Ethical Artificial Intelligence in Science Technology Engineering and Mathematics (STEM) Classrooms: Balancing Innovation with Responsible Skill Development among Tertiary Institution Students

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ABSTRACT

The increasing application of Artificial Intelligence (AI) tools in Science Technology Engineering and Mathematics (STEM) classrooms is revolutionising teaching and learning worldwide. However, this progress raises ethical concerns regarding responsible use, data privacy and the erosion of human thinking in learning. This descriptive survey study examined how STEM students in the three Lagos State-owned tertiary institutions in Nigeria perceived and responded to ethical issues in AI-driven learning environments and how these perceptions influence the development of responsible digital skills. A sample of 430 undergraduate 300 level STEM students participated in the study. Data were collected using the Ethical AI and Responsible Skill Development Questionnaire (EAIRSDQ) comprising sections on demographics, AI awareness, ethical understanding and responsible usage. The questionnaire was validated by three experts in AI ethics and educational measurement, and a pilot study yielded a Cronbach's alpha reliability coefficient of 0.87. Data were analyzed using descriptive statistics (mean) and inferential statistics (ANOVA). Results revealed strong students' level of awareness about ethical implications of AI tools in learning and responsible AI integration and use in STEM education for skills development. ANOVA result further showed significant differences in ethical awareness and responsible use across STEM disciplines. This implies that ethical AI literacy is influenced by disciplinary context, making uniform instructional approaches insufficient. Consequently, it is recommended that tertiary institutions adopt discipline-specific ethical AI frameworks, embed structured ethics training within STEM curricula and promote interdisciplinary integration to ensure consistent and responsible AI use across all fields.

Key words: Ethical AI, innovation, responsible skill development, STEM classrooms, tertiary institutions

INTRODUCTION

The rapid advancement of artificial intelligence (AI) in the context of the Fourth Industrial Revolution has redefined the competencies needed of 21st century learners, positioning AI literacy as a critical skill for academic, professional and societal participation (Mouta et al., 2023; Nguyen et al., 2023). AI has become deeply embedded in contemporary educational systems with its applications ranging from intelligent tutoring systems to predictive analytics and adaptive learning platforms (Holmes et al., 2021; Adewusi et al., 2025). Fundamentally, AI is the ability of machines to simulate human-like intelligence through algorithmic processes, including learning, reasoning, pattern recognition and decision-making (Kamalov et al., 2023; Kaser & Alexandron, 2023). These skills are transforming the creation, dissemination and evaluation of knowledge, especially in the fields of Science, Technology, Engineering and Mathematics (STEM) education.

AI technologies such as ChatGPT, Claude, DeepSeek, Notebook LM and Perplexity have become integral to students' academic experiences which enable their rapid problem-solving, content generation and individualised learning support. These technologies enhance instructional delivery by allowing educators to tailor content to individual learning needs, while institutions increasingly rely on AI-driven systems to monitor and improve learning outcomes (Luckin & Holmes, 2021).

Despite these transformative benefits of AI, its integration into STEM classrooms raises serious ethical concerns. du Boula (2022) stressed that the integration of AI into STEM education requires thoughtful ethical considerations. Researchers have consistently highlighted concerns related to data privacy, algorithmic bias, surveillance and the ethical use of student data (Holmes et al., 2022; Mouta et al., 2023; Madhloom et al., 2023). AI systems often operate through opaque algorithms, limiting transparency and making it difficult for users to interrogate or challenge automated decisions (Mittelstadt et al., 2016). This opacity raises critical questions about fairness, accountability and digital rights, particularly when large volumes of personal data are collected without explicit consent (Mittelstadt, 2019; Nguyen et al., 2023). Beyond technical concerns, broader socio-cultural implications emerge, including the potential erosion of human agency, creativity and critical thinking skills, which are foundational to STEM education (Dieterle et al., 2022; Mirea et al., 2024).

