approach supports the acquisition of foundational knowledge, strengthens problem-solving capabilities, promotes self-regulated learning strategies, and enhances collective participation skills.

Empirical evidence indicates that PBL has been widely adopted across diverse disciplines, including STEM education, English language instruction, and entrepreneurship training. Within entrepreneurship education, team-based teaching models and sustained group collaboration have been associated with enhanced learning outcomes, underscoring the importance of cooperative structures in effective implementation. Furthermore, PBL has proven adaptable across developmental stages—from primary and secondary education through to undergraduate and graduate programs [1].

Research further demonstrates consistent positive impacts of PBL on key student competencies. In university-level English instruction, technology-integrated PBL has been linked to measurable gains in language proficiency and essential 21st-century competencies, especially communicative effectiveness. A case study conducted in a junior high school in Jianyang, China, implemented a PBL initiative focused on rural agricultural product promotion as part of broader rural revitalization efforts; results indicated notably higher levels of student engagement, motivation to learn, cooperative capacity, and creative expression compared with conventional instructional approaches. Similarly, quasi-experimental studies in secondary education settings have reported significant

improvements in collaborative performance and creative thinking, with average score increases observed across multiple metrics. Engineering education research has likewise documented superior outcomes in listening comprehension and conceptual mastery among students engaged in PBL compared with peers in traditional instruction groups. These findings collectively affirm the robustness of PBL across varied educational systems and learner populations. However, practical implementation presents several considerations [4]. Group work may occasionally involve interpersonal friction or misalignment in expectations, which requires thoughtful scaffolding and facilitation to maintain productive learning dynamics. Successful adoption also depends on close alignment with curriculum frameworks and clearly defined learning goals—conditions that necessitate comprehensive teacher preparation and institutional support. Additionally, learners accustomed to more directive instructional formats may initially require transitional support to adjust to increased autonomy and responsibility in learning. Overall, effective PBL implementation is shaped by contextual factors, educator readiness, learner preparedness, and systemic enablers.

2.2. PBL in Geography Education

High school geography, with its broad interdisciplinary scope and its reliance on regional case studies to illustrate theoretical concepts, is characterized by its cross-disciplinary and place-based nature. These features align naturally with the pedagogical principles of problem-based learning. Geography is widely recognized as a synthesizing discipline that draws upon both the natural and social sciences, making it ideally suited to this approach [5]. Its integrative nature—and its focus on relationships between human and physical systems—further reinforces its suitability for problem-based learning. In practice, implementation has often centered around fieldwork. For example, a university-level geography education program incorporated a problem-based fieldwork activity investigating water quality and environmental impact along a major river system. Evaluation indicated that over 93% of students regarded the activity as important and necessary for their geographical learning, and a similar proportion reported heightened interest in the subject. Furthermore, students showed marked improvement in teamwork, communication, and systems thinking skills.

2.3. AI Integration in Geography PBL: Opportunities and Challenges

The integration of AI technology into project-based learning (PBL) in geography education has attracted growing scholarly attention. At the theoretical level, AI is increasingly viewed as a scaffolding tool that supports pedagogical design. Educators can leverage carefully constructed prompts to guide AI systems in assisting with the development of geography PBL projects aligned with curricular goals—such as formulating authentic driving questions, clarifying instructional roles, and designing formative and summative assessment strategies [1]. Specialized GeoAI tools, in particular, have demonstrated capacity to scaffold spatial reasoning, support critical evaluation of geospatial data, and foster awareness of socio-spatial dimensions embedded in geographic phenomena. At the practical level, current implementations are predominantly observed in higher education settings, where researchers are investigating how AI tools can be embedded across different phases of geography instruction. For example, in a university-level course on climate change, an instructor incorporated AI to co-design a community-engaged PBL initiative; student reflections highlighted emerging competencies in critical AI literacy, particularly regarding ethical implications and the contextual boundaries of technological interventions. Similarly, in an interdisciplinary course bridging economic and political geography, GeoAI applications within a PBL framework enhanced learners' cognitive engagement with spatial analysis, data interpretation, and socio-political contextualization. Nevertheless, successful integration faces several constraints. Effectiveness depends on multiple interrelated factors—including students' foundational knowledge, prior experiences with AI, and the degree to which AI functionalities are deliberately aligned with stated learning outcomes. While many students routinely use conversational AI platforms for personal productivity, their

educational application requires intentional pedagogical framing. Scholars emphasize that AI must be embedded within a reflective, critically oriented teaching approach rather than treated as a neutral or self-evident enhancement. Notably, existing literature reveals a significant gap: no empirical studies to date have specifically examined the implementation of AI-integrated PBL in senior high school geography classrooms.

