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Artificial intelligence opportunities and threats in the teaching and learning of science in higher education institutions

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Abstract

The advent of Artificial Intelligence (AI) has significantly changed pedagogical practices in the 21st century, bringing both positive and negative effects to education. This study explored the opportunities and threats brought by AI in the teaching and learning process in institutions of higher education. An interpretivist research paradigm, qualitative research approach, and case study design were used to gather data for the study. Data were collected from eight participants in two universities and one teacher training college in Eswatini through interviews and focus group discussions. Findings revealed that although students have begun using AI in Eswatini's higher education institutions, the Ministry of Education and Training (MOET) and institutions have not yet enacted policies and ethical standards to regulate its use in teaching and learning. Due to the unavailability of AI policies, learners engage in academic dishonesty by using AI to write essays and assignments for them. This poses a danger to institutions by producing "zombie graduates" who lack critical thinking and problem-solving skills. The study recommended that, for the effective use of AI, MOET and higher education institutions should enact policy guidelines and ethical standards regulating its use. The Eswatini Higher Education Council (ESHEC), as an education regulatory body, should establish AI compliance standards. Institutions should revise assessment methods by incorporating case studies, practical projects, presentations, and open-book examinations that require critical analysis and are difficult for students to complete using AI. Furthermore, institutions should train both students and lecturers on the proper use of AI.

Keywords: *Artificial Intelligence, AI, education, Eswatini, opportunities, science*

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1. Introduction

Though artificial intelligence (AI) gained popularity in the 21st century, Southgate et al. (2018) note that the term was coined in 1955, and the quest for machines to demonstrate human-like traits dates back to the 1940s. UNESCO (2019) traces the birth of AI to the 1956 Dartmouth Conference. Although AI has existed for nearly 60 years, it remained a fringe technology for much of that time. It has only gained significant momentum in recent years due to what UNESCO (2019) refers to as the "big leap," characterized by the abundance of big data, economically accessible computing power, and advances in machine learning. This indicates that, in the new millennium, AI development has been accelerated by the availability of large datasets required to develop robust modern AI systems and by innovations in data storage.

The introduction of virtual and online learning, which utilizes technological tools and applications in most higher education institutions, has further increased the relevance of AI to online pedagogies. The delivery of online learning in many developing countries accelerated during the COVID-19 pandemic lockdowns, which restricted staff and students from accessing institutional premises. The use of technology in pedagogy aligns with the African Union Commission's Agenda 2063, which advocates for education underpinned by science, technology, and innovation by the year 2063. Agenda 2063 also calls for the establishment of a Pan African Virtual University to provide mass post-secondary education, educating millions of Africans in science, technology, research, and innovation.

As online learning becomes more prominent in higher education, AI tools supporting digital learning platforms are increasingly relevant. O'Dea and O'Dea (2023) note that, although AI in higher education is becoming an important research area, its tools have not been widely adopted. Consequently, there is limited evidence on the pedagogical impact of AI on teaching and learning. The authors further argue that additional research is needed to explore the pedagogical benefits of AI tools in supporting learning and teaching, particularly in social science and science disciplines. Moreover, it is important to examine the views and perceptions of academic tutors and students regarding AI adoption in higher education. Heeg and Avraamidou (2023) assert that, while more studies have investigated the use of AI in education, only a few focus specifically on science education, highlighting the need for further research in this area.

According to UNESCO (2019), AI has begun to produce teaching and learning solutions that are undergoing testing in various educational contexts. However, UNESCO (2019) emphasizes that, although AI can improve learning outcomes, policymakers must anticipate its potential impact on the education sector to enable informed and appropriate policy responses. Southgate et al. (2018) further stress the need for comprehensive ethical, legal, and governance frameworks to ensure the responsible use of AI and to establish transparent processes that enforce accountability at both classroom and school-community levels.

Most education systems and institutions, including those in Eswatini, have not yet published clear policy guidelines for AI use in educational settings. Furthermore, there is limited empirical evidence on the opportunities and threats AI presents to pedagogy in higher education. This qualitative study investigated the opportunities and threats associated with AI in pedagogical practices in science education in Eswatini's higher education institutions. The study aims to generate strategies for best practices and make recommendations. It presents the theoretical framework, reviews the literature to provide a broader understanding of AI use in teaching and learning, discusses the methods used to gather data, and concludes with recommendations and areas for further research.

