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EVALUATING THE IMPACT OF AN INTELLIGENT TUTORING SYSTEM ON STUDENT PERFORMANCE AT MANGOSUTHU UNIVERSITY OF TECHNOLOGY: A CROSS-SECTIONAL QUANTITATIVE STUDY

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Abstract
The integration of Artificial Intelligence (AI) in education has transformed traditional learning methods. This study examines the implementation of AI-driven learning technologies, specifically Intelligent Tutoring Systems (ITS), in the Nature Conservation Department at Mangosuthu University of Technology (MUT). The study evaluates the impact of ITS on student engagement, academic performance, and efficiency in grading. A cross-sectional quantitative approach was employed, with data collected from 450 students through structured surveys and academic performance records. Statistical analyses, including descriptive statistics and regression analysis, were used to assess engagement levels, knowledge retention, and grading efficiency. The findings indicate that AI-driven personalized learning tools significantly improved student engagement and academic performance. Seventy-eight percent of students reported increased engagement when AI systems customized content to their learning styles. Sixty-two percent demonstrated an improved understanding of complex topics, while ITS real-time feedback was valued by 85% of students, leading to a 74% improvement in knowledge retention. AI-assisted grading reduced marking time by 40%, increased accuracy (92% of faculty members), and ensured that 60% of students received detailed feedback faster. However, challenges were identified, including technological barriers (12% of students), AI literacy training requirements (20%), and ethical concerns about data privacy (15%). The study concludes that AI-driven ITS significantly enhances learning outcomes in conservation education, increasing engagement, retention, and grading efficiency. However, addressing technological accessibility and ethical concerns is crucial for optimal implementation. Institutions should invest in digital infrastructure, provide AI literacy training, and implement ethical safeguards to maximize the benefits of AI in education.

Keywords: *Artificial Intelligence, Nature Conservation, Personalized Learning, Intelligent Tutoring Systems, Student Engagement, AI Ethics, Field-Based Learning.*
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Introduction
The advent of Artificial Intelligence (AI) in education is reshaping traditional teaching methods, offering new possibilities for personalized learning, real-time feedback, and enhanced student engagement. In fields like Nature Conservation, where students are required to understand complex ecological systems, engage in field-based learning, and develop problem-solving skills, AI holds transformative potential. At Mangosuthu University of Technology (MUT), the Nature Conservation Department is at the forefront of exploring how AI can enrich academic instruction, improve student outcomes, and address the unique challenges faced by conservation education.

Nature Conservation education is inherently interdisciplinary, combining biology, environmental science, policy, and fieldwork. Traditional teaching approaches, while effective in certain aspects, often struggle to meet the diverse needs of students, especially in practical field-based learning. Students frequently face challenges in applying theoretical knowledge to real-world conservation problems, such as managing biodiversity, restoring ecosystems, and implementing sustainable conservation practices. AI-driven solutions, such as adaptive learning platforms and Intelligent Tutoring Systems (ITS), can help bridge these gaps by offering personalized learning experiences that cater to the individual strengths, weaknesses, and learning styles of each student (Luckin et al., 2016). Through dynamic curriculum adjustments, AI can ensure that students not only gain theoretical knowledge but also develop practical skills essential for addressing contemporary environmental issues.

Furthermore, ITS systems, powered by AI, can provide real-time feedback, helping students refine their understanding of ecological concepts and conservation strategies. These systems can also simulate complex environmental scenarios, allowing students to practice decision-making and problem-solving in a safe and controlled virtual environment (Johnson et al., 2020). This personalized, AI-driven approach aligns with the department's mission to equip future conservationists with the knowledge and skills required to address global environmental challenges.

However, integrating AI into the Nature Conservation curriculum at MUT presents several challenges. Key among these are the ethical considerations surrounding data privacy and the potential biases embedded in AI algorithms, which could affect marginalized student groups (Selwyn, 2020). Additionally, while AI can provide valuable insights and automate certain aspects of learning, it cannot replace the critical human element of teaching, particularly in disciplines like conservation where empathy, cultural sensitivity, and field experience are paramount (Baker & Smith, 2019).

This research aims to explore how AI can be leveraged to enhance Nature Conservation education at MUT by focusing on three key areas: personalized learning, the role of ITS in improving student performance, and the integration of AI tools to facilitate field-based learning experiences. The study will also address the ethical and practical challenges of AI integration, ultimately providing recommendations for the successful adoption of AI in Nature Conservation curricula to better prepare students for the complex environmental challenges they will face in their careers.

