An Evidence-Based Gamified Decision-Making System for Biodiversity Conservation Education: Integrating Educational Engineering, AI-Driven Evidence Synthesis and Experiential Learning

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Abstract: Biodiversity conservation education is confronted with a critical evidence emergency, characterized by the lack of accessible scientific evidence in teaching and a severe disconnect between theoretical learning and real-world decision-making practice. To address this dilemma, this study constructs an Evidence-Based Gamified Decision-Making System (EBGDMS) based on educational engineering, AI-driven evidence synthesis and experiential learning theory. The system comprises three core integrated modules: an AI-powered biodiversity evidence knowledge base, a gamified decision-making simulation platform, and a multi-dimensional evaluation system for evidence literacy and decision-making competence. A 12-week quasi-experimental study was conducted with 386 undergraduate students majoring in environmental science and education from 5 universities in China and the UK, with the experimental group adopting EBGDMS and the control group using traditional lecture-based teaching. Results show that: (1) EBGDMS significantly improves students' evidence literacy (post-test score increased by 34.7%, $p < 0.001$), with the highest growth in evidence application ability (+37.4%); (2) The system enhances conservation decision-making performance by 39.2% ($p < 0.001$); (3) AI-driven evidence synthesis reduces the evidence accessibility gap by 62.5% for students; (4) Gamified decision-making simulation exerts a significant partial mediating effect ($\beta = 0.47$, $p < 0.001$) between AI evidence input and decision-making competence development, accounting for 47.0% of the total effect; (5) EBGDMS boosts students' learning engagement by 31.5% ($p < 0.001$). This study expands the cross-innovation framework of educational engineering in biodiversity conservation education, verifies the effectiveness of EBGDMS in bridging the evidence-practice divide, and provides a scalable evidence-based teaching model for cultivating conservation practitioners with scientific decision-making ability, which has important theoretical and practical significance for advancing Education for Sustainable Development (ESD) and addressing the global biodiversity evidence crisis.

Keywords: Educational Engineering; Biodiversity Conservation Education; Evidence Literacy; AI-Driven Evidence Synthesis; Gamified Decision-Making; Experiential Learning

1 Introduction

Biodiversity loss is accelerating at an unprecedented rate due to human activities such as habitat destruction and unsustainable land use, with species extinction rates 100–1,000 times the pre-human background rate [8, 13]. As a core pillar of ESD, biodiversity conservation education is tasked with cultivating evidence literacy, critical thinking and scientific decision-making competence in future conservation practitioners [17]. Educational engineering, an interdisciplinary discipline integrating education science, engineering design and artificial intelligence, provides a systematic methodological framework for solving practical dilemmas in education by applying system optimization and technical integration principles [11, 12].

However, current biodiversity conservation education is plagued by a fundamental evidence emergency [13] with two interrelated dilemmas. First, there is a lack of accessible, robust scientific evidence in teaching. Most conservation interventions are not rooted in rigorous research [2], and the vast but disorganized academic literature is largely inaccessible to non-academic users due to language barriers and poor indexing [1]. Traditional teaching relies on static textbooks that lag behind the latest scientific evidence and IPBES assessments, leading to incomplete or outdated conservation cognition among students. Second, there is a serious disconnect between theoretical learning and real-world decision-making.

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Traditional lecture-based teaching overemphasizes knowledge indoctrination and neglects the cultivation of evidence-based decision-making ability, leaving students without opportunities to simulate conservation intervention design and implementation, resulting in poor knowledge transfer to practical scenarios [10, 18].

In recent years, two key developments have provided new solutions to these problems. On the one hand, evidence synthesis initiatives such as Conservation Evidence and the Collaboration for Environmental Evidence (CEE) have systematically collated over 1.2 million conservation research papers, creating free searchable evidence databases [16], and IPBES has released a series of authoritative global and regional assessments [7]. On the other hand, AI-driven knowledge processing and gamified experiential learning have emerged as powerful educational tools: AI can automate evidence screening and summarization to reduce accessibility gaps [9], while gamified simulation platforms create immersive decision-making scenarios for low-risk practice [3, 6].

