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Exploring the Use of Generative Artificial Intelligence (GenAI) in Teaching, Learning, and Assessment of STEM Subjects

Chenga Dorji[1] and Purna Bdr. Subba[2]

Abstract

The rapid rise of generative AI (GenAI) tools presents both opportunities and challenges for transforming the teaching, learning, and assessment (TLA) of STEM subjects. This mixed-methods study examined the use of GenAI at Samtse College of Education (SCE), Bhutan, drawing on survey responses from 147 STEM students and four focus group interviews. The study investigated the integration, purposes, comfort and frequency of GenAI use, as well as the associated impacts, challenges and limitations. Findings indicate that SCE STEM students are rapidly integrating GenAI into their academic practices, with ChatGPT serving as the primary tool for assignment support, academic writing and information access. The results highlight the versatility and perceived usefulness of GenAI, while also pointing to risks such as overdependence, reduced tutor-student interaction and ethical concerns. Subject discipline and academic level, rather than gender, emerged as the strongest predictors of comfort and frequency of use. The study recommends establishing clear policies on academic integrity, acceptable use of GenAI, and data privacy and security, while providing students and faculty with clear guidelines to navigate both opportunities and risks.

***Keywords*:** Generative AI (GenAI), STEM, STEM subjects, STEM students, Science (Chemistry, Biology, Physics and Mathematics)

*Corresponding author: cdorji.sce@rub.edu.bt
Department of STEM Education, Samtse College of Education, Royal University of Bhutan

Introduction

Artificial intelligence (AI) is rapidly changing the world, and education is no exception. Most recently, generative artificial intelligence (GenAI), a technology capable of producing content such as text, images, music, code, and other complex outputs enabled by deep learning and neural network advances (Storey et al., 2025) has emerged as a transformative force in academia. GenAI can be used to personalize learning, provide feedback and create interactive learning experiences (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2023). This is particularly beneficial for Science, Technology, Engineering and Mathematics (STEM) subjects, which can be challenging for many students.

In Bhutan, STEM subjects are regarded as engines of growth, essential for driving national progress and innovation. Therefore, His Majesty the Fifth King of Bhutan in his Royal Kasho has commanded that improving STEM education be given the highest priority. The vision is for STEM subjects to become the language of everyday learning, with teachers fully trained and equipped to integrate AI as a central element in teaching and learning (The Bhutanese, 2021).

Samtse College of Education (SCE), a premier teacher training institution in Bhutan, has long been at the forefront of preparing teachers for secondary schools through its programmes in the arts and sciences. Within its academic structure, the Department of STEM Education plays a pivotal role in addressing Bhutan's growing demand for qualified STEM teachers. The department comprises of 18 faculty members, each specialising in either mathematics, physics, chemistry, biology or ICT and offers a range of programmes: undergraduate degrees (B.Ed Secondary in ICT and B.Ed Science with specialisations in Chemistry/Biology or Mathematics/Physics), postgraduate diplomas (PgDE) and master's degrees (M.Ed in Chemistry, Biology, Physics and Mathematics). The reintroduced B.Ed specifically reflect SCE's commitment to bridging the STEM teacher gap in Bhutanese schools.

To foster innovation in STEM education, SCE has established critical infrastructure, including a STEM Research Center (STEMRC) for collaborative projects and publications, a multimedia studio for developing teaching resources and enhanced digital facilities such as high-speed internet and a well-equipped library. The COVID-19 pandemic accelerated the adoption of ICT tools in pedagogy, aligning with Bhutan's broader educational transformation goals. At SCE, STEM faculty and students have begun using GenAI tools for tasks, including making lesson plans, generating supplementary learning materials, and writing projects and assessment. While GenAI holds immense potential to revolutionise education, its integration into STEM teaching, learning and assessment raises critical questions. These includes: How can the GenAI tools enhance pedagogical practices without compromising academic rigour? What ethical and cognitive implications arise when AI-generated content intersects with critical thinking and originality? To address these concerns, this study explored the transformative potential use of GenAI in STEM subjects at SCE, guided by the following research questions:

Main Research Question:

How can GenAI enhance teaching, learning and assessment of STEM Subjects at SCE?