2. Literature Review

2.1 Theory of Technological Innovation

Technological innovation continues to shape educational theory. Being innovative can enhance the knowledge and skills of those who engage in innovation. The concept of innovation was derived from the Austrian economist Joseph A. Schumpeter (1883–1950), whose book The Theory of Economic Development established him as a leading figure in innovation theory (Croitoru, 2012). Schumpeter viewed development as a historical process of structural change, substantially driven by innovation. Although Schumpeter's theory primarily focused on economic development, it laid a strong foundation for technological innovation theories and highlighted that innovation drives progress and development. Han (2020) notes that the guiding significance of the theory of technological innovation for educational reform lies in promoting the integration of technology into teaching and cultivating students' innovative abilities.

The United Nations (2021) asserts that recent developments in frontier technologies, including artificial intelligence, robotics, and biotechnology, have shown tremendous potential for sustainable development. Technology-enhanced learning initiatives have transformed teaching and learning over the past thirty years (Kirkwood & Price, 2013; Pentang, 2021). In Zhou's (2019) view, the application of AI in education requires educators to transform their teaching methods. It necessitates innovative teaching approaches and the integration of AI technology to promote educational innovation and development. The theory of technological innovation is suitable for this study, as the use of AI in pedagogical practices represents a novel and innovative approach in education.

2.2 Artificial Intelligence (AI)

The field of AI and its definitions have evolved since the 1950s (Heeg & Avraamidou, 2023), and to date, no single definition exists due to rapid developments in the field. Researchers outside computer science have also shown great interest in AI and its applications. Each research field has adapted the term "AI" to suit its own purposes. Heeg and Avraamidou (2023) note that the term Artificial Intelligence was introduced by John McCarthy in the 1950s, defining it as the science and engineering of making intelligent machines. Similarly, Anagnostopoulou et al. (2020) define AI as technology that simulates human intelligence and behavior, enabling machines to think and act like humans.

Popenici and Kerr (2017) broadly define AI as computing systems capable of engaging in human-like processes such as learning, adapting, synthesizing, self-correcting, and processing data for complex tasks. Southgate et al. (2018) describe AI as a term referring to machines or computer programs that can undertake tasks requiring human intelligence, such as planning, problem-solving, or logical reasoning. When machines or programs perform these tasks, they are considered AI systems. AI does not replace teachers; rather, it combines automation with the instructor's guidance (Thongprasit & Wannapiroon, 2022). It provides teachers with opportunities to employ diverse technological platforms and applications to modernize and enhance instructional delivery (Pentang, 2021).

2.3 Artificial Intelligence Tools in Higher Education

The integration of AI into education in developing countries is a recent phenomenon, and various terms are used to describe tools that facilitate teaching and learning. Some scholars

refer to them as AI applications, while others use the term intelligent technologies. This study uses the term tools to encompass all applications, equipment, and systems that enable the use of AI in teaching and learning. Their use largely depends on context and availability. Some of these tools are discussed.

Intelligent Learning Management System. Van Vaerenbergh and Perez-Suay (2022) assert that Intelligent Learning Management Systems (ILMS) combine traditional Learning Management Systems (LMS) with predictive modeling and interactive capabilities powered by AI. LMSs continuously collect data from user interactions and instructional interventions. The first type of ILMS applies learning analytics techniques to model student data and derive actionable insights. A second type incorporates interactive features, enabling learners to interact with automated tutors. For example, when a learner solves an exercise via the LMS, the system can answer questions and provide real-time feedback.

To interpret learner input, such as drawings, written text, or spoken messages, the automated tutor uses information extractors. For mathematical problems, a reasoning engine calculates solutions, while explainer AI techniques convey explanations to the learner (Van Vaerenbergh & Perez-Suay, 2022). Adenowo (2018) notes that intelligent learning platforms also analyze data to monitor learner progress and assessment performance, improving both evaluation efficiency and the handling of the teaching-learning process.

Intelligent Tutoring Systems. Van Vaerenbergh and Perez-Suay (2022) and Graesser et al. (2012) describe Intelligent Tutoring Systems (ITS) as computer-based tools that provide interactive educational environments. ITS adapt to learners' needs while following the curriculum's instructional agenda. Modern ITS collect large volumes of learner interaction data and use data-driven techniques such as machine learning and data mining to refine predictive and analytical models. Many ITS began as academic projects and have since evolved into commercial solutions, such as ViLLe ITS, which gathers learner data to improve tutoring effectiveness (Kurvinen et al., 2020).