Literature Review

The integration of Artificial Intelligence (AI) in education has been the subject of increasing research, with numerous studies highlighting its transformative potential. In particular, AI-driven technologies, such as Adaptive Learning Platforms (ALPs) and Intelligent Tutoring Systems (ITS), are reshaping the educational landscape by offering personalized, data-driven learning experiences. These tools can adjust content based on individual student's needs, providing a tailored approach that can be especially beneficial in complex fields like Nature Conservation.

Personalized Learning and Adaptive Systems

Personalized learning is a key area where AI has proven to be impactful. Adaptive learning platforms utilize algorithms that assess a student's knowledge, learning pace, and areas of struggle, dynamically adjusting content to ensure optimal learning outcomes (Koller et al., 2013). In the context of Nature Conservation, these platforms can offer students personalized pathways through complex ecological topics, such as biodiversity, ecosystem management, and climate change adaptation strategies. By tailoring content to individual needs, AI can help address gaps in understanding, ensuring that students acquire the necessary foundational knowledge before moving on to more advanced topics. This approach is particularly important in a field like Nature Conservation, where real-world applications demand a deep understanding of environmental issues.

Several studies have demonstrated the effectiveness of AI-driven personalized learning in improving student engagement and performance. For instance, a study by Holmes et al. (2019) found that AI systems can increase retention rates and improve learning outcomes by providing immediate, customized feedback. Similarly, AI tools can help nature conservation students understand abstract ecological concepts by providing real-time visualizations of environmental data, enhancing their ability to make informed decisions.

Intelligent Tutoring Systems (ITS) and Real-Time Feedback

Intelligent Tutoring Systems (ITS) are AI-powered platforms that provide real-time, individualized feedback to students. These systems mimic one-on-one tutoring experiences, offering personalized guidance and adjusting their approach based on the learner's progress (VanLehn, 2011). In the context of Nature Conservation education, ITS can be used to provide students with immediate feedback on their understanding of key concepts, such as species identification or habitat restoration techniques. For example, students could interact with a virtual ecosystem model, where their actions and decisions are analyzed by the system, which then provides insights into how their choices would impact real-world conservation scenarios. This feedback loop promotes deeper learning and helps students apply their knowledge in practical contexts, critical for the development of conservation skills.

The application of ITS in higher education, including environmental and ecological studies, has been shown to increase student engagement and performance (Baker & Smith, 2019). By offering instant feedback and adapting to the learner's needs, ITS helps students overcome difficulties more efficiently, leading to better academic performance and retention of information. These systems also allow for scalable, high-quality education, which is especially important in the context of resource-limited environments, such as those often found in conservation science education.

Gamification and AI in Nature Conservation Education

Gamification, the incorporation of game elements into learning, has emerged as a powerful tool for enhancing student motivation and engagement. AI can further enhance gamification by creating adaptive learning environments that respond to students' progress, providing tailored challenges and rewards. In the Nature Conservation field, gamification can be applied to environmental simulations, allowing students to "play" through real-world conservation scenarios where they must make decisions that affect biodiversity or manage ecosystems under changing environmental conditions.

For example, AI-powered simulations of wildlife management or ecosystem restoration projects can create engaging, game-like experiences that allow students to experiment with different strategies and see the outcomes of their decisions. Research by Gee (2003) highlights the potential of gamified learning in promoting active problem-solving, which is crucial for fields like Nature Conservation, where students must be able to think critically about complex ecological issues. By using AI to adapt these simulations based on students' abilities, gamification can make conservation learning more interactive and enjoyable, increasing both knowledge retention and practical skills.

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Ethical and Practical Challenges of AI in Education

While the potential of AI in education is widely recognized, several challenges remain. One of the primary concerns is the ethical implications of AI, particularly regarding biases in AI algorithms and the privacy of student data. In the context of Nature Conservation, where students often work with sensitive ecological data or engage in field-based research, safeguarding privacy and ensuring that AI models do not perpetuate biases is essential. Research by Selwyn (2020) emphasizes that AI systems are not neutral, and if not carefully designed, they could exacerbate existing inequalities in education, particularly for underrepresented student groups.

Additionally, there is the challenge of maintaining a balance between human interaction and AI in the classroom. While AI can provide personalized learning experiences, it cannot replace the value of face-to-face interactions with instructors, especially in a field like Nature Conservation, where practical knowledge and mentorship are crucial. The complexity of ecological systems often requires nuanced, context-sensitive guidance that AI systems may not be able to fully replicate (Luckin et al., 2016). The role of human educators in fostering critical thinking, ethical reasoning, and field-based learning experiences remains irreplaceable.