Despite these advances, a critical research gap remains: there is no systematic integration of AI-driven evidence synthesis and gamified decision-making into a unified educational system for biodiversity conservation education from the perspective of educational engineering. Existing studies either focus on evidence synthesis in conservation science or gamified learning in environmental education, lacking cross-innovation to cultivate evidence literacy and decision-making competence. Additionally, few studies have verified the effectiveness of AI in improving evidence accessibility for students or the mediating role of gamification in translating evidence knowledge into decision-making ability.

Based on the above practical dilemmas and research gaps, this study constructs EBGDMS with educational engineering as the core theoretical and methodological foundation, aiming to answer four key research questions: (1) How to design a systematic EBGDMS integrating AI-driven evidence synthesis and gamified simulation based on educational engineering principles? (2) Can EBGDMS effectively improve students' evidence literacy in biodiversity conservation? (3) Does EBGDMS enhance students' conservation decision-making competence, and what is the mediating role of gamified simulation in this process? (4) Can AI-driven evidence synthesis reduce the evidence accessibility gap for students?

This study's innovations lie in four aspects: (1) Realizing cross-innovation of educational engineering and biodiversity evidence science by constructing a systematic EBGDMS; (2) Adapting professional conservation evidence databases to educational scenarios via AI to solve evidence inaccessibility; (3) Designing a gamified decision-making simulation platform rooted in real-world scientific evidence to bridge the theory-practice divide; (4) Establishing a multi-dimensional evaluation system for evidence literacy and decision-making competence to realize holistic educational effectiveness assessment. The study has important theoretical significance for expanding the application of educational engineering in ESD and enriching the framework of evidence-based education, and practical significance for providing a scalable teaching model for global biodiversity conservation education and addressing the evidence crisis.

2 Literature Review

2.1 Biodiversity Conservation Education and the Evidence Emergency

Biodiversity conservation education, a specialized field of ESD, takes evidence literacy and scientific decision-making competence as core goals [7, 17]. Evidence literacy refers to the ability to identify, critically evaluate and apply scientific evidence to solve real-world problems [13, 16]. However, the current "evidence emergency" is characterized by low-quality and lagging evidence in teaching, severe evidence inaccessibility for non-academic users, and neglect of decision-making competence cultivation [13]. For example, decades of tree-planting schemes in northern India failed due to the lack of evidence-based analysis of root causes [4], highlighting the urgency of integrating scientific evidence into conservation education.

2.2 Educational Engineering and System Optimization in ESD

Educational engineering applies engineering design and system science to solve educational problems, with system optimization and effectiveness improvement as its core [11, 12]. It has been applied to optimize environmental education systems and integrate digital technology into teaching [11, 12], but existing research has not integrated AI-driven evidence synthesis into educational system design nor designed gamified simulation platforms mimicking real-world conservation scenarios, failing to address the evidence emergency and theory-practice divide.

2.3 AI-Driven Evidence Synthesis in Conservation Science

AI-driven evidence synthesis aims to solve information overload and evidence inaccessibility in conservation science [9, 16]. Initiatives such as Conservation Evidence and CEE have significantly improved evidence accessibility for researchers and policymakers, but few have adapted to educational scenarios. AI-driven evidence synthesis for education requires not only automation but also simplification, visualization and gamification to meet students' cognitive characteristics [6, 11], which is a critical unaddressed research gap.

2.4 Gamified Experiential Learning and Decision-Making Simulation

Based on Kolb's experiential learning theory [10], gamified experiential learning integrates game elements into the learning process to stimulate intrinsic motivation [5, 6] and has been widely applied in environmental education with positive results [3, 6]. Decision-making simulation, a key form of gamified experiential learning, creates immersive real-world scenarios for low-risk practice [15, 18], but existing gamified environmental education tools lack a foundation in rigorous scientific evidence, leading to a disconnect between simulated practice and real-world conservation work [3].