The risks associated with AI are further amplified by patterns of over-reliance among students. Emerging evidence suggests that excessive dependence on AI tools may lead to diminished critical thinking, reduced cognitive engagement and weakened problem-solving abilities (Kasneci et al., 2023; Selwyn, 2024). In STEM contexts, where deep conceptual understanding and analytical reasoning are essential, such dependency poses a serious threat to the development of competence and intellectual autonomy. Studies have also shown that unchecked AI use can compromise students' metacognitive development and encourage passive acceptance of machine generated outputs, thereby limiting their ability to critically evaluate information and make informed decisions (Akgun & Greenhow, 2021; Sambasivan et al., 2021). Consequently, ethical competence has become a fundamental dimension of digital literacy that require deliberate integration into educational practice (Binns & Veale, 2020; Williamson & Eynon, 2020).

These global concerns take on heightened significance within the Nigerian higher education context, where the integration of AI intersects with unique structural, institutional, and socio-economic challenges (Jain & Jain, 2024). According to National Bureau of Statistics (NBS) and the Joint Admissions and Matriculation Board (JAMB), Nigeria hosts one of the largest tertiary education systems in sub-Saharan Africa, with an estimated student population exceeding two million approaching 2.5 million in recent counts across universities, polytechnics and colleges of education (NBS, 2023; JAMB, 2024). In recent years, there has been a growing emphasis on digital transformation as a means of aligning with global educational trends, as reflected in national initiatives such as the National Information Technology Development Agency (NITDA) AI policy framework of 2022 and the subsequent National Artificial Intelligence Strategy (NITDA, 2025).

Within STEM education in Nigeria, AI is increasingly recognized as a strategic tool for enhancing instructional efficiency, providing real-time feedback and promoting innovation (Ekwu et al., 2025; Ukala et al., 2025). Empirical evidence indicates that AI can improve student engagement, facilitate understanding of abstract concepts, and provide alternative pathways for experiential learning, particularly in resource-constrained environments (Adewusi et al., 2025). Despite this progress, significant constraints persist. Many Nigerian institutions face infrastructural challenges, including unreliable electricity supply, limited internet connectivity, and inadequate access to modern digital tools (Imoniri, 2025). These limitations create a digital readiness gap that affects the equitable implementation of AI technologies. Furthermore, disparities in access to digital resources contribute to widening educational inequalities, as students in well-resourced institutions benefit disproportionately from AI-enabled learning opportunities (Matjie et al., 2026).

The issue of algorithmic bias is particularly critical, given its linguistic diversity and socio-cultural complexity (White & Case, 2025). AI systems trained predominantly on Western datasets may fail to adequately represent Nigeria local contexts, thereby reinforcing epistemic marginalization and limiting the relevance of generated knowledge (Salami, 2024). At the policy and curricular levels, the integration of AI in Nigerian education remains fragmented. Regulatory bodies such as the National Universities Commission (NUC) and the National Commission for Colleges of Education (NCCE) are in the early stages of establishing comprehensive and unified

frameworks for the ethical use of AI in higher education, with recent efforts focused on validating AI integration through stakeholder workshops (NCCE, 2026; NUC, 2026). Moreover, AI ethics is not systematically embedded within STEM curricula, leaving many students without the necessary knowledge and skills to navigate the ethical dimensions of AI use (Adigun et al., 2025). This absence of structured AI literacy education increases the risk of misuse, dependency and uncritical engagement with AI technologies.

Given these complexities, the integration of ethics into AI enhanced STEM education is both necessary and urgent. AI ethics education plays a critical role in equipping students with the capacity to understand, evaluate, and responsibly use AI technologies (du Boulay, 2022). It fosters awareness of the societal implications of AI, promotes critical engagement with algorithmic systems and supports the development of responsible digital citizenship. As noted by the World Economic Forum (2020), future professionals will require hybrid competencies that combine technical expertise with ethical reasoning, underscoring the need for a holistic approach to STEM education.

In spite of the growing global discourse on AI ethics, empirical research on students' ethical awareness and preparedness in Nigerian AI-enhanced STEM classrooms remains limited (Nguyen et al., 2023). Gaps such as absence of context-specific data, insufficient alignment between curricula and emerging digital competencies and a lack of institutional frameworks to guide ethical AI integration. These gaps highlight the need for an investigation and contextually grounded interventions. This study investigates how tertiary institution students perceive and respond to ethical concerns surrounding AI in STEM. The following research questions guide the study:

1. What is the level of awareness among STEM students about the ethical implications of AI tools in learning?

2. How do students perceive responsible AI integration and use in STEM education for skills development?

3. Are there differences in the level of ethical AI awareness and responsible use among STEM students across STEM disciplines?