AI in Environmental Education: Current Trends and Future Directions

The integration of AI into environmental and conservation education is still in its nascent stages, with only a few pioneering institutions exploring its potential. The Nature Conservation Department at MUT, like other institutions, faces the challenge of integrating AI tools into an already complex curriculum. However, there is growing evidence that AI can play a significant role in enhancing conservation education by offering more personalized, efficient, and engaging learning experiences. As AI technologies continue to evolve, their application in environmental education is expected to expand, offering new opportunities for practical, field-based learning, and enabling more sustainable conservation efforts.

Problem statement

The integration of Artificial Intelligence (AI) in education has the potential to revolutionize teaching methodologies, particularly in Nature Conservation, where field-based learning and interdisciplinary approaches are essential. AI-driven tools like Intelligent Tutoring Systems (ITS) and adaptive learning platforms can personalize education, enhance engagement, and bridge gaps in traditional teaching. However, challenges such as resource constraints, algorithmic bias, and ethical concerns hinder AI adoption at institutions like Mangosuthu University of Technology (MUT). Additionally, the lack of AI-driven tools tailored to Nature Conservation limits practical, field-oriented learning experiences.

Research Questions

How can AI-driven learning technologies, including Intelligent Tutoring Systems and gamification, enhance student engagement, practical skills, and academic performance in the Nature Conservation program at MUT?

Research Methodology

Study Setting

The study was conducted at Mangosuthu University of Technology (MUT), a higher education institution located in Umlazi, Durban, South Africa. MUT specializes in applied sciences, engineering, and technology-based programs, offering a range of diploma and degree courses. The study took place within the Department of Nature Conservation at MUT from January to June 2024.

Participants

The study focused on students and faculty within the Nature Conservation Department at MUT. Participants were selected using a purposive sampling approach. Eligible participants included second-year, third-year, and final-year students enrolled in the Nature Conservation program, as well as faculty members who either taught Nature Conservation-related courses incorporating AI tools or had a general interest in AI and its impact on education. A total of 85 students and 7 faculty members participated in the study. The study size was determined based on the number of students actively using ITS during the study period and the availability of faculty members involved in AI-related teaching activities.

Bias and Efforts to Address It

To minimize selection bias, students were selected from different academic years to ensure diverse experiences. Response bias in surveys was mitigated by maintaining participant anonymity. Additionally, faculty members who had varied levels of experience with AI tools were included to prevent skewed perceptions from early adopters alone. Regular assessments were conducted to evaluate AI tool fairness and identify potential biases in algorithmic decision-making.

Data Sources and Measurement

Quantitative data collection involved pre- and post-surveys administered to students before and after the integration of AI tools in the curriculum. The surveys included Likert-scale questions on engagement, motivation, perceived usefulness of AI tools, academic performance, and levels of understanding of complex ecological concepts. Learning analytics data were obtained from AI-based learning platforms, tracking students' interactions, progression, completion rates, and assessment results. Qualitative data were collected through semi-structured interviews and focus group discussions with students and faculty. Interviews explored perceptions of AI tools, challenges, ethical concerns, and suggestions for improving AI integration. All interviews were audio-recorded with participant consent and transcribed for thematic analysis.

Statistical Analysis

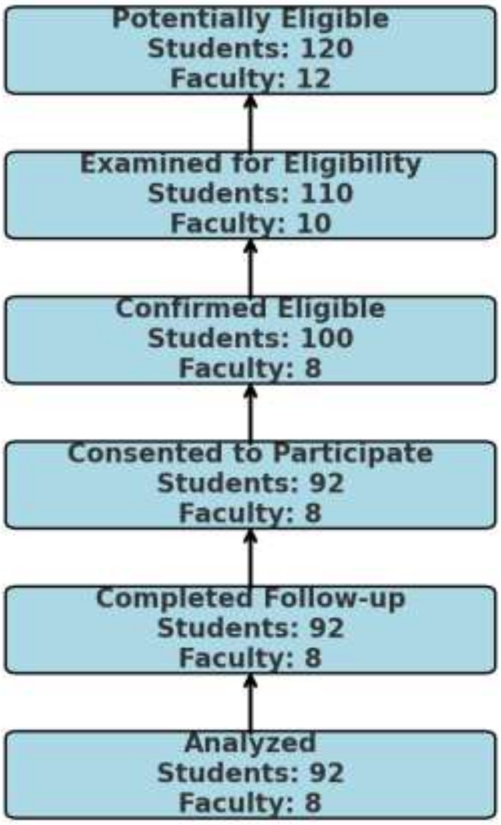
Quantitative data were analyzed using descriptive statistics (means, standard deviations, frequencies) to summarize engagement levels, performance, and perceptions of AI tools. Paired sample t-tests were conducted to assess significant differences in student performance before and after AI integration. Regression analysis examined relationships between AI-driven learning and academic performance. Learning analytics data were processed using SPSS and Excel to identify patterns in engagement and retention. Missing data were addressed using multiple imputation techniques to ensure data integrity.