Educational Robots. Educational robots integrate multiple disciplines and serve as intelligent teaching tools that supplement instruction. They encourage active questioning, self-learning, and human-computer interaction (Xu et al., 2021). Chatzichristofis (2023) states that educational robotics is a versatile tool that supports learning in various environments. While primarily suited for science, mathematics, technology, and computing, educational robots can also be applied to fields such as arts, theatre, and literature. They provide practical activities

that create engaging learning experiences, enhancing problem-solving, critical thinking, and collaboration skills.

Gradescope. Gradescope is an online grading platform designed to streamline the assessment of various assignments and examinations (Lee, 2023). After manually grading a few examples, AI can apply the grading scheme to the remaining work. The platform allows flexible rubric creation and supports automated grading and feedback on essays, assignments, and quizzes, saving teachers' time and providing timely feedback to learners (Prakash Jasta, 2023; Xu et al., 2021). AI assessment tools also analyze large datasets to identify patterns and insights, facilitating data-driven assessment strategies.

ChatGPT. ChatGPT, launched by OpenAI in November 2022, is a generative AI model with significant potential in language understanding and knowledge retention (OpenAI, 2022). GPT stands for Generative Pre-trained Transformer and allows natural, conversational interactions with computers (UNESCO, 2023). ChatGPT uses natural language processing to generate AI-based written responses to prompts. While it can assist with data analysis or provide opinions, its outputs are based on statistical analysis of vast Internet texts and do not represent definitive positions (UNESCO, 2023). ChatGPT can help teachers generate questions, assignments, quizzes, and interactive content, including simulations and games tailored to students' learning styles (Kasneci et al., 2023; Estrellado & Millar, 2023; Agbong-Coates, 2024).

Turnitin. Turnitin is software designed to detect plagiarism and improper citation. Recent studies highlight its educational role in improving learners' understanding of academic integrity, thereby enhancing the quality of student submissions (Abrahamson & Mann, 2018).

Google Translate. In the era of globalization, translation tools have become essential in bilingual classrooms. Technological advancements have made translation easier and more convenient. Google Translate (GT), capable of translating over 100 languages, is widely used in teaching and learning activities (Phuong et al., 2021; Thanh & Hong, 2021). It allows learners to access and translate information from sources not written in their native language, supporting research and learning across multiple languages.

Chatbots. Chatbots are computer programs designed to simulate human conversation through text or voice interfaces (Sreenivasu et al., 2023). They are increasingly used in education to provide personalized learner support, automate administrative tasks, and enhance engagement (Yeruva et al., 2022). Chatbots can function as virtual tutors, offering instant

feedback, answering questions, providing tailored recommendations, and guiding learners through their educational journey (Sridhar et al., 2022). This technology improves learner engagement and motivation, and higher education institutions should explore ways to leverage it to enhance pedagogical practices.

2.4 Pedagogical Implications

Although the use of AI is still a new phenomenon in higher education institutions in developing countries, it has significant potential benefits. This section discusses some of these benefits.

Personalised learning. Rana et al. (2022) note that AI in education has enabled personalised learning, revolutionising the way learners engage with content. Personalised learning tailors teaching methods to learners' individual needs, interests, strengths, and weaknesses. Zarei et al. (2022) explain that personalised learning uses technology to adapt instruction to each learner's level and pace. AI plays a vital role by analysing data through machine learning algorithms to identify patterns in learners' preferences, behaviours, and achievements. This data is then used to provide tailored learning experiences that meet the specific needs of each learner. Harry (2023) asserts that personalised learning improves learning outcomes and increases learner engagement, while Lee (2023) adds that AI is essential for implementing personalised learning in large classes, where traditional methods would be challenging.

AI supports learners with a variety of resources. Lee (2023) states that AI provides learners with diverse resources. Intelligent tutoring systems offer instant personalised feedback, AI-powered assessment tools track progress and highlight areas for improvement, and research and writing aids streamline information gathering and enhance writing quality. Translation tools allow learners to access materials in multiple languages, while AI also supports idea generation. Jantakun et al. (2021) note that AI tutors provide additional support, collectively contributing to a richer learning experience.