METHODOLOGY

Design and Sample

The study employed a descriptive survey design to obtain data on students' awareness, perceptions and responses to ethical concerns in AI-driven STEM education across institutions in Lagos State, Nigeria. A sample of 430 undergraduate 300 level STEM students from the three Lagos State-owned tertiary institutions participated in the study. A stratified random sampling technique was utilized to ensure adequate representation across major STEM fields, specifically the Faculties/Colleges of Engineering, Environmental Science, Science and Science Education in each institution. This is to ensure that the diverse levels of AI integration inherent in different STEM disciplines are proportionally captured, thereby enhancing the representativeness of the data. To further minimize sampling bias and increase the generalizability of the findings, participants were randomly selected within each faculty/college. Selecting 300 level students was a deliberate methodological choice, as these individuals possess the necessary academic maturity and disciplinary grounding to critically assess the ethical dimensions of AI within their specific fields.

The frequency of respondents across institutions and faculties/colleges is presented in the table below.

Table 1: Respondents Demography

Institutions	Lagos State University of Education (LASUED), Oto/Ijanikin	138
	Lagos State University (LASU), Ojo	149
	Lagos State University of Science and Technology (LASUTECH), Ikorodu	143
Faculties/Colleges	Science	111
	Engineering	107
	Environmental science	119
	Science Education	93

Instrumentation and Data Collection

Data were collected using a self-designed instrument tagged "Ethical AI and Responsible Skill Development Questionnaire" (EAIRSDQ). The questionnaire contained three sections which include demographics, awareness of AI Tools in STEM education, perceptions of ethical issues and responsible digital skill development. The instrument was designed on 4-Likert Scale type of strongly agreed (SA) - 4, agreed (A) - 3, disagreed (D) - 2 and strongly disagreed (SD) - 1 respectively.

The instrument was validated by three experts; two in AI ethics and one in science education. After modification, removal and addition of certain items as suggested by these experts, the final copy of the instrument was acclaimed to meet construct validity and was adopted for use in the study. However. a pilot test was conducted with 45 students who were not part of the study sample and using Cronbach's alpha reliability method to yield coefficient of 0.87, indicating high internal consistency and suitability for use.

To maximize reach and ensure a high response rate, the researchers employed a structured electronic data collection strategy over a four-week period. This modality was selected to leverage the efficiency and accessibility of a secure Google Forms platform, which is particularly suited for the digitally literate STEM student. Consequently, to ensure the instrument reached the intended stratified sample, the survey link was distributed through class representatives, who acted as research assistants. This peer led distribution method was utilized to increase the credibility of the request and encourage higher engagement within the various faculties/colleges.

Ethically, the researchers implemented a real-time monitoring protocol to track daily response rates and ensure the proportional representation of each discipline. The respondents were explicitly assured of anonymity and confidentiality to ensure that their participation remained voluntary and their identities protected. Upon the conclusion of the four-week window, the dataset underwent a rigorous validation and cleaning phase. This involved screening for incomplete entries and duplicated submissions.

Data Analysis

Data collected were analyzed using descriptive statistics (mean) and inferential statistics (analysis of variance, ANOVA). The mean was used to determine the level of awareness among STEM students about the ethical implications of AI in learning, and how students perceive responsible AI integration and use in STEM for skills development. The ANOVA (0.05 significant level) was employed to determine the differences in the level of ethical AI awareness and responsible use among STEM students across disciplines. The analysis was conducted using SPSS 23.0.