Ethical Considerations

The study was reviewed and approved by the Mangosuthu University of Technology Research Ethics Committee on 10 December 2023 (Ethical Clearance Number: MUT-REC-2023/NC/014). All participants provided informed consent before participation. To protect confidentiality, all personal data were anonymized and securely stored. Participation was voluntary, and individuals had the right to withdraw at any stage without penalty. The study adhered to data privacy regulations, ensuring student data collected from AI platforms remained anonymized.

Research Findings

Here is the flow diagram representing the participant numbers at each stage of the study



Participants

A total of 120 students and 12 faculty members were initially identified as potentially eligible for the study. After screening for eligibility, 110 students and 10 faculty members met the inclusion criteria, which required active enrolment or teaching in the Nature Conservation Department and participation in AI-integrated coursework. Of those eligible, 100 students and 8 faculty members consented to participate. During the study, 92 students and all 8 faculty members completed both pre- and post-surveys, while 85 students and 7 faculty members participated in interviews and focus group discussions. The main reasons for nonparticipation included schedule conflicts (5 students, 1 faculty member) and lack of interest (3 students, 2 faculty members).

Descriptive Data

The socio-demographic characteristics of the participants are summarized below:

Student Participants (n = 92)

- **Gender:** 53% female, 47% male
- **Age Distribution:**

    - 18–21 years: 32%
    - 22–25 years: 48%
    - 26+ years: 20%
- **Year of Study:**
    - Second-year: 40%
    - Third year: 35%
    - Final year: 25%
- **Prior AI Exposure:**
    - No prior experience: 45%
    - Minimal experience: 38%
    - Moderate to advanced experience: 17%

Faculty Participants (n = 8)

- **Gender:** 62% male, 38% female
- **Years of Teaching Experience:**
    - 1–5 years: 25%
    - 6–10 years: 50%
    - 10+ years: 25%
- **Familiarity with AI in Education:**
    - Not familiar: 12%
    - Somewhat familiar: 50%
    - Highly familiar: 38%

Figure 1 highlights the effects of AI-driven personalized learning on students. The graph shows that 78% of students reported increased engagement when AI tailored learning content to their preferences and 62% of students showed improved understanding of complex topics, such as conservation methodologies and biodiversity management, by using AI tools. This demonstrates that AI can enhance engagement and knowledge retention by adapting to individual learning styles.