Sub-questions:

1. What GenAI tools are integrated in STEM subjects, and for what purposes are they used?
2. How do gender, academic level and subject discipline relate to students' comfort with and frequency of using GenAI for learning and academic purposes?
3. How does GenAI impact students' learning?
4. What challenges and limitations do students face when using GenAI?

By exploring these questions, this research sought to provide actionable insights for SCE and similar institutions navigating the opportunities and challenges of using Gen AI in STEM subjects. The findings aim to inform policies and practices that harness the potential of GenAI, while safeguarding innovative teaching and learning practices and academic integrity standards in Bhutan's evolving educational landscape.

Literature Review

Introduction to Generative AI in Education

Generative artificial intelligence refers to AI systems capable of producing content such as text, images, music, code, and other complex outputs through advances in deep learning and neural networks (Storey et al., 2025). In recent years, it has emerged as a transformative force in academia, reshaping teaching, learning and assessment, particularly in higher education. Depending on their purpose, different types of GenAI tools are available to support a range of academic activities, including paraphrasing, summarizing, code generation and academic writing. Among these, ChatGPT has gained prominence due to its accessibility, versatility and rapid content generation capabilities (Yu, 2024; Zhai, 2023). Furthermore, its integration with immersive technologies such as virtual and augmented reality facilitates simulation-based learning environments, including virtual laboratories in physics, biology and engineering (Lyu, 2023). Collectively, these innovations enable more personalised learning experiences, streamline administrative tasks and enhance teaching methodologies.

Benefits of GenAI in Education

Generative artificial intelligence has demonstrated substantial potential to enhance efficiency, personalisation and engagement in education, particularly within STEM fields. For example, Llic et al. (2024) highlight how ChatGPT provides personalised support tailored to individual learning needs, thereby improving students' overall learning experiences and fostering greater engagement with AI technologies. Building on this, Rodriguez et al. (2025) report that ChatGPT supports cognitive development across both lower and higher order levels of Bloom's taxonomy, enabling learners to practice analysis, creation and optimisation skills. Another important benefit of GenAI lies in the immediacy and clarity of its feedback. Escalante et al. (2023) found that AI-generated feedback enhances writing quality by supporting iterative revision processes, making learning more interactive and responsive. Similarly, Lee and Moore (2024) describe GenAI as a “conversation catalyst” that enriches student-tutor dialogue, particularly during preparatory or formative learning activities, thereby expanding opportunities for deeper engagement.

Learners’ digital literacy also influences how effectively they leverage GenAI. Postgraduate students, for instance, tend to demonstrate greater proficiency and confidence in using such tools, largely due to higher levels of self-regulation and digital competency (Eke, 2023). Beyond individual learning, GenAI has cognitive implications as well. Zhang and Reicherts (2025) argue that AI can augment human decision making by offering alternative perspectives and analytical pathways. When combined with reflective practices, this augmentation has the potential to strengthen critical thinking; a core competency in STEM problem solving.

Challenges of GenAI in Education

Despite its many advantages, the adoption of GenAI also raises significant cognitive, ethical, and pedagogical challenges. A central concern relates to its potential impact on learning depth and critical thinking. Yu (2024) cautions that misuse of AI tools may erode students’ ability to think critically, while Zhai (2023) similarly warns that overreliance on AI for academic tasks risks compromising originality and academic rigour. Echoing this, Hsu and Fang (2019) argue that excessive automation can undermine independent reasoning abilities, which are essential for tackling complex STEM problem solving.

Beyond cognitive concerns, GenAI also poses challenges to pedagogical relationships. Vazquez et al. (2024) highlight the erosion of relational pedagogy, where reliance on AI reduces direct human interaction between educators and students, potentially weakening the social and emotional dimensions of learning. Academic integrity issues further complicate the picture. Cotton et al. (2023) and Eke (2023) emphasise that plagiarism, unauthorized assistance and unequal access to AI tools threaten fairness and credibility in assessment practices.

Ethical challenges also remain pressing. UNESCO (2023) warns that without targeted AI literacy training, students are vulnerable to misinformation, algorithmic bias and unethical usage. As Yu (2024) observes, navigating these complexities requires educators to act not only as innovators but also as adaptors, fostering a synergistic relationship with AI while prioritising ethical integration, safeguarding student privacy and promoting responsible technology use.