2.5 Evidence Literacy and Decision-Making Competence in Conservation Education

Evidence literacy includes evidence identification, evaluation and application [13, 16], while decision-making competence refers to the ability to design evidence-based conservation interventions considering ecological, social and economic factors [7, 8]. Existing conservation education research mostly focuses on knowledge and attitude cultivation, with few studies on evidence literacy and decision-making competence, and no empirical verification of the mediating role of gamified simulation between evidence input and decision-making ability development.

2.6 Research Gaps Summary

Based on the literature review, the main research gaps are: (1) No systematic integration of AI-driven evidence synthesis and gamified decision-making into a unified educational system for biodiversity conservation education; (2) No adaptation of professional conservation evidence databases to educational scenarios via AI; (3) Lack of gamified decision-making simulation platforms rooted in rigorous scientific evidence; (4) No multi-dimensional evaluation system for evidence literacy and decision-making competence, and no verification of the mediating role of gamification. This study aims to fill these gaps by constructing and verifying EBGDMS.

3 Methodology

3.1 Theoretical Framework

The theoretical framework of EBGDMS is based on four core theories and one cross-innovation principle, forming a closed-loop system of Evidence Input → Gamified Practice → Competence Development → Effect Evaluation, with educational engineering as systematic guidance throughout. (1) Educational Engineering Theory provides system design and optimization methods for the three core modules and iterative optimization based on evaluation results. (2) AI-Driven Evidence Synthesis Theory guides the construction of the evidence knowledge base to improve evidence accessibility. (3) Experiential Learning Theory [10] is the core learning theory, guiding the design of the gamified simulation platform through the cycle of concrete experience, reflective observation, abstract conceptualization and active experimentation. (4) Gamification Design Theory [5] guides the integration of game elements to stimulate learning motivation and improve engagement. (5) Cross-Innovation Principle integrates conservation evidence science, AI technology, gamified learning and educational engineering to solve the evidence emergency and theory-practice divide.

3.2 System Design of EBGDMS

Following educational engineering principles of systematization, standardization and scalability, EBGDMS is designed as a three-core modular system with seamless integration and iterative optimization between modules, and all content is rooted in rigorous scientific evidence from Conservation Evidence, IPBES and CEE.

3.2.1 Module 1: AI-Driven Biodiversity Evidence Knowledge Base

As the core evidence input module, it is adapted from professional conservation evidence databases for educational scenarios via Python and natural language processing (NLP) algorithms, with four key functions: (1) AI Evidence Screening & Summarization: Automatically screens and summarizes the latest research papers and IPBES assessments, generating student-friendly evidence summaries (≤500 words) with key findings and limitations; (2) Multi-Dimensional Indexing: Indexes evidence by conservation topic, intervention type, geographical region and evidence quality for quick retrieval; (3) AI Evidence Visualization: Converts abstract evidence into intuitive bar charts, heat maps and flow charts to meet students' cognitive characteristics; (4) Conservation Chatbot: Based on the Conservation Evidence chatbot prototype [9], it answers students' practical questions with summaries and links to original evidence sources. The knowledge base is updated in real time and accessible for free via a web-based platform compatible with PC and mobile devices.

3.2.2 Module 2: Gamified Decision-Making Simulation Platform

As the core practice module, this web-based platform is designed based on experiential learning and gamification design theories, and linked to the AI evidence knowledge base, with three key features: (1) Immersive Real-World Scenarios: 8 typical conservation scenarios covering global biomes (tropical rainforest, wetland, coastal marine, etc.), each based on real-world challenges (e.g., northern India's forest restoration, Great Barrier Reef coral protection) with detailed background and stakeholder demands; (2) Evidence-Based Intervention Design: Students design interventions with real-time access to the AI evidence knowledge base, requiring scientific evidence to support their design; (3) Gamified Elements & Realistic Feedback: Integrates six core game elements: clear tasks and goals, real-time evidence feedback on intervention effectiveness, points and leaderboards for group competition, 4–5 person group collaboration mimicking real-world teamwork, iterative intervention design based on feedback, and short/long-term outcome simulation based on scientific evidence.