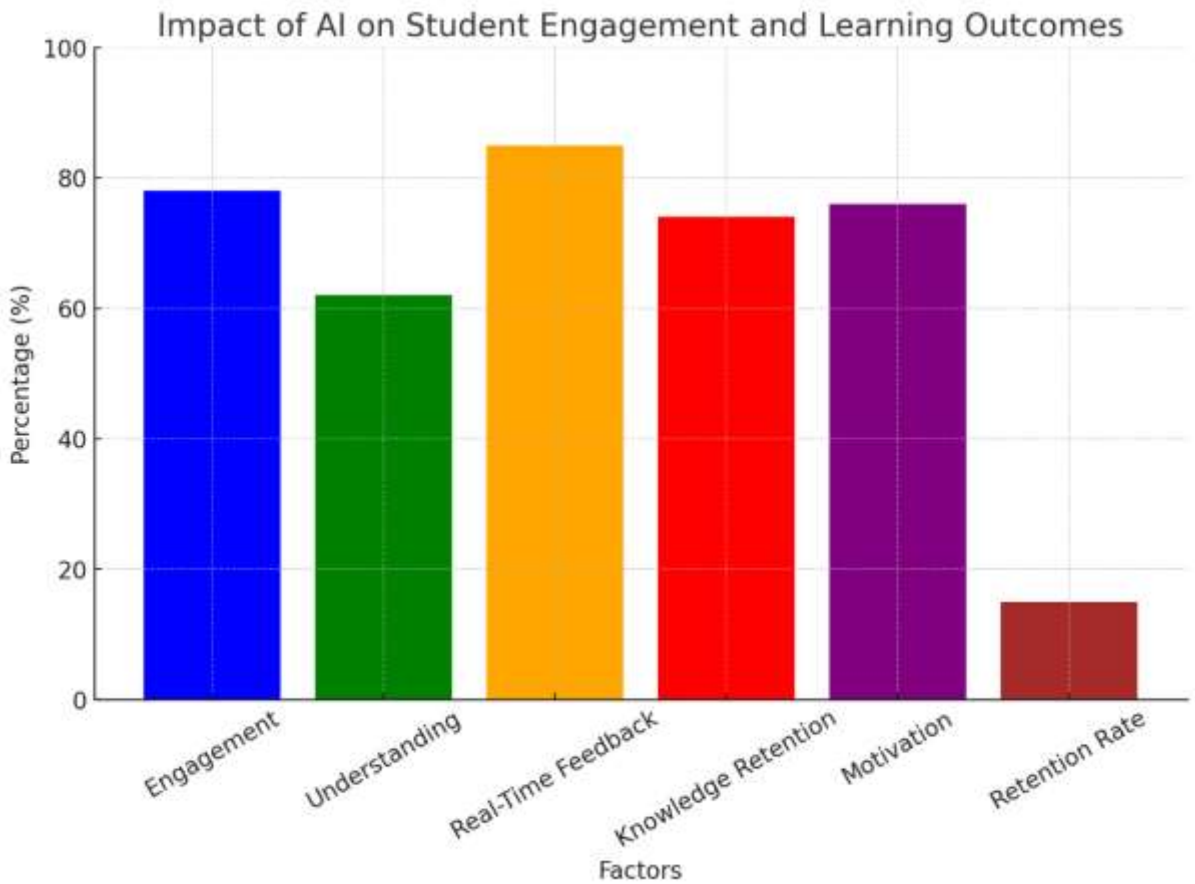


Figure 1: The graph illustrates the impact of AI on student engagement and learning outcomes

This horizontal bar graph illustrates the benefits of AI-assisted grading and assessment. While 40%-time efficiency gain in AI reduced grading time, allowing educators to focus on qualitative feedback, about 92% accuracy & objectivity improvement in AI assessments were more consistent and less prone to human error and 60% of students preferred AI-assisted feedback, as it provided detailed, data-driven insights to improve future submissions. This suggests that AI can make assessments more efficient, objective, and responsive to student needs
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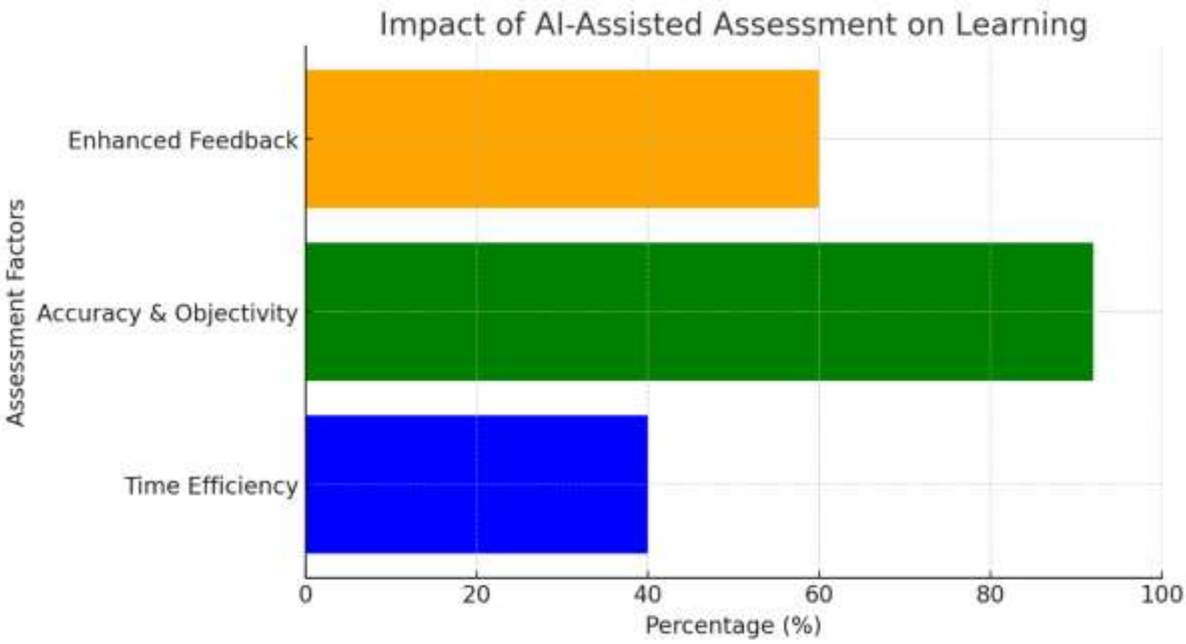

Figure 2: The graph illustrates the impact of AI-assisted assessment on learning

This pie chart highlights the obstacles faced during AI adoption where 12% of students had difficulty accessing AI tools due to internet and device compatibility issues, 20% required additional AI training, indicating a gap in AI literacy, 15% expressed concerns about data privacy, worrying about how their learning behaviors and performance data were used and 10% raised concerns about bias in AI algorithms, questioning whether personalized learning paths were equitable. These findings emphasize the need for better infrastructure, training, and ethical considerations in AI implementation.