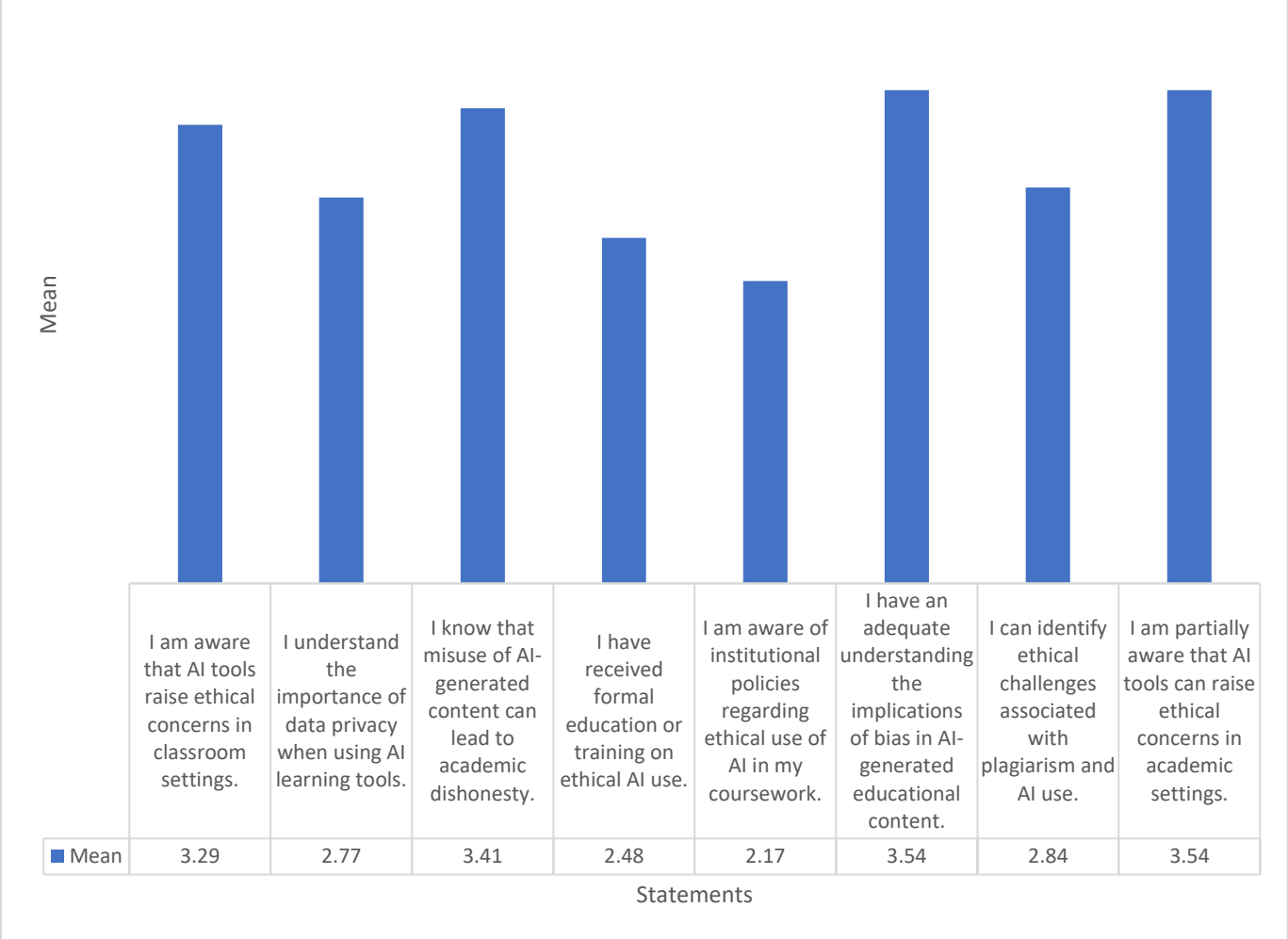
In answering the research questions, the mean of 2.50 was used as a decision benchmark. This is methodologically grounded in scale calibration and central tendency logic, particularly for 4-point rating scales; 1.00–2.49 (Low), 2.50–3.49 (Moderate) and 3.50–5.00 (High), (Fraenkel & Wallen, 2012; Nworgu, 2015).

RESULTS

Research question one sought to determine the level of awareness among STEM students about the ethical implications of AI tools in learning. To answer this question Figure 1 reveals varying levels of awareness among STEM students. The statement, *"I am aware that AI tools raise ethical concerns in classroom settings,"* recorded a mean score of 3.29, indicating a strong level of awareness. Similarly, students showed a moderate understanding of data privacy concerns (Mean = 2.77) and the misuse of AI-generated content leading to academic dishonesty (Mean = 3.41). However, awareness was notably low regarding formal education or training on ethical AI use (Mean = 2.48) and knowledge of institutional policies guiding AI use (Mean = 2.17), highlighting significant gaps in structured guidance.