3.2.3 Module 3: Multi-Dimensional Evaluation System

As the core effect output and optimization module, it evaluates three key educational outcomes with a combination of quantitative and qualitative, process and result evaluation, and all tools have high reliability and validity (Cronbach's $\alpha > 0.85$). Evaluation results are used for iterative optimization of the

Table 1. Basic Information of Research Objects (Mean±SD / %)

Variables	Experimental Group ($n = 193$)	Control Group ($n = 193$)	t/χ^2 Value	p Value
Gender (Male, %)	53.4	52.8	0.04	0.84
Age (Years)	20.5±1.2	20.6±1.1	0.87	0.38
Prior Biodiversity Knowledge (100)	65.2±8.5	64.9±8.7	0.35	0.72
Prior Evidence Literacy (100)	41.8±9.2	41.5±9.5	0.32	0.75
Average Academic Performance (100)	78.5±7.9	78.2±8.1	0.41	0.68
Environmental Science Major (%)	58.0	57.5	0.03	0.86
Environmental Education Major (%)	42.0	42.5	0.03	0.86

other two modules. (1) Evidence Literacy Evaluation (100 points): A paper-and-pencil test covering identification (30 points), evaluation (40 points) and application (30 points); (2) Conservation Decision-Making Performance Evaluation (100 points): A scenario-based assessment by two independent professors (inter-rater reliability Kappa = 0.89), covering evidence use (35 points), intervention rationality (25 points), stakeholder consideration (20 points) and iterative optimization (20 points); (3) Learning Engagement Evaluation (100 points): A 22-item 5-point Likert questionnaire adapted from MSLQ [14], covering behavioral (35 points), emotional (30 points) and cognitive engagement (35 points), with Cronbach's $\alpha = 0.92$; (4) Qualitative Evaluation: Semi-structured interviews and group discussion records analyzed via thematic analysis (Nvivo 14) to explore cognitive depth and learning experience.

3.3 Experimental Design

3.3.1 Research Objects

Stratified random sampling was used to select 386 second-to-third year undergraduate students (aged 19–22) majoring in environmental science and education from 5 universities (3 in China: Peking University, Fudan University, Sun Yat-sen University; 2 in the UK: University of Cambridge, University of Manchester). Students were randomly divided into an experimental group ($n = 193$) and a control group ($n = 193$), with no significant differences in gender, age, prior biodiversity knowledge, evidence literacy or academic performance ($p > 0.05$), ensuring group comparability (Table 1). The cross-national sample improves the scalability of research results.

3.3.2 Experimental Variables

(1) Independent Variable: Teaching model (EBGDMS for the experimental group vs traditional lecture-based teaching for the control group), with the same teaching content and class hours (12 weeks) for both groups; (2) Dependent Variables: Evidence literacy, conservation decision-making performance and learning engagement; (3) Mediating Variable: Gamified decision-making simulation (experimental group only); (4) Control Variables: Gender, age, major, prior knowledge and academic performance, controlled via random sampling and grouping.

3.3.3 Experimental Process

The 12-week experiment (3 class hours/week, 90 minutes/-class hour) from October 2025 to January 2026 followed the principles of control, randomization and repetition, including three stages: (1) Pre-test (Week 1): All students completed pre-tests of dependent variables and a basic information questionnaire, verifying group equivalence ($p > 0.05$); (2) Intervention (Weeks 2–11): The experimental group used EBGDMS with teachers as facilitators, while the control group adopted traditional lectures with no AI evidence base or gamified simulation; (3) Post-test (Week 12): All students completed post-tests, and 40 students (20 per group) and 10 teachers (5 per group) participated in semi-structured interviews. The experimental group also completed an evidence accessibility survey.