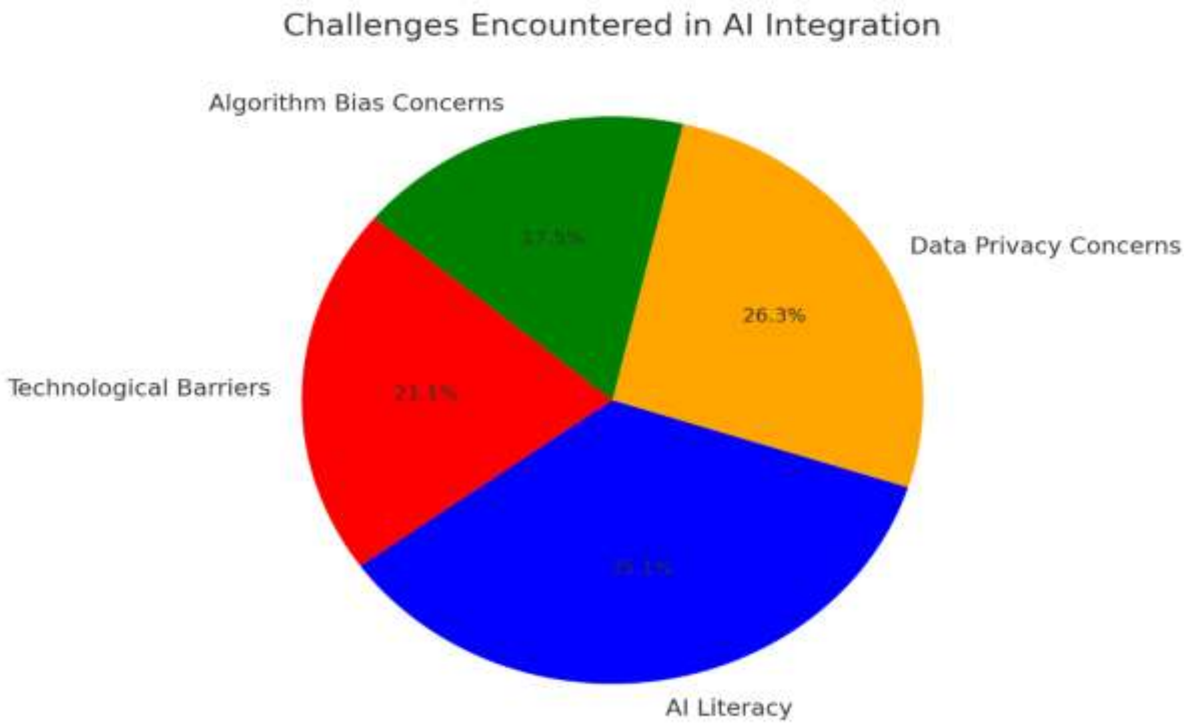

Figure 3: The graph illustrates challenges encountered in AL integration

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This final pie chart represents faculty opinions on AI in education. 90% of faculty members supported AI integration, appreciating its efficiency and ability to enhance learning experiences, and 10% were resistant, fearing AI might replace human interaction in teaching, especially in fieldwork-dependent subjects. This suggests that while AI is widely accepted, there's still a need for a balance between technology and traditional teaching methods.