2.4. Conclusion

In summary, while initial efforts have emerged to integrate artificial intelligence with project-based learning in geography education, significant gaps persist in the existing literature. Empirical investigations remain limited in scope and quantity, with most conducted at the tertiary level; systematic integration of AI tools into high school geography project-based learning is especially underexplored. To address this gap, this study designed and implemented a high school geography project-based learning unit incorporating AI tools [6]. Through thematic analysis of written reflections from 20 students, the study seeks to answer two questions: (1) how do students assess the usefulness and trustworthiness of AI-provided information within a geography project-based learning context? and (2) how does participation in an AI-integrated geography project-based learning experience influence their understanding of geography's nature and value?

3. Methodology

A single case study design is well suited for in-depth investigation of complex phenomena within natural settings, as it preserves contextual richness and enables comprehensive understanding of real-world occurrences [7]. This approach supports detailed case description and thematic analysis through triangulation of multiple data sources. Accordingly, this study adopts a qualitative single case study design, focusing on a project-based learning initiative integrated with artificial intelligence tools at a senior international high school.

The research was conducted at an international senior high school located in Dameisha, Yantian District, Shenzhen, Guangdong Province. The school's schedule includes daily free time from 3:30 PM to 7:00 PM, enabling teachers to organize field trips to the nearby Dameisha coastal area for data collection and environmental exploration. This scheduling flexibility contrasts with most public high schools in China, where rigid curricular timetables typically limit opportunities for extended outdoor learning. Dameisha Beach is a prominent local tourist destination, characterized by its sandy shoreline, coastal vegetation, and distinctive geomorphological features. Leveraging these resources, the geography teacher developed a two-month project-based learning unit centered on sustainable tourism development in the Dameisha area. A total of 20 students participated, including the two researchers. All participants had completed prior geography coursework and possessed foundational knowledge of geographical concepts, as well as basic map interpretation and spatial analysis skills. Upon project completion, participants submitted written self-reflections documenting their learning experiences throughout the PBL process. All 20 reflections—including those of the researchers—were collected, anonymized, and subjected to thematic analysis. The first researcher read all reflections, identified salient elements, and generated initial codes, which were then clustered into overarching themes related to AI integration, geographical learning outcomes, and PBL engagement. The second researcher independently reviewed the coding framework to ensure consistency and interpretive rigor. Informed consent was obtained from all participants for academic use of their anonymized reflections [8]. To mitigate potential insider bias, systematic coding protocols and iterative peer review were implemented throughout the analytical process.

4. Project Design and Implementation

4.1. Summary of the Project

This project focuses on the coastal resources of the Dameisha area in Yantian District [9]. It integrates geography with computer science, biology, and art, emphasizing technological empowerment and interdisciplinary learning. The project centers on vegetation and landforms along the coastal walkway. The AI-integrated geography project-based learning (PBL) design adheres to core PBL principles: it is guided by a compelling driving question, grounded in an authentic local context, structured around student-led inquiry, and oriented toward publicly shareable outcomes. It addresses real-world challenges while strengthening students' ability to apply interdisciplinary knowledge to everyday situations. Furthermore, it fosters competencies in data analysis, AI application, and collaborative teamwork.

The design framework is presented in Figure 1 below. This figure outlines the project implementation pathway, the disciplinary domains involved, the team structure, and the final outputs. The implementation pathway consists of six phases: Preparation, Fieldwork, Data Processing, Visualization & AI, System Build, and Presentation & Products [10]. This framework reflects the foundational design philosophy of the AI-integrated geography PBL project.