Global Perspectives and Policy Directions

Policy responses to GenAI in education have emerged worldwide, though they differ considerably in pace and scope. UNESCO (2023) documents initiatives in China, Japan, and Singapore where AI literacy is integrated into school curricula and teacher professional development, reflecting a proactive approach to preparing both students and educators for an AI-driven future. Such initiatives also signal a shift in the educator's role from being primarily knowledge transmitters to becoming facilitators who guide learners to engage critically, ethically, and creatively with AI-generated content (Chan & Tsi, 2024; Yu, 2024;). At the same time, the integration of GenAI into education raises important questions about balancing technological efficiency with pedagogical integrity. Escalante et al. (2023) caution that while AI tools can enhance learning efficiency and broaden educational access, these benefits are not guaranteed unless they are embedded within sound teaching practices. To achieve this balance, policy priorities increasingly emphasise equitable access, comprehensive AI literacy training and robust frameworks for responsible use. Collectively, these measures aim to ensure that educational systems harness the advantages of GenAI without compromising academic standards, human values or the relational dimensions of teaching and learning.

Methodology

A sequential mixed-methods design, guided by a pragmatic research paradigm, was employed to explore the integration of GenAI in teaching, learning, and assessment within STEM disciplines at SCE. This study was conducted over a seven-month period with quantitative data collected first, followed by the qualitative data collected to provide comprehensive insights into the research questions. The study population comprised STEM students enrolled in B.Ed Secondary in ICT, B.Ed Science, PgDE in STEM, and M.Ed programmes (Physics, Chemistry, Biology and Mathematics). Quantitative data were collected through random sampling of students, while qualitative data were gathered through focus group interviews (FGIs).

A structured survey questionnaire was developed to assess students' use of GenAI for learning, perceived usefulness, and challenges related to GenAI integration in STEM subjects. The instrument included six sections: a) Demographic details, b) Use of GenAI for learning (7 items) c) Likert-scale items (1–5) evaluating readiness to use GenAI in learning (12 items). d) Likert-scale items (1–5) evaluating benefits of GenAI in learning (14 items). e) Likert-scale items (1–5) evaluating challenges of GenAI in learning (21 items), and f) Sharing of experiences of having used GenAI for learning (1 item). The survey was administered online via Google Forms. To ensure reliability, a pilot test was conducted with 21 respondents and internal consistency was validated using Cronbach's alpha ($\alpha = 0.92$). Prior to analysis, the data was cleaned and recoded as necessary. Descriptive statistics, including frequencies and crosstabs were performed on the survey data. The results were then summarised and used to interpret the relevant demographic and categorical variables. Principal component analysis (PCA) was conducted to explore the GenAI's impact and challenges on students' learning. The analysis aimed to refine the measurement scale by eliminating non-performing items and establishing a robust component structure. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.816, indicating strong inter-correlations suitable for PCA. Bartlett's Test of Sphericity confirmed the ($\chi^2 = 1491.01$, $p < .001$). Using the Kaiser criterion (eigenvalues >1), six components were retained namely; (a) comfort level with GenAI, (b) learning and interaction, (c) academic performance and productivity, (d) limitations with GenAI, (e) future of GenAI in education, and (f) privacy and data security, collectively explaining 64.13% of the total variance. The correlation analysis revealed moderate to strong interrelationships among key variables in GenAI driven education. Academic performance demonstrated significant positive correlations with comfort using GenAI ($r = 0.55$) and optimism about the future of GenAI in education ($r = 0.44$). Tutor-student interaction correlated moderately with awareness of GenAI limitations ($r = 0.41$) but showed no direct link to academic outcomes. Privacy/data security concerns also aligned moderately with academic performance ($r = 0.32$) and future GenAI adoption ($r = 0.30$) and each component demonstrated acceptable reliability when the lower limit reduced to .60 as shown in Table 1 since the measurement scales were adapted.

Table 1
Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.672	.678	6

To gain deeper qualitative insights into the six identified themes, four FGIs were conducted using semi-structured questionnaires. One FGI involved B.Ed Science students (4 participants, mixed gender), another involved M.Ed Science students (4 participants across Physics, Chemistry, Biology and Mathematics), and two groups involved B.Ed secondary in ICT students (3-4 participants per group, mixed gender). The focus group interview questions were pilot tested for clarity and authenticity. The collected raw data were transcribed, coded and analysed thematically.