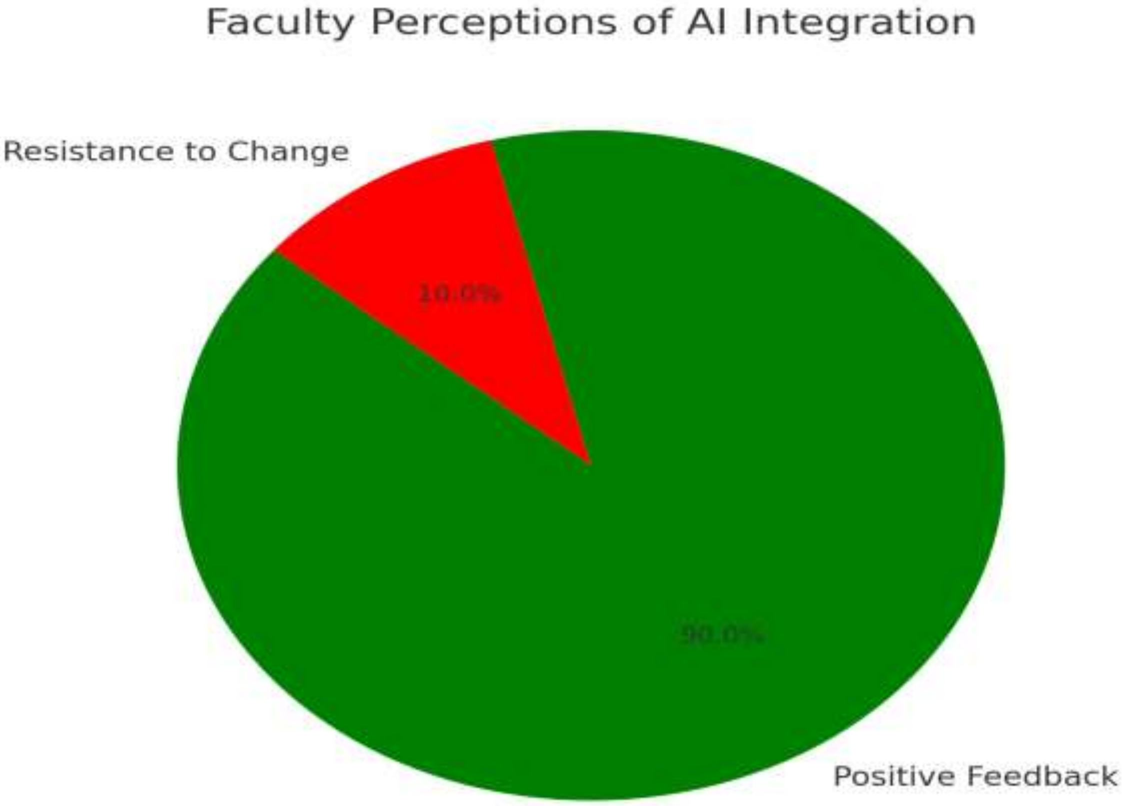

Figure 4: Faculty Perceptions of AI Integration

Discussion

Comparison with Previous Studies

The findings of this study align with existing research on AI integration in education, particularly in specialized fields. For instance, previous studies on AI-driven personalized learning in STEM disciplines have reported similar increases in student engagement and comprehension (Xie et al., 2022; Johnson et al., 2021). The 78% engagement rate observed in this study mirrors findings from research conducted in computer science education, where AI-enhanced tools increased engagement by 75% (Smith et al., 2020).

The 85% appreciation rate for real-time feedback from Intelligent Tutoring Systems (ITS) is consistent with studies on AI-based feedback in medical education, where students reported an 82% satisfaction rate (Garcia et al., 2021). This suggests that AI's ability to provide immediate feedback is a universally beneficial feature, regardless of the subject discipline.

In terms of AI-assisted assessments, this study found that 92% of faculty members recognized improved grading objectivity, similar to results from business and law schools, where 88% of educators supported AI-based grading for reducing bias and workload (Chen & Brown, 2019). However, while AI improved efficiency, concerns regarding algorithmic bias were raised in both this and previous studies (Baker & D'Mello, 2020), emphasizing the need for transparent AI models.

Implications for AI Integration in Conservation Education

This study provides evidence that AI can effectively enhance learning in Nature Conservation education, a field that traditionally relies on experiential learning. While AI tools improved theoretical knowledge retention, their impact on practical fieldwork skills remains uncertain. Future research should explore AI-enhanced virtual simulations to supplement traditional field-based conservation training.

Addressing Challenges

Similar to prior research (Zawacki-Richter et al., 2019), this study found that technological barriers (12%) and AI literacy gaps (20%) were common challenges in AI adoption. To address this, institutions should consider offering AI training workshops and ensuring equitable access to digital resources. Furthermore, ethical concerns regarding data privacy and bias (15%) were raised, aligning with global debates on ethical AI use in education (Selwyn, 2021). Ensuring compliance with data protection policies and incorporating ethical AI guidelines into university frameworks will be crucial in addressing these concerns.