On the more positive side, students demonstrated high awareness of the implications of bias in AI-generated content (Mean = 3.54) and ethical concerns in academic settings (Mean = 3.54). The ability to identify ethical challenges related AI also reflected moderate awareness (Mean = 2.84). Generally, the findings suggest that students possess a moderate to high understanding of general ethical concerns associated with AI.

Figure 1: Level of Awareness among STEM Students about the Ethical Implications of AI Tools in Learning

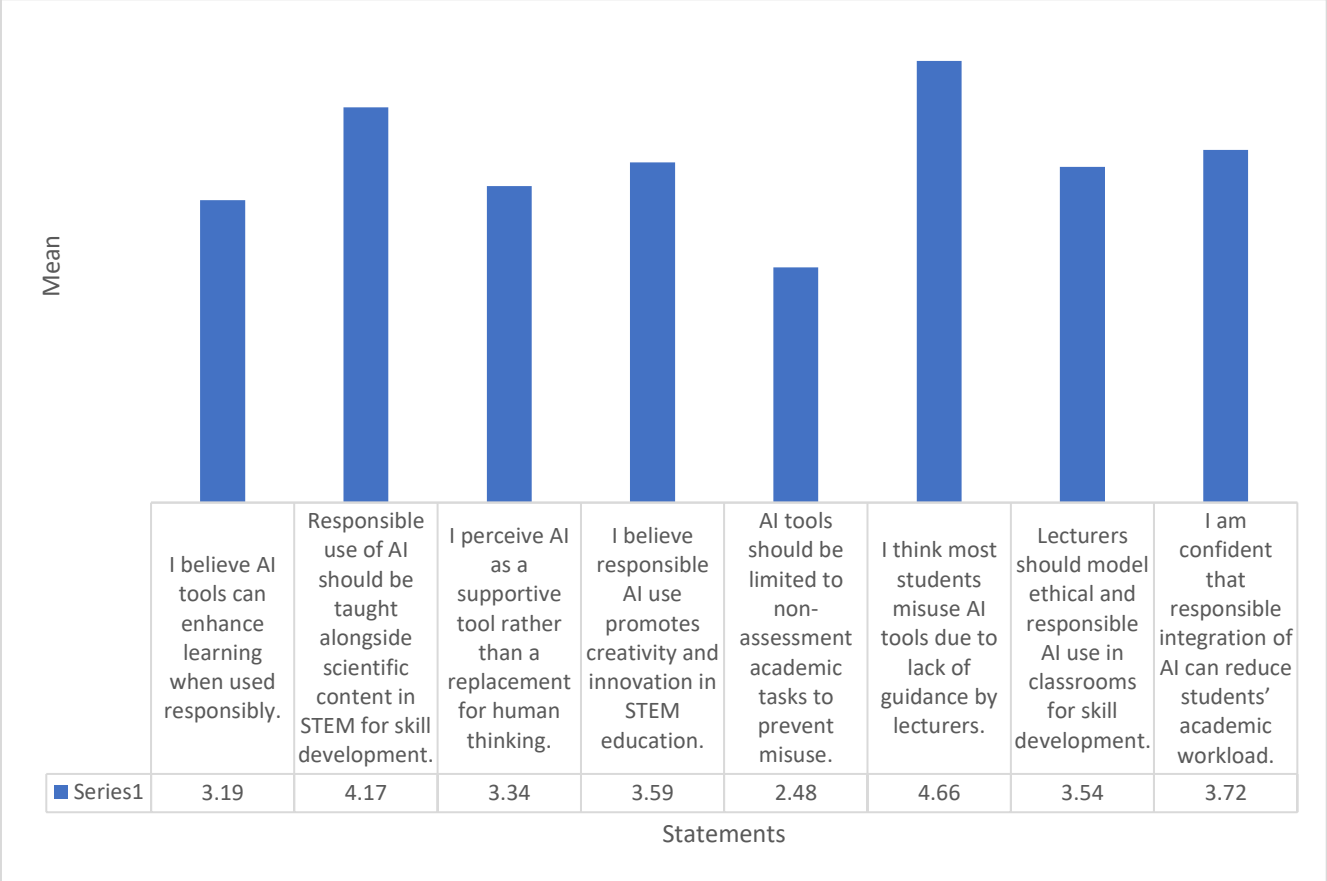


Research question two sought to find out how students perceive responsible AI integration and use in STEM education for skills development. To answer this question, Figure 2 reveals that students generally have positive perceptions toward the responsible use of AI tools in STEM education. The belief that AI can enhance learning when used responsibly had a moderate mean score of 3.19, while the view that responsible AI use should be

taught alongside scientific content recorded a high mean of 4.17, indicating strong support for its integration into the curriculum. Students believed that AI is a supportive tool rather than a replacement for human thinking (Mean = 3.34) and also strongly believed that responsible AI use promotes creativity and innovation (Mean = 3.59).

However, the suggestion that AI tools should be limited to non-assessment tasks to prevent misuse had a low mean of 2.48, showing that students prefer guided use over restrictions. Notably, the highest level of agreement was with the statement that most students misuse AI tools due to lack of guidance by lecturers, which had a mean of 4.66, reflecting a strong concern about inadequate mentorship. This concern is echoed in the support for the statement that lecturers should model ethical and responsible AI use (Mean = 3.54). Finally, the belief that responsible AI integration can reduce students' academic workload received a high mean of 3.72.

Figure 2: Students perception of responsible AI integration and use in STEM education for skill development



Research question three sought to determine the differences in the level of ethical AI awareness and responsible use among STEM students across disciplines.

An x-ray of the group means (Table 1) shows that: Engineering students (M = 3.67) exhibit the highest ethical awareness, followed by Environmental Science (M = 3.49), Science Education (M = 3.34) shows moderate levels and Science (M = 3.21) records the lowest mean. These differences indicate that applied and interdisciplinary fields (Engineering, Environmental Science) may provide more exposure to real-world ethical considerations, thereby enhancing students' ethical awareness and responsible use compared to more theoretically oriented disciplines.