For ethical reasons, participants were labeled as FG1 (S1–S4), FG2 (S5–S8), FG3 (S9–S12) and FG4 (S13–S15). The qualitative findings were then triangulated with the quantitative results using a convergent triangulation approach, thereby providing a comprehensive and contextual understanding of how GenAI influences STEM subjects at SCE.

Demographics Characteristics

A total of 147 respondents participated in the survey, with a dominant representation of females (65.3%, n=96) compared to males (34.7%, n=51). The majority of the participants were young with 84.4% (n=124) aged between 16-22 years, while the remaining 15.6% (n=23) were 23 years or older. In terms of academic focus within STEM subjects, most participants were enrolled in ICT subject (65.3%, n=96), while the remaining 34.7% (n=51) were in Science. The distribution across programme levels showed that undergraduates constituted the largest group (85.7%, n=126), with postgraduates making up the remaining 14.3% (n=21).

Table 2

Age Group Distribution Within Gender

Age Group	Gender	Count	% with Age
16–22 years old	Male	34	27.4%
	Female	90	72.6%
23 years & above	Male	17	73.9%
	Female	6	26.1%

As shown in the above *Table 2,* among participants aged 16-22 years, females accounted for 72.6% (n=90), while males represented 27.4% (n=34). In contrast, for those aged 23 years and above, males were the majority (73.9%, n=17), with females comprising 26.1% (n=6). Subject-wise, female participation was higher in ICT (75.0%, n=72) compared to Science (47.1%, n=24). Conversely, males were more evenly distributed with 52.9% (n=27) in Science and 25.0% (n=24) in ICT.

Table 3

Programme Level Wise Within Gender

Age Group	Gender	Count	% with Age
Undergraduate	Male	36	28.6%
	Female	90	71.4%
Postgraduate	Male	15	71.4%
	Female	6	28.6%

At the programme level, most undergraduate students were female (71.4%, n=90), while postgraduate students were predominantly male (71.4%, n =15), as shown in the above Table 3.

Results

This section presents the results of each question generated by coalescing the analysis of quantitative and qualitative data.

What GenAI tools are integrated in STEM subjects, and for what purposes are they used?

To examine the integration of GenAI tools in STEM subjects and their purposes, survey data (n = 147) across two items provided quantitative insights, while FG1-FG4 offered contextual confirmation, particularly on variations in tool choice across academic levels and task types.

Generative AI Tools Used

Analysis of open-ended survey responses produced three usage categories as presented in Table 4.

Table 4

Generative AI Tools Used

Frequently Used Tools	*ChatGPT*: Dominant across all responses, mentioned by over 90% of participants. Used for paraphrasing, assignment support, brainstorming and presentation development. *Gemini* and *QuillBot*-Frequently cited for text generation, grammar correction, and rephrasing.
Moderately Used Tools	Includes *Perplexity AI*, *Snapchat AI*, *Question AI*, *MagicSchool.ai* and *Gamma*.
Less Common Tools	Tools with lower adoption, such as *MyAI*, *Bing Chat*, *DALL-E*, *Codeium AI*, *ClaudeAI*, *Canva AI*, *Tome AI* and others.

Focus group discussions confirmed that tool choice often depended on academic level and task type with postgraduate students showing more diverse tool usage patterns.

Purpose of Using GenAI Tools

Open-ended responses from the survey indicated that GenAI tools are primarily integrated into STEM learning for academic purposes. The most common use reported by 85 participants, was assignment completion and academic writing. These tools were employed to draft assignments, rephrase text, and generate ideas to improve quality and efficiency of the writing.

Information gathering and conceptual understanding ranked second, with 62 respondents using GenAI tools to search for relevant content, summarise information, and prepare for examinations or presentations. Language refinement was also a frequent application, cited by 38 respondents who used tools such as QuillBot and ChatGPT to correct grammar, enhance clarity, and improve the overall structure of their academic writing. Additionally, 22 respondents used GenAI tools to design or enhance presentations, while 30 participants leveraged them for research support and idea exploration. Concept clarification, reported by 25 respondents, involved using GenAI tools to resolve academic doubts in STEM subjects. Some participants applied these tools for technical problem solving, particularly in mathematics and coding (15 responses). A smaller group of nine respondents reported non-academic uses, such as seeking health advice or generating quiz content for entertainment.