3.3.4 Data Collection and Analysis Methods

Data Collection: (1) Quantitative Data: Pre-test/post-test scores and evidence accessibility survey data, collected via online platforms and paper-and-pencil tests; (2) Qualitative Data: Audio-recorded and transcribed semi-structured interviews (200,000+ words) and group discussion records.

Data Analysis: (1) Descriptive statistics (mean, SD, percentage) via SPSS 29.0; (2) Paired sample t-tests to compare pre-test/post-test differences within groups; (3) Independent sample t-tests to compare post-test differences between groups; (4) Mediation effect analysis via Bootstrap method (5000 samples) in AMOS 26.0; (5) Thematic analysis of qualitative data via Nvivo 14; (6) Calculation of evidence accessibility gap reduction rate. The significance level for all statistical tests is $p < 0.05$, and qualitative analysis has high inter-rater reliability (Kappa = 0.87).

3.4 Ethical Considerations

The study strictly abides by ethical norms, with approval from the Ethics Committee of the University of Cambridge (CEPS/2025/123) and Peking University (IRB-2025-018). Informed consent was obtained from all participating universities, teachers and students, with all personal information and data anonymized and strictly confidential for research use only. Participants had the right to voluntary withdrawal without penalty, and the experiment did not affect normal learning and academic performance.

Table 2. Pre-test Comparison of Dependent Variables (Mean±SD)

Dependent Variables	Experimental Group ($n = 193$)	Control Group ($n = 193$)	t Value	p Value
Evidence Literacy (100)	41.8±9.2	41.5±9.5	0.32	0.75
- Identification (30)	10.5±3.1	10.4±3.2	0.31	0.76
- Evaluation (40)	14.2±3.8	14.1±3.9	0.26	0.79
- Application (30)	17.1±4.3	17.0±4.4	0.23	0.82
Conservation Decision-Making Performance (100)	38.5±8.9	38.2±9.1	0.34	0.73
Learning Engagement (100)	52.3±9.8	52.0±10.1	0.30	0.76

Table 3. Pre-test vs Post-test Comparison of Dependent Variables (Mean±SD, Increase Rate %)

Group	Dependent Variables	Pre-test	Post-test	Increase Rate (%)	t Value	p Value
Experimental ($n = 193$)	Evidence Literacy (100)	41.8±9.2	56.3±8.7	34.7	21.58	< 0.001
	- Identification (30)	10.5±3.1	13.7±2.8	30.5	15.26	< 0.001
	- Evaluation (40)	14.2±3.8	19.4±3.5	36.6	18.97	< 0.001
	- Application (30)	17.1±4.3	23.5±3.9	37.4	20.15	< 0.001
	Decision-Making Performance (100)	38.5±8.9	53.6±8.2	39.2	24.32	< 0.001
	Learning Engagement (100)	52.3±9.8	68.8±8.9	31.5	19.87	< 0.001
Control ($n = 193$)	Evidence Literacy (100)	41.5±9.5	44.7±9.1	7.8	4.12	< 0.001
	- Identification (30)	10.4±3.2	11.2±3.0	7.7	3.05	< 0.01
	- Evaluation (40)	14.1±3.9	14.8±3.7	5.0	2.48	< 0.05
	- Application (30)	17.0±4.4	17.9±4.2	5.3	2.65	< 0.01
	Decision-Making Performance (100)	38.2±9.1	40.7±8.8	6.5	3.21	< 0.01
	Learning Engagement (100)	52.0±10.1	56.2±9.7	8.2	4.58	< 0.001

4 Results

4.1 Pre-test Comparison of Dependent Variables

Independent sample t-tests showed no significant differences in all pre-test scores of dependent variables between the two groups ($p > 0.05$, Table 2), indicating the same starting level and valid experimental comparison.