Collaborative learning. Prakash and Jasta (2023) argue that AI promotes collaborative learning by facilitating group work, fostering communication among learners, and providing intelligent feedback. Vygotsky's constructivist teaching and learning theory emphasises collaboration and idea sharing, enabling learners to develop a deeper understanding of concepts.

Real-time monitoring and intervention. Lee (2023) highlights that AI-powered learning analytics tools enable real-time monitoring of learner performance, identifying areas of difficulty. This allows teachers to provide prompt feedback and implement timely interventions before challenges escalate.

Early detection of special needs learners. Tuomi (2018) notes that AI-based approaches allow early identification of learners with special needs, such as dyslexia. A notable example is the Swedish company Lexplore, which developed a system to detect dyslexia by tracking eye movements during reading. The system uses pattern recognition and is expanding to the US and UK for school- and district-wide deployment. AI-based systems have also been developed for diagnosing autism spectrum disorder and attention deficit hyperactivity disorder. Early detection enables timely interventions before conditions worsen. The Eswatini Ministry of Education and Training (MOET, 2018) policy supports inclusive education and the early identification of learners with special needs.

2.5 Challenges of AI in Teaching and Learning

Despite the opportunities AI offers to pedagogy, it presents several challenges:

Bias in the design of AI. Kaliraj and Devi (2021) note that AI systems rely on the knowledge of their developers, which may limit their intelligence and introduce biases. Such biases can become problematic when systems are broadly adopted in contexts where they do not fit all learners. Harry (2023) emphasises that AI systems trained on biased data can perpetuate inequalities and unfair treatment of certain learners.

Cost and access. Harry (2023) highlights that implementing and maintaining AI systems can be costly, posing challenges for educational institutions, especially those with budget constraints. AI infrastructure, software, and training place significant financial pressure on higher education institutions. In developing countries, ensuring equitable access across geographic and socio-economic contexts is a challenge. Hilbert (2015) warns that while AI creates opportunities, it may exacerbate existing inequalities, leaving disadvantaged populations excluded from AI-driven education and deepening the digital divide.

Limitations on data. Kaliraj and Devi (2021) argue that the reliability of AI outcomes depends on the quality of existing data. Gaps or inaccuracies in data pose challenges for AI developers, potentially limiting the system's effectiveness.

Policy and ethical issues. Most countries have yet to enact comprehensive policies regulating AI in education. The U.S. Department of Education (2023) notes that many countries are still developing AI policies and are concerned with ethical implications. Sallam, Salim, Barakat and Al-Tammemi (2023) and Atlas (2023) highlight ethical concerns and risks of academic dishonesty as key challenges. Without clear policy frameworks, the risk of plagiarism and other forms of academic misconduct increases.

2.6 Strategies for Effective Use of AI in Higher Education Institutions

Since AI adoption in developing countries' higher education institutions is still nascent, institutions must implement strategies to ensure effective use:

Enactment of AI policies. The U.S. Department of Education (2023) emphasises the urgent need for AI policies. Policies help ensure the quality and fairness of data used in AI models, supporting unbiased decision-making in educational applications. They also enable institutions to assess how AI technologies may affect equity, incorporating human oversight and checks to mitigate negative impacts. Policies should ensure data privacy and security for teachers, students, and other stakeholders in educational institutions.

Developing AI ethics guidelines. Heeg and Avraamidou (2023) note that ethical challenges in AI design and implementation are often overlooked. They recommend that science curriculum developers follow the seven key requirements outlined in the European Commission's Ethics Guidelines for Trustworthy AI (2018) to ensure fair, safe, and impartial application. The European Commission (2022) further recommends ethical principles including human agency and oversight, transparency, traceability, explainability, diversity, non-discrimination, accessibility, stakeholder participation, inclusivity, privacy, and data governance. Prakash and Jasta (2023) emphasise that as AI becomes more integrated into educational systems, establishing ethical frameworks is vital, especially in Eswatini where MOET (2018) lacks specific AI guidelines.

Educator involvement and training in AI. The U.S. Department of Education (2023) asserts that teachers should participate in decisions about AI-enabled technologies and evaluate tools suitable for their classroom contexts. Educators require technological literacy, including knowledge of AI, to be meaningfully involved. Liua et al. (2021) stress the importance of building teams of highly skilled educators, providing innovative teacher training, integrating AI into education, and aligning training with actual school development needs. Involving and

training educators in AI programs is essential to ensure successful integration of technology into pedagogy.