Overall, ChatGPT dominates GenAI tools used in STEM education, serving as a multi-purpose academic aid. The primary functions revolve around supporting assignment completion, enhancing academic writing, and facilitating information access. While technical problem solving and personal use are less common, respondents highlight the adaptability of these tools beyond traditional academic applications.

How do gender, academic level, and subject discipline relate to students' comfort and frequency of using GenAI for learning and academic purposes?

To examine how comfort and frequency of using GenAI vary by gender, academic level and subject discipline, cross tabulations were conducted to present subgroup means and standard deviations.

Comfort Levels

Overall, students reported moderate comfort with GenAI (*M* = 2.87, *SD* = 0.69 on a 1-4 scale). Gender differences were negligible, with males (*M* = 2.92, *SD* = 0.66) reporting slightly higher comfort than females (*M* = 2.84, *SD* = 0.70). By discipline, ICT students (*M* = 2.89, *SD* = 0.68) showed marginally greater comfort than science students (*M* = 2.84, *SD* = 0.70). Academic level showed the most notable difference: postgraduates (*M* = 3.10, *SD* = 0.77) reported higher comfort than undergraduates (*M* = 2.83, *SD* = 0.67).

Frequency of Use

Frequency of use indicated similar patterns like comfort levels. Gender differences were minimal (females: *M* = 3.67, *SD* = 0.75; males: *M* = 3.65, *SD* = 0.77). ICT students reported more frequent use (*M* = 3.69, *SD* = 0.65) than science students (*M* = 3.61, *SD* = 0.92). Postgraduate students again demonstrated higher engagement (*M* = 3.90, *SD* = 0.83) compared to undergraduate students (*M* = 3.62, *SD* = 0.74).

In summary, postgraduate students consistently reported greater comfort and more frequent use of GenAI than undergraduate students, with ICT students also showing slightly higher scores than science students. Gender differences were minimal across both comfort and frequency measures, suggesting that academic level and discipline play a more prominent role than gender in integrating GenAI for learning purposes.

How does GenAI impact students' learning?

To explore the impact of GenAI on learning, both quantitative and qualitative data were analysed. Quantitative findings from composite items on tutor-student interaction and academic performance provided an overview of students' general perceptions, while FGIs offered deeper insights into their effects on engagement, critical thinking, collaboration, academic integrity, and GenAI-driven feedback.

Learning Interactions and Cognitive Skills

Students reported moderately positive perceptions of tutor-student interaction (*M* = 3.47, *SD* = 0.77), though qualitative data revealed a mixed picture. Some participants (FG1: S1, S2; FG3: S10, S12) observed a decline in direct interaction with lecturers, with S1 noting that students "rarely approach teachers anymore" due to reliance on GenAI. Others (FG2: S5) described the opposite effect, reporting that GenAI use led to more prepared and meaningful class discussions, despite S6 acknowledging an overall reduction in interaction frequency between students and tutors. Perceptions of critical thinking were similarly mixed. While some (FG1: S3, S4; FG3: S11) expressed concern that GenAI fosters over dependence and weakens independent reasoning, others (FG2: S7) viewed it as a catalyst for deeper evaluation, particularly through cross-checking information from GenAI.

Collaboration and Academic Integrity

The impact of GenAI on collaborative learning varied. Certain students (FG1: S1; FG3: S10) reported that GenAI use during group work sometimes resulted in one student completing most of the tasks, whereas others (FG2: S5) viewed it as an equaliser, enabling more balanced participation because every member could contribute with the support of GenAI. Regarding academic integrity, detection tools such as Turnitin were generally supported for promoting fairness (FG1: S3, S4; FG3: S13; FG2: S6), though some students (FG2: S8) cautioned against penalising work solely for being GenAI-assisted.

Academic Performance, Productivity, and Feedback

Students reported generally positive perceptions of academic performance (M = 3.85, SD = 0.67). Many participants (FG2: S6, S7; FG4: S13) indicated that GenAI helped them prepare for exams and take more organised notes, while others (FG1: S1) noted reduced knowledge retention with over-reliance on AI-generated content. GenAI-driven feedback was valued for its speed, non-judgmental tone, and anonymity, which encouraged questions and lowered anxiety (FG1: S3; FG3: S14, S9). Nonetheless, some participants (FG1: S3; FG2: S5) found AI feedback to be generic and lacking the contextual understanding that a human tutor might provide.