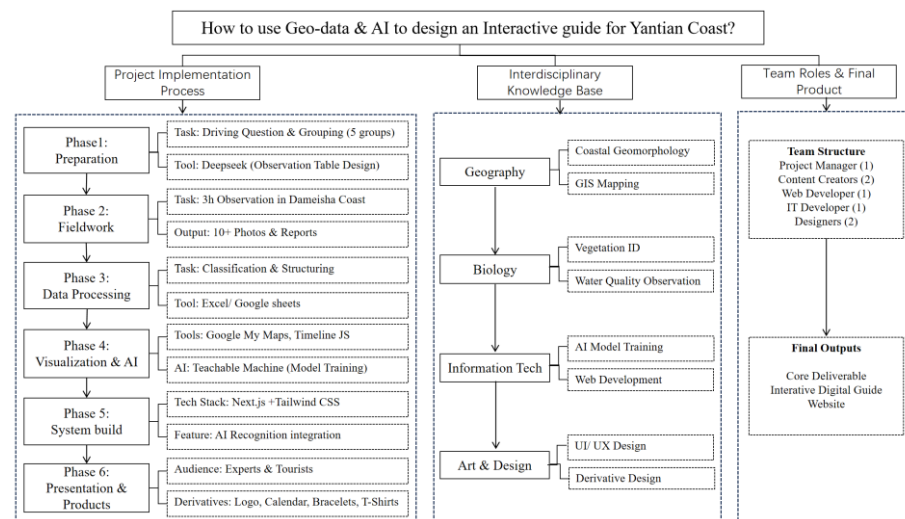


Figure 1. Framework of the AI-integrated PBL Project

4.2. The Driving Question

In the AP Human Geography course, students developed proficiency in using GIS for spatial data analysis [11]. To reinforce this competency, the teacher designed an assignment requiring students to independently collect geographic data and visualize it using GIS tools. Dameisha Coast—a well-known seaside destination in Shenzhen—draws large numbers of families with children. During visits, young children frequently express curiosity about coastal landforms and vegetation, posing questions to their parents, who often lack the specialized knowledge to respond adequately. This everyday situation highlights a broader public need for accessible geographical understanding and offers an authentic, context-rich foundation for pedagogical design. Concurrently, recent advances in artificial intelligence—including image recognition and natural language processing—enable new approaches to democratizing geographic information for non-specialist audiences. Integrating these three dimensions—classroom skill extension, real-world public engagement, and AI-enabled accessibility—the project is guided by the following driving question: "How can we utilize geographic data and AI technology to design an interactive digital browsing system for the Yantian coast, helping more people understand its natural landscape and cultural history?"

4.3. Implementation Phases

4.3.1. Preparation/Initial Question

In the preparation phase, the teacher introduced the project's driving question and guided students in preliminary discussions centered on the theme: "How can we use geographic data and AI technology to design an interactive guide system?" The class of 20 students was divided into five groups of three to four members, with each group assigned one of five observation categories: landforms, vegetation, seawater properties, marine life, and special phenomena [12]. To support subsequent fieldwork, a structured observation table was developed using an AI tool, specifying the types and formats of information each group was required to record.

4.3.2. Fieldwork

Students conducted a three-hour field observation at Dameisha Coast during the daily free time slot from 3:30 PM to 7:00 PM. Each group focused on its assigned thematic category, documenting coastal vegetation and landforms through smartphone photography while recording observed natural phenomena and environmental features. All groups submitted at least ten representative images along with a comprehensive observation report [13].

4.3.3. Data Processing

Following field observation, each group submitted a minimum of 10 images along with a comprehensive observation report. The collected images and records were systematically organized in Excel to generate a structured electronic datasheet, documenting the absolute geographic coordinates of each vegetation type or landform, associated photographs, classification, and salient geographical characteristics. This dataset served as the foundational input for GIS analysis and supported both AI model training and website content development.