The ANOVA result in Table 2 reveals significant differences in the level of ethical AI awareness and responsible use among STEM students across various disciplines. The result indicates a statistically significant main effect of discipline on ethical awareness and responsible use among STEM students across various disciplines $F(3,96)=4.14$; $p<.05$, $\eta^2=.17$. With a partial eta squared of .17, this explains about 17% of the variance in awareness and use, reflecting a moderate effect. The finding suggests that students' ethical awareness and responsible use differ meaningfully across academic disciplines.

Table 1: Mean and Standard Deviation of Ethical Awareness and Responsible Use by Disciplines

Discipline	N	Mean	SD
Science	111	3.21	0.58
Engineering	107	3.67	0.55
Environmental Science	119	3.49	0.60
Science Education	93	3.34	0.62

Table 2: ANOVA Showing Differences in Ethical Awareness and Responsible Use Across Disciplines

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Between Groups	26.78	3	8.93	4.14	.01	.17
Within Groups	62.28	96	0.65			
Total	89.06	99				

DISCUSSION OF FINDINGS

This study investigated STEM students' ethical awareness, perceptions of responsible AI use and disciplinary differences in AI ethics literacy. Findings from research question one indicates varying levels of awareness among STEM students regarding the ethical implications of using AI tools. A good awareness was recorded concerning general ethical concerns such as the misuse of AI tools for academic dishonesty and data privacy violations. There was greater awareness of AI bias, indicating that students recognize algorithmic discrimination but may not fully understand its underlying implications.

However, awareness declined sharply in more institutionalized and policy-oriented areas, such as knowledge of formal training on ethical AI use and institutional policies guiding AI application. This gap highlights the absence of structured ethical AI education, mirroring global concerns raised by Holmes et al. (2021) who emphasized the dangers of leaving ethical reasoning to intuition in technology-rich environments. Similarly, Afolabi (2024). noted that the lack of digital ethics education may compromise students' digital autonomy. Hagendorff (2020) also underscored the importance of grounding AI use in ethical awareness to prevent societal and educational harm.