What challenges and limitations do students face when using GenAI?

The results focused on students' experiences and perceptions regarding the limitations, risks, and concerns associated with the use of GenAI.

Challenges and Limitations in using GenAI

Quantitative analysis of the composite item [Limitations with GenAI] yielded a mean score of M = 3.53 (SD = 0.82), indicating that while students recognise the presence of limitations, their agreement is cautious and marked by some variability in experience. Qualitative findings uncovered a range of challenges students face when using GenAI. A recurring concern was inaccuracy in content generation, including the fabrication of academic references. For example, S1 (FG1) noted instances such as the provision of fake Digital Object Identifier (DOIs) for academic article, report, or other scholarly content. Additionally, S12 (FG3) noted mathematical errors in responses. These issues led students like S10 (FG3) to seek alternative resources such as YouTube, while others like S8 (FG2) turned to their lecturers for verification and support. Ethical concerns were also raised. S2 (FG1) criticised GenAI for delivering "unethical answers" and lacking emotional intelligence, emphasising the tool's inability to apply contextual judgment or moral reasoning.

Broader Concerns Related to AI in Education

Despite overall optimism about the future of GenAI in education, reflected in the Future of AI in Education] score (M = 3.85; SD = 0.80), students expressed apprehensions about long term implications. FG1 (S3) and FG3 (S10) expressed concerns about the decline in critical thinking, creativity, and skill development, while also warning about the potential replacement of teachers. While some students (FG2: S6; FG4: S15) recognised GenAI's potential to support educational equity, especially in rural areas, others emphasised the need for better training and guidance. However, not all agreed on this approach. For instance, S8 (FG2) opposed mandatory use of GenAI in training programs.

Privacy and Data Security

Students showed strong concern for privacy and data security as reflected in the composite item [Privacy and Data Security in AI Use] mean score of M = 3.90 (SD = 0.66), indicating a strong agreement on the importance of these issues. Focus group interviews highlighted specific worries, including code leakage (FG4: S15) and the use of personal emails linked to GenAI (FG3: S12). Nonetheless, a few students like S13 (FG4) reported feeling safe when using GenAI cautiously such as inputting instructions only without sharing sensitive data.

Discussions

This study examined the integration, purposes, comfort, and frequency of using GenAI as well as the impacts, challenges, and limitations associated with their use. The findings reveal several key insights that contribute to and extend existing knowledge on GenAI in higher education.

ChatGPT's Dominance and Diverse Tool Adoption

The most notable finding is the overwhelming dominance of ChatGPT, reported by over 90% of participants, which underscores its versatility as an academic support tool for paraphrasing, assignment writing, and brainstorming. Other tools such as Gemini, QuillBot, and PerplexityAI were moderately used, while DALL-E, Canva AI, Codeium AI, and Tome AI showed limited uptake. This aligns with Ilić et al. (2024) and Rodriguez et al. (2025), who noted that ChatGPT enhances learning across Bloom's taxonomy, particularly in analysis, creation, and optimisation. Similarly, Escalante et al. (2023) reported widespread student use of QuillBot for academic writing enhancement, consistent with this study. Like students in other contexts (Escalante et al., 2023; Ilić et al., 2024; Rodriguez et al., 2025), STEM students at SCE also adopt ChatGPT for academic productivity. However, unlike these previous studies, the findings here additionally show experimentation with emerging multimodal tools such as Canva AI and MagicSchoolAI. This suggests a gradual shift from purely text-based applications to creative and presentation focused use. The dominance of ChatGPT likely reflects its broad usability, free access, and adaptability to academic writing tasks, making it more appealing than specialised tools. The limited uptake of creative GenAI tools could be explained by the STEM programme at SCE being focused on academic writing rather than on design or media tasks.

Comfort and Frequency of Use

Another key finding is that postgraduate students consistently reported greater comfort and frequency of use than undergraduate students, while ICT students reported slightly higher use than science students. Gender differences were negligible. This finding supports Eke (2023), who argued that academic maturity and disciplinary exposure to technology drive AI adoption more than demographic factors like gender. The similarity with Eke (2023) suggests that maturity and disciplinary orientation remain the strongest predictors of GenAI use. The study showing negligible gender gaps difference may indicate that STEM programmes at SCE offer more equal access and exposure to GenAI tools across genders, minimizing disparities. The stronger uptake among postgraduate students can be attributed to higher academic demands, particularly in research, where GenAI tools assist in literature review, summarisation, and drafting academic work. ICT students' higher adoption is consistent with their ICT education programme and familiarity with coding/problem solving tasks. The negligible gender differences may reflect Bhutan's educational policies that emphasise gender equity in education and balanced access to technology.