4.3.4. Visualization & AI

In this phase, students engaged in data visualization and AI model development. First, they used Google My Maps to plot the precise locations of each observation point on an interactive map, annotating each with descriptive information about the associated vegetation or landform features. Second, they employed Timeline JS to assemble a chronological narrative of historical materials and images related to the Yantian coastal area, while also using AI tools to generate predictive visualizations of future coastline configurations under varying sea-level scenarios [4]. For AI model development, students utilized the Teachable Machine platform, training an image recognition model on field-collected photographs to classify vegetation types and landform characteristics. Throughout the process, they iteratively refined parameters—including learning rate and training dataset size—to enhance classification accuracy.

4.3.5. System Build

In this phase, students developed the interactive digital guide system. Initial efforts to implement all functionalities on a Notion website revealed limitations in interactivity. Following collaborative evaluation, the team transitioned to a Next.js and Tailwind CSS framework. The resulting website incorporated visualization outputs from prior phases, including the Google My Maps interactive map, the Timeline JS timeline, and the Teachable Machine AI model [14]. Users interact with the system by uploading or capturing images of landforms or plants via their devices; the system then automatically identifies and classifies the subject, delivering immediate feedback. After completing the initial implementation, students performed iterative testing to verify functional integrity across all components.

4.3.6. Presentation & Products

In the final phase, students presented their work to external stakeholders, including representatives from the Meisha Subdistrict Office, the Dameisha Coastal Park Management Office, and visitors to Dameisha Beach [14]. Feedback included recommendations to align student-collected data with official government datasets to enhance model accuracy and to integrate gamification elements to improve interactivity

for visitors; suggestions also emphasized incorporating environmental protection themes and optimizing the website interface—such as increasing font size and adopting child-friendly design features. To extend public engagement, students developed complementary products, including a plant calendar showcasing local vegetation and landforms, and plant essential oil bracelets bearing the project name.

4.4. Integration of AI Tools

In this project, AI tools were integrated from two main aspects: first, the teacher's intentional and purposeful use of AI tools in designing the geography PBL project; second, students' active engagement with AI assistance during project implementation, where AI functioned as a "practice guide"—a role supported by the international high school context that enables student access to personal electronic devices [11].

First, the teacher employed AI tools during the design phase to provide technical support for project implementation. In the preparation stage, a structured observation table was developed using an AI platform. During data visualization, students trained an image recognition model to identify vegetation types and landform features using a no-code machine learning tool, and constructed a historical timeline using an interactive web-based platform, incorporating AI-generated predictive visualizations of future coastline changes [15]. These tools were embedded across multiple stages of the PBL process, supporting student groups in data collection, information processing, and final output creation.

Second, during implementation, students treated AI as a "technical guide." While the teacher served as the theoretical guide and project designer, AI delivered concrete, step-by-step procedural support. For instance, when building the website framework with a modern web development framework and integrating the AI recognition feature, students consulted AI tools for code examples, platform selection guidance, and debugging strategies. When training models using the no-code machine learning tool, AI provided real-time feedback on parameter optimization. As reflected in student journals, AI offered actionable solutions to technical challenges—complementing the teacher's conceptual instruction on geographical principles and project goals by addressing the practical "how-to" dimensions of implementation.

5. Result

Upon project completion, students were asked to submit written self-reflections to evaluate and reflect on their learning experience. All 20 participating students submitted reflections addressing their use of AI tools, their evolving understanding of geography, and their overall engagement with the project. The reflections included those of the two authors, which were anonymized prior to analysis. Thematic analysis was applied to all submissions. The first author conducted an initial reading of all reflections, identified salient elements, and developed preliminary codes. These codes were subsequently organized into overarching themes centered on AI integration, geographical learning outcomes, and project-based learning experiences. The second author independently reviewed the coding framework to ensure analytical consistency.

This study sought to address two core questions: How do students perceive the practicality and reliability of AI-generated information within a geography project-based learning context? How does integrating AI into a geography project-based learning activity shape students' conceptual understanding of the discipline? Through systematic coding and thematic categorization of the 20 reflections, three primary dimensions emerged: students' evaluations of AI utility—including perceived strengths and limitations; iterative interactions with AI that shaped response quality and depth; and shifts in students' disciplinary understanding of geography. Additional findings highlighted enhancements in collaborative competencies and challenges related to time management during project execution [6].