Research and development. Prakash and Jasta (2023) highlight that AI tools require ongoing research and careful implementation to maximise their benefits while addressing associated challenges. Continuous evaluation is critical to assess AI's impact on education, monitor learner outcomes, gather feedback from educators and learners, and improve the design and deployment of AI tools.

3. Methodology

This study employed an interpretivist research paradigm to understand the phenomenon from the participants' point of view (Creswell, 2015). The qualitative research approach enabled the researcher to enter institutions of higher education and gather detailed information directly from participants in their natural settings. A case study design allowed the researcher to focus on three institutions of higher learning and examine them in depth (McMillan & Schumacher, 2014). In-depth interviews and focus group discussions were used to collect data from lecturers. Groenland and Dana (2019) describe interviews and focus group discussions as effective methods for obtaining detailed information from participants. The interactive nature of these methods enabled the researcher to gather comprehensive and rich data on the use of AI in pedagogical practices.

All participants were purposively selected based on their in-depth knowledge of AI and its application in pedagogical practices within the science discipline in higher education institutions. Flick (2014) asserts that purposive sampling is appropriate when targeting information-rich participants who can provide insights into critical issues related to the research topic. Two universities and one teacher training college participated in the study. Seven lecturers took part in a focus group discussion, and one Head of Department (HoD) participated in a face-to-face interview, resulting in a total of eight participants. This number was considered adequate for a qualitative study, which does not require a large sample. Although the results of this study cannot be generalized to all higher education institutions, they may be transferable to institutions with similar contexts.

Data were analyzed using a thematic approach, a qualitative research technique that involves identifying, analyzing, and reporting themes within the collected data (Braun & Clarke, 2019). Participants' narratives were interpreted to draw meaning and address the

research questions. Findings from the thematic analysis were presented in narrative form, with participants' contributions quoted verbatim (McMillan & Schumacher, 2014). A review of the relevant literature was used to contextualize and discuss participants' contributions.

Table 1

Data collection and analysis flow

Step 1	Step 2	Step 3	Step 4	Step 15	Step 6	Step 7
Preparing data collection instruments.	Selecting institutions & making appointments with participants.	Collecting data from the field.	Familiarising with data.	Generating initial codes	Generating, evaluating & naming themes.	Writing the report.

Source: Byrne (2022)

The trustworthiness of the findings was ensured through peer debriefing and adherence to the focus group discussion and interview guides. The research report was also shared with participants to verify that it accurately reflected their responses. Ethical guidelines were followed, including the non-disclosure of participants' names and the names of their institutions (McMillan & Schumacher, 2014; Creswell, 2015). Participants signed consent forms before participation and were informed of their right to withdraw from the study at any time without consequence. Data were securely stored in lockable cabinets and on password-protected computers to prevent unauthorized access. Permission to conduct the study was granted by the Ministry of Education and Training (MOET).

4. Findings and Discussion

This section analyses, presents and discusses findings in a narrative and verbatim way. Data were collected from eight lecturers in two universities and one teacher training college in Eswatini through interviews and focus group discussions. Findings are presented under themes that emerged from data interpretation. Participant's institutions were coded as institution A, institution B and institution C. Participants were given code names such as participant 1 Institution A, participant 2 institution B, participant 5 institution A.

Theme 1: Understanding of Artificial Intelligence

Participants displayed different understanding of what AI entails. Their understanding of AI is presented verbatim:

> *"Ok, AI is where by robots and internet are giving us information that they harness and act as a human being, which means they are more than internet when they retrieve information in the world wide web and give us* P 1 Institution C.
> *AI is the use of computers or robots to do work that naturally was conducted by human mind"* P 1 Institution B.
> *"AI is the inputting of data in machines so that it can be accessed quickly when wanted e.g. machine learning, computer science in terms of algorithm. You ask it or prompt it and it gives you what you want. AI can teach e.g. a robot tutor can teach and answer questions, grade work and assess tasks"* P 2 Institution B.
> *"AI is when we are using like say computer gadgets to make life easier when doing something in education. Like using ICT, it enhances us to pass information to learners"* P1 Institution A.
> *"The use of technology for teaching and learning"* P2 Institution A.
> *"IA is a technological platform where you get information readily available for various things. Getting readily available information using technology saves time than using piles of books"* P4 Institution A.
> *"I think AI is this conspicuous information that we have in the cyber space. It comes in various forms for all the subjects in the planet. You ask AI about anything and it gives you information about that. AI touches on so many spheres in life in addition to education"* P5 Institution A.