Empirical evidence from Usher and Barak (2024) strengthens this interpretation. Their study showed that an explicit-reflective online ethics module significantly enhanced students' awareness of privacy, flawed datasets and social bias, as well as their problem-solving abilities in ethical dilemmas. This suggests that with targeted instruction, students can develop deeper and more actionable ethical competencies.

Findings from research question two reveal that STEM students hold largely positive perceptions about the integration of AI for responsible skill development in STEM education. The highest agreement was that AI should be taught alongside scientific content, reflecting students' belief in integrating ethical AI literacy with domain-specific learning. There was also substantial agreement that responsible AI promotes innovation and creativity, and that AI should be viewed as a supportive tool rather than a replacement for human thinking.

A central concern was the lack of lecturer guidance**,** with the strongest agreement indicating that many students misuse AI tools due to inadequate mentorship**.** This insight aligns with Sambasivan et al. (2021) who argued that ethical leadership and modeling by educators are key to fostering responsible technology use in educational settings. Consequently, while some students opposed restricting AI in assessment tasks**,** their preference for guided use over prohibition reveals a balanced perspective acknowledging risks but valuing AI's potential. This corresponds with Chan and Hu (2023), and Saibu et al. (2016) who noted that successful technology adoption hinges on attitudinal readiness**,** appropriate support structures and instructor modeling**.** Consequently, Espinoza-Vidaurre et al. (2024) highlighted that perceptions of AI and trust in education systems directly influence

academic integrity, especially when shaped by ethical leadership. This supports the current study's conclusion that positive perceptions are reinforced when educator involvement and institutional trust are visible.

The results from research question three reveal statistically significant differences in students' ethical awareness and responsible use across STEM disciplines with a partial eta squared indicating a moderate effect size**.** However, the high intercept value confirms that STEM students generally hold a high baseline awareness and responsible use, but depth varies by disciplines. Engineering students recorded the highest awareness levels and responsible use**,** likely due to their frequent exposure to AI technologies and technical coursework that embeds ethical discussions more explicitly.

This finding aligns with Kim et al. (2025), who noted that while GenAI usage patterns may be consistent across majors, confidence and perceived usefulness remain highly discipline-dependent especially between STEM and non-STEM majors. The disparity in awareness highlights the influence of the learning environment. As Harper (2024) noted that faculty training levels directly shape how students encounter responsible AI practices. This is further supported by Espinoza-Vidaurre et al. (2024), who argue that foundational values such as justice, responsibility and trust are significantly stronger in environments where students receive structured, rather than incidental, exposure to AI ethics. Consequently, these results suggest that the high baseline observed in this study is a foundation that must be further refined through discipline-specific ethical training.

CONCLUSION

The study reveals that STEM students have a moderate to high awareness of the ethical implications of AI, particularly concerning issues like academic dishonesty and bias. However, awareness is low in areas such as formal training and institutional policies, highlighting the need for structured education on ethical AI use. Students generally hold positive perceptions of responsible AI integration, supporting its use in enhancing learning and promoting innovation, while emphasizing the need for lecturer guidance due to concerns about misuse. Additionally, the results show significant differences in awareness and responsible use across disciplines, with Engineering students displaying the highest awareness levels, likely due to greater exposure to AI technologies.

RECOMMENDATIONS

Based on the findings, it is recommended that;

1. Tertiary institutions should institutionalise structured training on ethical AI use across all STEM disciplines to address identified gaps in students' awareness and ensure consistent ethical competence.
2. Ethical considerations should be systematically embedded into STEM projects and capstone activities, requiring students to critically evaluate risks, algorithmic bias and the broader societal implications of AI-driven systems.
3. Discipline-specific approaches should be adopted, especially in fields with lower exposure to AI, to ensure that all STEM students develop a well-rounded understanding of the ethical dimensions of AI technologies in education.
4. Tertiary institutions should implement clear institutional AI policies, staff training and continuous workshops, aligned with bodies such as National Universities Commission and National Commission for Colleges of Education. Position ethical AI competence as a core STEM graduate skill.

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