5.1. Students' Perception of the Practicality and Reliability of AI - Provided Information

Sixteen students reported that artificial intelligence significantly enhanced efficiency in information searching and conceptual development. Throughout the project, participants progressed from initial exposure to proficient application of AI tools, increasingly viewing them as effective assistants for integrating and organizing information.

"While researching the history of the Yantian Coast, I found online materials highly fragmented and difficult to navigate efficiently [16]. After turning to AI, it synthesized relevant historical content into a well-structured summary, greatly improving my information retrieval process."

Another student, tasked with designing derivative products, observed:

"When selecting color schemes for the calendar design, I lacked confidence in my aesthetic judgment. I consulted AI for harmonious color combinations and ultimately adopted a blue-and-white palette that conveyed visual balance and comfort."

Additionally, students employed AI as a personalized learning support tool [17]. One participant aiming to develop a WeChat mini-program to extend the project's outreach stated:

"With no prior experience in mini-program development—and no peer support available in class—I relied on AI to guide me step by step [5]. It provided clear procedural instructions and real-time troubleshooting assistance, enabling me to complete the development independently."

These accounts collectively reflect student recognition of AI's utility in information synthesis, creative ideation, and skill acquisition. Nevertheless, seven students noted inconsistencies or inaccuracies in AI-generated outputs and consistently applied critical evaluation when interpreting AI-provided data and recommendations.

One student, while seeking official contact details for the Dameisha management office, encountered:

"AI generated a fictitious telephone number, requiring additional time and effort to locate the authentic contact information."

A student conducting historical research remarked:

"Verifying the historical accuracy of AI-provided content about the Yantian Coast demanded substantial time investment, which partially offset the initial efficiency gains."

Such experiences reinforced student awareness of AI's limitations as an authoritative information source. Importantly, their reflections extended beyond acknowledging potential errors: they described concrete verification strategies—including cross-referencing outputs across multiple AI platforms—demonstrating the emergence of disciplined critical thinking during project implementation.

5.2. Impact of AI - Integrated Geography PBL Projects on Students' Understanding of Geography

Regarding geographical learning efficacy, nine students reported improved understanding of abstract geographical concepts through real-life application [9]. One student wrote:

"I previously found the concept of human–environment interaction confusing and struggled to grasp how humans and the environment influence one another [6]. After participating in this project-based learning (PBL) initiative, I developed a clear understanding of this concept."

Another student noted:

"I previously did not appreciate why space and location are fundamental in geography [11]. Through this PBL project, I learned that location confers distinct advantages—such as access to mineral resources, tourism potential, and trade opportunities—for nearby communities."

A student further reflected on the broader relevance of geography:

"I used to view geography as limited to topics like vegetation, water systems, landforms, and urban development—subjects often approached through rote

memorization [8]. Now I recognize that geographical perspectives help explain diverse phenomena, and geographical thinking is deeply embedded in everyday life."

Regarding the PBL experience, thirteen students reported enhanced understanding of collaborative learning. One student wrote:

"I typically worked independently and felt discouraged when tasks proved difficult. This PBL project helped me recognize the value of teamwork and demonstrated how collective effort leads to more effective outcomes."

Meanwhile, ten students indicated experiencing significant time pressure [11]. One student noted:

"I regularly stayed up until 1 or 2 a.m. to finalize the project report, which left me fatigued during daytime classes."

Another student wrote:

"Time was severely constrained; I dedicated nearly all my free time to completing the project within the deadline."

These findings indicate that while PBL implementation effectively strengthens collaborative competencies, it also poses notable demands on students' time management and overall workload.

6. Discussion

First, student perceptions of AI exhibited a dual nature. On the one hand, the majority of students recognized the practical value of AI in information retrieval, creative inspiration, and skill guidance. This recognition aligns with findings from prior research emphasizing AI's role as a cognitive scaffold in teaching and learning. On the other hand, AI occasionally generated inaccurate information. From a technical perspective, this limitation reflects current constraints in model training and data grounding. However, the process of identifying and correcting such inaccuracies supported the development of students' critical thinking skills, as they learned to evaluate information validity and progressively strengthened their personal AI literacy.