Though participants provided different responses, they indicated that AI refers to information residing on platforms in cyberspace, which can be accessed through computers connected to the internet. They gave examples of AI tools, such as a robot tutor capable of teaching and answering questions. Participants' assertions are supported by Popenici and Kerr (2017), who view AI as computing systems capable of engaging in human-like processes such as learning. When machines and computer programs perform actions and functions that require human intelligence, they are considered AI systems (Southgate et al., 2018). Participants noted that a robot tutor can facilitate teaching and learning, answer questions, and assess and grade tasks. This demonstrates that participants understood AI as capable of performing activities typically carried out by human educators.

Theme 2: Role of AI in Education

Participants emphasized that AI plays key roles in education, particularly when lecturers and students are conducting research on a specific topic.

> *"AI acts as a source of readily available information in real time. It's more of an online library, pocket library and academic walk-mate"* P 1 Institution B.
>
> *"The role of AI in education is that it can retrieve information fast on the internet when given precise instruction. Most universities in developed countries now use AI in terms of teaching. We should up-skill ourselves and adopt AI in teaching and learning instead of running away from it"* P 1 Institution C.
>
> *"AI is there to assist educators and learners to get new knowledge and latest information without using printed books that at times have outdated information. Learners and lecturers should however not abuse" AI* P3 Institution A.

Participants' assertions indicate that, when not misused, AI helps learners and lecturers access up-to-date information compared to outdated hardcover printed books. Rabatseta et al. (2024) note that in library and information services, AI can perform a range of operations such as information retrieval. Adelakun (2024) argues that AI technologies enhance the performance of information retrieval systems, enabling them to process large volumes of data with speed and accuracy. AI-driven systems also provide advanced search capabilities, including image recognition, voice search, and sentiment analysis, thereby expanding the scope and functionality of information retrieval.

Participants further emphasized that AI has contributed to the transformation of education, particularly in teaching and learning methods.

> *"AI encourages the learners to be independent and learn on their own at their own pace than only relying on the teacher. Education has transformed due to the use of technology. It is no longer teacher centred, it can now take place through AI tools even if the teacher is not there"* P2 Institution A.

The use of technology to transform teaching and learning is supported by Schumpeter's theory of technological innovation, which advocates for the integration of technological tools in education. This theory continues to shape educational discourse. Schumpeter viewed development as a historical process of structural change, substantially driven by innovation (Croitoru, 2012; Han, 2020). Zhou (2019) advises educators to transform teaching methods by incorporating AI technologies to promote innovation in education.

In line with participants' assertions about self-paced learning, Harry (2023) argues that AI can personalize the learning experience for each student, allowing them to learn at their own pace and according to their individual abilities and needs. This supports a learner-centered approach, which can lead to improved learning outcomes and increased engagement. Similarly, Madlela (2014) asserts that the Department of Basic Education, through the CAPS 2012 curriculum documents, calls for a shift from a teacher-centered approach to a learner-centered one, an approach that considers learners' needs and abilities while allowing them to progress at their own pace.

Theme 3: Artificial Intelligence Tools Used in Science Education

Most participants reported that ChatGPT is the AI tool most frequently used by students in their institutions. They also mentioned other platforms such as Moodle, Google Classroom, Zoom, and WhatsApp. When asked, "Which AI tools are used in teaching and learning in your institution?" participants responded:

> *"Eeh, that one is a difficult one, because the uptake of AI is not uniform in all departments. We used to use Moodle. I tried using GeoJebra for maths but there were challenges due to expensive data and lack of adequate training"* P1 Institution A.
>
> *"We do not have a specific method of using AI. Now they are introducing Shinfu software where grades are recorded. It will be upgraded to something like Moodle"* P3 Institution A.
>
> *"We have official LMSs that are regulated, but there are also those that are not regulated like ChatGBT and social media platforms like WhatsApp that students use"* P1 Institution A.
>
> *"I have seen people using slides go. You create prompts and create PowerPoint slides. You give it instructions, outline, colour, background, contrast and the number of slides and it creates them"* P 2 Institution B.