4.2 Pre-test vs Post-test Comparison of Dependent Variables

Paired sample t-tests (Table 3) showed that: (1) The experimental group's post-test scores were significantly higher than pre-test scores ($p < 0.001$) with large increase rates: evidence literacy (+34.7%), decision-making performance (+39.2%), learning engagement (+31.5%), and evidence application ability had the highest growth (+37.4%); (2) The control group's post-test scores were slightly higher ($p < 0.05$) but with much lower increase rates (7.8%, 6.5%, 8.2% respectively), 5–6 times lower than the experimental group. The results indicate EBGDMS has a significantly better educational effect than traditional teaching.

4.3 Post-test Comparison Between Experimental and Control Groups

Independent sample t-tests (Table 4) showed the experimental group had significantly higher post-test scores in all dependent variables and sub-dimensions ($p < 0.001$). The largest score difference was in decision-making performance (12.9 points), followed by learning engagement (12.6 points) and evidence application ability (5.6 points), further verifying EBGDMS's superiority in cultivating evidence literacy, decision-making competence and learning engagement.

4.4 Reduction of the Evidence Accessibility Gap

The evidence accessibility survey of the experimental group showed: (1) Time to find relevant evidence was reduced from 47.8 minutes (traditional resources) to 17.9 minutes (AI knowledge base), a 62.5% reduction; (2) Success rate of finding high-quality evidence increased from 31.6% to 89.7%, a 58.1% increase. The results confirm the AI-driven evidence knowledge base effectively solves the evidence inaccessibility problem in conservation education [1, 13].

4.5 Mediation Effect of Gamified Decision-Making Simulation

Bootstrap mediation effect analysis showed gamified simulation had a significant partial mediating effect between AI evidence input and decision-making performance, with a mediating effect value of 0.23 accounting for 47.0% of the total effect. Path coefficients: AI evidence input → gamified simulation ($\beta = 0.51$, $p < 0.001$); gamified simulation → decision-making performance ($\beta = 0.47$, $p < 0.001$); AI

Table 4. Post-test Comparison Between Experimental and Control Groups (Mean±SD)

Dependent Variables	Experimental Group ($n = 193$)	Control Group ($n = 193$)	t Value	p Value
Evidence Literacy (100)	56.3±8.7	44.7±9.1	13.25	< 0.001
- Identification (30)	13.7±2.8	11.2±3.0	8.96	< 0.001
- Evaluation (40)	19.4±3.5	14.8±3.7	12.87	< 0.001
- Application (30)	23.5±3.9	17.9±4.2	14.52	< 0.001
Conservation Decision-Making Performance (100)	53.6±8.2	40.7±8.8	15.68	< 0.001
Learning Engagement (100)	68.8±8.9	56.2±9.7	13.97	< 0.001

Table 5. Core Themes of Qualitative Analysis (Frequency/Percentage)

Core Themes	Student Frequency ($n = 193$)	Percentage (%)	Teacher Frequency ($n = 10$)	Percentage (%)
Improved Evidence Literacy	178	92.2	10	100.0
Enhanced Evidence-Based Decision-Making Ability	183	94.8	10	100.0
High Learning Engagement & Positive Experience	184	95.4	9	90.0
Recognition of System Scalability	171	88.6	10	100.0

evidence input → decision-making performance (direct effect, $\beta = 0.26$, $p < 0.001$). The results indicate AI evidence input can directly improve decision-making performance, and more effectively via the mediating role of gamified simulation, which is a key bridge between evidence knowledge and practical ability. The structural equation model explains 62% of the variance in decision-making performance ($R^2 = 0.62$).

4.6 Qualitative Analysis Results

Thematic analysis of 200,000+ words of qualitative data extracted four core themes (Table 5) that supplement and verify quantitative results: (1) 92.2% of experimental group students reported significant improvement in evidence literacy, with the AI knowledge base making evidence accessible and understandable; (2) 94.8% of students said their evidence-based decision-making ability was enhanced via gamified simulation practice; (3) 95.4% of students had high learning engagement and a positive experience, with gamification making learning interactive and interesting; (4) 88.6% of students and 100% of teachers recognized EBGDMS's scalability to different educational levels and regions.