Impact of GenAI on Learning

Students perceived GenAI as enhancing productivity, academic writing, and exam preparation, but qualitative data revealed mixed: some reported reduced tutor-student interaction and knowledge retention, while others valued deeper discussions and improved critical evaluation. Collaboration outcomes were similarly mixed, with some students reporting inequities in group work and others highlighting more inclusive participation. These findings resonate with Hsu and Fang (2019), who highlighted AI's dual role in fostering evaluation skills while also risking dependency. Similarly, Nixon et al. (2024) argued that while GenAI can track group interactions and provide insights into participation equity, there remains a risk of widening existing disparities if only privileged groups benefit from AI enhanced learning. The concern about reduced knowledge retention aligns with Fan et al. (2024), who argue that ChatGPT support can foster dependence on technology and potentially trigger metacognitive laziness, whereby learners become less inclined to engage in self-regulated learning behaviors. Meanwhile, positive perceptions of AI-driven feedback are consistent with Lee and Moore (2024) and Escalante et al. (2023), though concerns about generic responses echo Madrigal et al. (2024) on weakened relational pedagogy. The STEM students' case mirrors global findings in terms of AI's productivity benefits and risks of dependency. However, students here placed particularly strong emphasis on reduced face-to-face interaction, perhaps more than in other contexts where GenAI is embedded into hybrid learning models. The differences may reflect the centrality of teacher-student relationships in Bhutanese classrooms, where relational pedagogy is highly valued. Consequently, any reduction in direct interaction is more acutely felt. At the same time, students' willingness to use GenAI for cross-checking outputs suggests a growing metacognitive awareness, aligning with literature on GenAI prompting evaluative reasoning.

Challenges and Limitations

The study revealed that students faced challenges such as inaccuracies, fabricated references, mathematical errors, ethical concerns, and strong worries about privacy and data security. Despite these concerns, students remained optimistic about the future role of GenAI in education. These findings echo UNESCO (2023) and Zhai (2023), who highlighted risks of misinformation, plagiarism and dependency. Students' concerns about fabricated references reflect similar issues reported globally. Privacy and security concerns are consistent with international warnings on data risks (Madrigal et al., 2024). While accuracy and ethical issues are universal, STEM students' emphasised privacy and data security more strongly than in some global studies. This heightened concern may stem from limited access to the national-level AI governance frameworks and a lack of clear institutional policies in Bhutan. Students may therefore approach GenAI with greater caution, perceiving stronger risks in the absence of protective mechanisms.

Conclusion

This study examined the integration, purposes, comfort, and frequency of using GenAI among STEM students, as well as the impacts, challenges, and limitations associated with their use. This study demonstrates that STEM students are rapidly integrating GenAI into their academic practices, with ChatGPT serving as the central tool for assignment support, academic writing, and information access. The findings underscore the versatility and perceived use of GenAI**,** while also highlighting the risks of dependence, reduced tutor-student interaction, and ethical concerns. Subject discipline and academic level not gender emerged as the strongest predictors of comfort and frequency of use.

The study holds considerable significance for multiple stakeholders. For Bhutan's broader education system, it aligns with national efforts to strengthen STEM education and digital learning, offering evidence-based recommendations for institutional policies, ethical guidelines, capacity development, and student support. For faculty and curriculum developers, it highlights the urgent need to provide professional development (PD) to teachers and guidelines to maximise the academic benefits of GenAI, while mitigating risks such as plagiarism, inaccuracies, and cognitive offloading. For students, the findings encourage more informed and ethical engagement with GenAI use. On a global scale, this research contributes a valuable case study addressing common challenges in GenAI integration, such as ethics, equity, and pedagogy. Finally, the study informs both institutional and national policymaking and identifies priority areas for future research, including longitudinal studies on impact, the development of GenAI resilient assessments, and solutions to accuracy and bias concerns.

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