Participants viewed AI tools as broad, encompassing both regulated Learning Management Systems (LMSs) and unregulated software such as ChatGPT and social media platforms like WhatsApp. They noted that information accessed from AI robot tutor sessions and scientific simulations can be delivered to learners through the WhatsApp application. Ngakane and Madlela (2024) revealed that WhatsApp, as a social media platform used by almost all learners, is an effective tool for research supervision. Similarly, Madlela and Umesh

(2025) demonstrate that social media platforms such as WhatsApp can support Inquiry-Based Learning (IBL), which stimulates active learner engagement in class. Van Vaerenbergh and Perez-Suay (2022) emphasize that LMSs are among the AI tools widely used in teaching and learning.

A review of the literature further reveals additional AI tools applied in education beyond those mentioned by participants. These include Intelligent Tutoring Systems, Educational Robots, Gradescope, Turnitin, Google Translate, and Chatbots. This suggests that participants had limited knowledge of the broader range of AI tools available for teaching and learning. Their focus was primarily on LMSs, ChatGPT, and social media platforms like WhatsApp, overlooking other AI tools identified in the literature.

Theme 4: Benefits of Using AI in Science Education

Participants acknowledged that although AI is not yet properly regulated in their institutions, it provides several benefits in the teaching and learning process.

> *"AI is fast in terms of giving the responses. You should have subject knowledge and skills of information retrieval. You need to understand the subject area, so that you can distinguish between good information and garbage information form AI"* P 1 Institution C.

This assertion shows that participants were aware that although AI provides information quickly, users must possess information retrieval skills and subject knowledge to avoid accessing and consuming inaccurate or misleading content. The U.S. Department of Education (2023) warns that AI can automatically generate output that is inappropriate or incorrect and further cautions that associations or automations created by AI may amplify existing biases.

Participants also observed that AI promotes virtual learning by eliminating space and time barriers.

> *"Through AI tools like chatbots lecturers are able to connect with learners remotely. This allows teaching and learning to continue even if the lecturer and learners are no longer physically together"* P3 Institution A.

Since the onset of Covid-19, the pace of remote learning has accelerated due to technological advancements, including the availability of AI tools. Madlela (2022) encourages

institutions to leverage available technologies to promote remote learning. Participants similarly viewed AI tools as readily accessible resources that can enhance remote teaching and learning. Madlela and Ngakane (2024) further emphasize the importance of technological tools in addressing time and space constraints in Open Distance Electronic Learning (ODeL). This perspective aligns with the theory of technological innovation, which advocates for cultivating students' innovative abilities by integrating technology with teaching to reform education.

> *"When using AI you are able to get a lot of information for teaching and learning. It saves time to look for manual and hard copies that might not be available. It substitutes physical library and it is accessible if you have internet. It offers convenience even at night, it remove space and time constraints"* P 2 Institution B.
>
> *"Learners can actively participate in class because they can get information from AI. Educators can no longer dump information as if learners do not know. For teaching and learning to occur there should be exchange of information. Learners can exchange information among themselves using AI tools after school hours"* P5 Institution A.

Lee (2023) asserts that AI provides various technological resources to support learners. Madlela and Umesh (2024) reveal that technological platforms enhance instructional delivery and promote the use of IBL, which encourages active learner participation in class. The availability of AI technological resources enables learners to access information and learn either individually or collaboratively. Prakash and Jasta (2023) further emphasize that AI tools can facilitate collaborative learning experiences by supporting group work and fostering communication and collaboration among learners.

Theme 5: Challenges of AI in Teaching and Learning Science

Participants acknowledged that although AI makes positive contributions to teaching and learning, as a relatively new phenomenon in education it also presents several challenges.

> *"The greatest challenge of AI is on the assessment part especially on assignment writing. Students cheat and get answers from AI without any understanding. In most cases some students score high marks in assignments where they use AI, and go on to fail final examinations where it is difficult for them to use AI"* P 2 Institution A.
>
> *"Students are much ahead of lecturers when it comes to AI. They know how to beat AI detection using the very AI which changes the content to show as if it is*

> *written by human not AI (human AI tools) you copy and paste AI information written by AI to the human AI tool and it changes information to taste as if it is written by a human being. Now AI can even beat tools like Turnitin plagiarism check"* P 1 Institution C.
>
> *"Students use AI unethically and commit academic dishonest. This violates assessment principles due to lack of authenticity, origionality and validity"* P1 Institution B.
>
> *"AI is likely to produce graduate zombies who do not think since students copy information from AI applications without applying it. This does not promote critical thinking on the part of students"* P 2 Institution B.
>
> *"To be honest with you, the kind of graduates that we are going to produce is going to be shall*ow. *Students are now lazy to conduct aggressive research. They command AI applications such as Chat GPT to answer questions for them and then pretend as if they are the ones who answered those questio*ns. *At times during examinations some students use digital watches to communicate with others outside to tell them answers"* P5 Institution A.