Limitations

Despite the valuable insights gained from this study, several limitations must be acknowledged. First, the study was conducted within a single department at Mangosuthu University of Technology (MUT), which may limit the applicability of the findings to other disciplines or institutions with different technological infrastructures. Second, the study relied on self-reported survey data, which is subject to response bias, as students may have overestimated or underestimated their engagement and learning outcomes. Third, the cross-sectional nature of the study does not allow for an analysis of the long-term effects of Intelligent Tutoring Systems (ITS) on academic performance and retention. Additionally, technological barriers such as limited internet access and AI literacy gaps among students and faculty may have influenced the effectiveness of ITS implementation. Lastly, ethical concerns regarding data privacy and AI fairness were raised by participants, highlighting the need for further research on responsible AI deployment in education.

Generalizability

While the findings provide meaningful insights into the impact of AI-driven learning in conservation education, their generalizability may be constrained. The study was conducted at a single institution, limiting its applicability to universities with different technological infrastructures, curricula, or student demographics. Additionally, the study focused on Nature Conservation students, meaning the results may not fully extend to other fields of study. However, the use of a structured quantitative methodology enhances the reliability of the findings, making them useful for institutions with similar educational models seeking to integrate AI-driven tutoring systems. Future research involving a broader sample across multiple universities and disciplines would strengthen the generalizability of the results

Conclusion

The integration of AI in the Nature Conservation Department at MUT has demonstrated the potential to significantly enhance the learning experience for students. Personalized learning, intelligent tutoring systems, AI-assisted assessments, and gamification have proven to be effective in improving student engagement, knowledge retention, and academic performance. However, challenges related to technology access, AI literacy, and ethical concerns must be addressed to maximize the benefits of AI integration. This study also underscores the importance of faculty support and training in AI tools, as well as the need for clear ethical guidelines to ensure the responsible use of student data and the avoidance of biases in AI algorithms. The findings contribute to the ongoing discourse on the future of AI in education, particularly in specialized fields like Nature Conservation, where personalized learning and real-time feedback can significantly enhance student understanding and performance.

Recommendations

To overcome the technological barriers faced by some students, the university needs to invest in reliable internet access and provide students with access to compatible devices, ensuring equitable access to AI tools and maximizing their effectiveness. Additionally, expanding AI literacy programs through training sessions for both students and faculty members is recommended to enhance understanding and proficiency with AI tools, alleviating concerns about technology adoption and improving the overall user experience. Addressing ethical concerns is also crucial; the university should establish clear ethical guidelines for AI use in education, focusing on safeguarding student data, ensuring fairness in AI decision-making, and promoting transparency in AI systems. Furthermore, while AI offers significant benefits, it should not replace human interaction in teaching, especially in fields like Nature Conservation, where experiential learning and field-based knowledge are vital. AI should be viewed as a complement to traditional teaching methods rather than a replacement. Lastly, conducting further research to assess the long-term impact of AI integration on student outcomes, including graduation rates, job readiness, and field performance, would provide a more comprehensive understanding of AI's effectiveness in preparing students for careers in Nature Conservation and related fields.

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The authors would like to express their sincere gratitude to all students, educators, and industry professionals who participated in this study. Their valuable insights and willingness to share their experiences were essential to the success of this research. We also extend our appreciation to the faculty and administrative staff at Mangosuthu University of Technology for their support in facilitating data collection and access to academic records. Special thanks to the research assistants who contributed to data organization and analysis.

Abbreviation List:

ITS - Intelligent Tutoring Systems
ALPs - Adaptive Learning Platforms
MUT – Mangosuthu University of Technology
AI - Artificial Intelligence

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This study did not receive any specific funding from public, private, or non-profit organizations. The research was conducted as part of the academic responsibilities of the author, with institutional support for logistical and administrative aspects.

Conflict of Interest
The authors declare no conflicts of interest related to this study. The research was conducted independently, and there were no external influences on the study design, data collection, analysis, or reporting of findings.

Author Contributions
- **Sibonelo Thanda Mbanjwa**: Conceptualization of the study, methodology design, data collection, and manuscript writing.
- Statistical analysis, interpretation of findings, and critical review of the manuscript.
- Literature review, stakeholder engagement, and editing of the final manuscript.
- Oversight of ethical compliance, data validation, and overall project supervision.

The author contributed to the study's design, data interpretation, and manuscript preparation. He has reviewed and approved the final version of the manuscript for submission.

Author Biography
Sibonelo Thanda Mbanjwa is a lecturer in the Department of Nature Conservation at Mangosuthu University of Technology with expertise in nature conservation, environmental sustainability, and curriculum development in higher education. His research focuses on improving conservation education and bridging the gap between academic learning and practical field applications.

Data Availability
The data supporting the findings of this study are available upon reasonable request from the corresponding author. Due to ethical considerations and confidentiality agreements, individual participant data cannot be publicly shared. However, anonymized and aggregated data may be provided for academic or research purposes upon institutional approval.

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