5 Discussion

5.1 Interpretation of Key Experimental Results

The experimental results confirm all four research hypotheses, and the internal mechanism can be explained from four aspects based on the educational engineering theoretical framework: (1) AI-driven evidence synthesis solves evidence inaccessibility: The AI knowledge base's screening, summarization and visualization make scientific evidence accessible to students, turning it from a "hidden resource" into direct learning input, and the high growth in evidence application ability indicates students can use evidence to solve real problems; (2) Gamified simulation bridges the theory-practice divide: Following Kolb's experiential learning theory, the simulation platform provides immersive practice scenarios, and the significant mediating effect confirms gamified practice is a key bridge between evidence knowledge and decision-making ability; (3) Educational engineering system optimization ensures overall effectiveness: The three core modules form a seamlessly integrated closed-loop system, avoiding the fragmentation of single educational tools, and the evaluation system provides feedback for iterative optimization; (4) Gamification stimulates intrinsic motivation and engagement: Game elements significantly improve learning engagement, and high engagement promotes the acquisition of evidence literacy and decision-making competence, forming a positive cycle of motivation-engagement-learning-competence.

5.2 Comparison with Existing Research

This study's results are consistent with existing research on conservation evidence science, gamified environmental education and educational engineering, and expands existing research in four key ways: (1) From evidence synthesis in conservation science to evidence-based education system design for biodiversity conservation, filling the gap between evidence science and education; (2) From general gamified learning to evidence-based gamified decision-making simulation, cultivating not only knowledge but also core decision-making competence; (3) For the first time, empirically verifying the mediating role of gamified simulation between evidence input and decision-making ability, enriching the gamified experiential learning framework; (4) The cross-national sample confirms EBGDMS's scalability for students from different cultural and educational backgrounds, a key advantage for global conservation education.

5.3 Practical Implications

The research results provide targeted practical implications for global biodiversity conservation education practitioners, administrators, conservation scientists and policymakers:

1. For University Educators: Abandon traditional lecture-based teaching, adopt EBGDMS to cultivate evidence literacy and decision-making competence, shift teachers' role from knowledge transmitters to evidence use facilitators; integrate AI evidence knowledge bases into teaching, design scenario-based tasks requiring scientific evidence application; use gamified simulation platforms to create immersive scenarios and encourage multi-stakeholder teamwork-style group collaboration.

2. For Educational Administrators: Allocate special funding to develop and promote scalable AI evidence bases and gamified simulation platforms, provide free access for low- and middle-income countries (LMICs); revise curriculum standards to list evidence literacy as a core competency and incorporate it into compulsory courses; organize teacher training on AI and gamified teaching methods and establish an exchange mechanism.

3. For Conservation Scientists and Evidence Synthesis Initiatives: Strengthen the educational adaptation of evidence synthesis results, develop student-oriented resources; enrich evidence source diversity by collecting LMICs' research and integrating indigenous and local ecological knowledge (ILEK); establish a long-term collaboration mechanism between conservation science and education circles to update evidence resources in real time.

4. For Policymakers: Integrate evidence-based conservation education into national sustainable development strategies and link it with UN SDGs; formulate professional certification standards for conservation practitioners including evidence literacy requirements; build a university-environmental agency cooperation platform, incorporate real-world conservation projects into EBGDMS scenarios, and realize the two-way transformation of educational and practical achievements.

5.4 Limitations of the Study

This study has several limitations that point to future research directions: (1) Short intervention duration: The 12-week intervention only reflects short-term effects, with no long-term follow-up of competence retention and practical application; (2) Limited sample scope: The sample only includes undergraduate students from China and the UK, not covering K-12 students, vocational education students or LMICs' students, making it impossible to verify EBGDMS's adaptability to different educational stages and regions; (3) Simplified simulation scenarios: The platform simplifies real-world complex factors (political games, natural disasters, social cultural conflicts), leading to a gap between simulated and actual decision-making; (4) Insufficient ILEK integration: The AI knowledge base is dominated by Western academic research, with insufficient integration of ILEK, limiting applicability in regions with rich indigenous resources; (5) Lack of comparison with other innovative models: Only comparing EBGDMS with traditional teaching, without analyzing its relative advantages with other innovative models (project-based learning, field practice).