Second, the AI-integrated PBL practice enhanced students' understanding of geographical knowledge [5]. The GIS maps in textbooks were transformed into active processes of data collection, analysis, processing, and visualization, helping students grasp geographical concepts within authentic, context-rich settings. This finding resonates with observations that project-based fieldwork enables learners to connect academic knowledge with real-world environmental phenomena. It also supports the view that geography's integrative nature makes it especially well-suited to project-based learning, as it invites students to engage with complex, open-ended problems. All students reported a meaningful shift in their perception of geography's relevance and applicability—a significant outcome of this study.

PBL implementation exhibited a dual nature—the benefits of collaborative learning coexisted with challenges related to time management—which is consistent with broader literature on project-based pedagogy. Group work in PBL can sometimes lead to coordination difficulties and varying levels of engagement among participants. Time pressure has also been widely documented as a practical constraint in implementing such approaches. On the one hand, students developed practical competencies that extend beyond textbook-based instruction. On the other hand, participation in the PBL project required additional time investment, leading some students to report feelings of workload intensity. This finding suggests that integrating PBL into senior high school curricula entails both pedagogical advantages and operational considerations, requiring educators to thoughtfully align project expectations with students' overall academic responsibilities.

Several limitations of this study should be acknowledged. First, the sample size is limited and drawn from a single institution [9]. Only 20 reflective entries were collected, and the results lack statistical generalizability. Participants were enrolled at one international high school in Shenzhen, an institution with distinctive curricular and demographic features; therefore, findings are most directly applicable to similar international school contexts. Second, this study adopted a qualitative methodology

rather than a quantitative design. The conclusions are based on thematic analysis of students' written reflections, which inherently involve interpretive judgment. Third, because the researchers were also involved in facilitating the intervention, potential insider perspectives may have influenced data interpretation.

7. Conclusion

This study designed an AI-integrated high school geography project-based learning (PBL) initiative and analyzed the self-reflections of 20 participating students, yielding two principal findings.

First, from the student perspective, the integration of AI tools within the PBL framework yielded positive learning outcomes. On one hand, AI tools enhanced learning efficiency; on the other, they supported the development of critical thinking skills and contributed to foundational AI literacy.

Second, from the teacher perspective—encompassing design and implementation—the AI-integrated PBL approach presented three key considerations, alongside corresponding practical insights. The first pertained to project design: selecting and integrating appropriate AI tools—such as Teachable Machine and Timeline JS—into a coherent PBL framework required careful evaluation of functionality, reliability, and pedagogical alignment. The second involved project management: assigning a student project coordinator role improved task tracking and progress monitoring across groups, reducing coordination demands on the teacher while fostering student leadership and responsibility. This structure proved especially supportive for educators new to PBL implementation. The third consideration concerned collaborative workflow and timeline adherence: the final presentation phase required synthesizing outputs from all project stages into a unified document and presentation. Delays in any stage risked cascading effects on subsequent tasks, resulting in compressed timelines and heightened time pressure for students. To mitigate this, establishing clearly defined milestones at the outset—and embedding flexible contingency measures for schedule adjustments—proved essential.

This study also had several limitations: the sample size was limited and drawn from a single international high school, constraining the generalizability of the findings; the qualitative methodology may entail interpretive subjectivity, and the dual role of researchers as both facilitators and analysts introduced potential insider influence. Future research could broaden participation, incorporate comparative or control-group designs, and integrate quantitative measures to strengthen validation.

In summary, integrating AI tools into high school geography PBL holds demonstrable educational value while presenting distinct implementation considerations. For students, the approach supports critical thinking development, fosters emerging AI literacy, and deepens appreciation of geography's relevance to real-world contexts. For teachers, successful implementation depends on competencies in AI tool selection and integration, structured project management, and responsive facilitation of collaborative group work. Sustained effectiveness requires systematic attention to instructional design, tool curation, time planning, and role distribution.

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