5.5 Future Research Directions

Based on the findings and limitations, the following future research directions are proposed: (1) Conduct 1–2 year long-term follow-up research to track competence retention and practical application, and analyze factors affecting long-term effects; (2) Expand the sample to K-12 students, vocational college students and LMICs' students, and explore EBGDMS's regional adaptation mode; (3) Optimize the simulation platform by adding real-world complex constraints and dynamic scenario evolution mechanisms to improve decision-making ability transferability; (4) Strengthen ILEK integration into the AI knowledge base with the participation of local communities and indigenous scholars to improve inclusiveness; (5) Conduct comparative experiments with other innovative teaching models to clarify EBGDMS's relative advantages and applicable scenarios; (6) Develop a lightweight mobile APP of EBGDMS to lower the use threshold and promote popularization; (7) Establish a global evidence-based conservation education network to share resources and carry out international joint teaching and research.

6 Conclusion

Biodiversity loss is a severe global environmental problem, and biodiversity conservation education is an important way to cultivate future conservation practitioners. However, the current "evidence emergency"–lack of accessible scientific evidence in teaching and a serious theory-practice divide–restricts the cultivation of students' evidence literacy and scientific decision-making ability, and further affects the effectiveness of real-world conservation work.

To address this core dilemma, this study constructs the systematic EBGDMS with educational engineering as the core foundation, integrating AI-driven evidence synthesis, gamified decision-making simulation and experiential learning theory. The three core modules (AI evidence knowledge base, gamified simulation platform, multi-dimensional evaluation system) form a closed-loop educational system of "evidence input → gamified practice → competence development → effect evaluation → system optimization", with all content rooted in rigorous international scientific evidence.

A quasi-experimental study with 386 Sino-British undergraduate students verified EBGDMS's effectiveness: it significantly improves students' evidence literacy (+34.7%), conservation decision-making performance (+39.2%) and learning engagement (+31.5%); the AI knowledge base reduces the evidence accessibility gap by 62.5%; gamified simulation exerts a significant partial mediating effect ($\beta = 0.47$) between AI evidence input and decision-making performance, accounting for 47.0% of the total effect; qualitative results confirm students' positive learning experience and recognition of EBGDMS's scalability.

This study makes important theoretical, practical and cross-disciplinary contributions: (1) Theoretical contribution: Expands the application of educational engineering in ESD, enriches the evidence-based education and gamified learning framework, verifies the mediating mechanism of gamified simulation, and builds a theoretical bridge between conservation evidence science and education; (2) Practical contribution: Constructs a scalable evidence-based gamified teaching model and provides a complete set of operational tools and resources, offering targeted suggestions for all stakeholders and contributing to addressing the global evidence emergency; (3) Cross-disciplinary contribution: Promotes the cross-innovation of conservation science, educational engineering, AI and cognitive psychology, and provides a reference for the interdisciplinary development of environmental education.

Existing scientific evidence for effective conservation is massive, and the main causes of biodiversity decline are clear. What is lacking is evidence-based action and a new generation of practitioners with strong evidence literacy and decision-making ability. EBGDMS is an important attempt to fill this gap, integrating scientific evidence into conservation education and cultivating students' practical ability via gamified practice. In the face of the global biodiversity crisis, evidence-based conservation education is not only an educational innovation but also a moral and practical imperative.

The promotion of EBGDMS requires joint efforts from education, conservation science, policy and local communities. With continuous optimization and expanded application, EBGDMS is expected to cultivate more high-quality conservation practitioners worldwide, promote the transformation of global biodiversity conservation from "experience-based" to "evidence-based", and contribute to reversing biodiversity loss and achieving the UN Sustainable Development Goals. Protecting biodiversity is protecting humanity's future, and evidence-based conservation education is the cornerstone of building this future.

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