Participants' assertions reveal that AI can encourage academic dishonesty, as students may use it to generate answers for assessments and present them as their own work. This practice can result in graduates who have not seriously engaged with information or developed critical thinking and problem-solving skills. Sparrow (2022) argues that chatbots such as ChatGPT or GPT-3 can provide answers to a wide range of challenges, undermining significant aspects of the teaching and learning process. Similarly, Google's rival, Bard, can offer seemingly plausible answers to nearly any problem (Kleinman, 2023). Chatbots may generate grammatically well-formed responses, which, when combined with a few credible-looking references, may be sufficient to evade detection even by experienced evaluators (Sweeney, 2023). Such academic dishonesty and unethical behavior can result in graduates who lack essential critical thinking and problem-solving abilities. Sallam et al. (2023) and Atlas (2023) identify ethical considerations and the risk of academic dishonesty as key challenges in the use of AI in education.

Participants also noted that most institutions lack adequate technological infrastructure to support the use of AI. For instance, many do not have access to applications such as Turnitin to check for plagiarism.

> *"Another challenge in the context of Eswatini is that institutions have limited budgets to invest in technological infrastructure, as a result they don't have tools to detect that information is downloaded from AI"* P 1 Institution C.
>
> *"Most learners plagiarise information when writing assignments. Students are always ahead on technology and AI than lecturers. So the level of cheating is always high. In essay competition students download essays or command AI to write essays for them. Plagiarism is a serious academic fraud, but we do not have tools to detect it due to lack of proper technological infrastructure and tools"* P 2 Institution B.
>
> *"At times AI gives students falsified information and fabricated references that cannot be located. At times it gives them generic facts that are not context specific. This is how we catch students that they have used information from AI, but it is difficult to penalise them without tangible proof like a similarity index report"* P1 Institution B.

These assertions indicate that the lack of adequate technological infrastructure and software in institutions makes it difficult for lecturers to address academic challenges arising from students' misuse of AI in assessments. Harry (2023) notes that implementing and maintaining AI systems can be costly, posing challenges for educational institutions, particularly those already facing budget constraints. The expenses associated with AI infrastructure, software, and training place considerable pressure on the budgets of most higher education institutions. In addition to insufficient technological infrastructure, participants highlighted that many lecturers lag in technological proficiency, often depending on when they were born and trained. They further noted that some lecturers do not invest in developing their technological skills, which limits their understanding of AI applications and the complexities of plagiarism in education.

Another challenge raised by participants is the absence of institutional policies regulating the use of AI.

> *"We don't have even the policies, procedures and legislation for the use of AI. Currently the Ministry of Education and Training (MOET) and Eswatini Higher Education Council (ESHEC) do not have policies governing the use of AI in higher education to monitor AI use and ethical issues"* P 1 Institution C.

Since policies stipulate academic regulations and guidelines, it can be argued that without a clear AI policy framework in education, there is a high risk of academic dishonesty

and the misuse of AI by students. The United States Department of Education (2023) notes that the development of public policies regarding AI in education is still in its infancy, and most countries have not yet enacted regulations governing the use of AI. Some of these countries are also concerned with the ethical implications of AI in education (United States Department of Education, 2023). The Eswatini Ministry of Education and Training Policy of 2018 does not include clauses that specifically address the use of AI in education. Such gaps make it difficult for higher education institutions in the country to regulate AI usage by both students and lecturers.

Theme 6: Strategies for Effective Use of AI in Teaching and Learning

Although AI presents challenges in higher education institutions, it is a reality that these institutions must accept and manage, as it also offers significant opportunities. The United Nations (2021) asserts that recent developments in frontier technologies, including artificial intelligence, have demonstrated tremendous potential for sustainable development. Zhou (2019) argues that AI technology requires the transformation of educators' teaching methods, necessitating its integration to promote innovation and the development of education. Participants suggested strategies that could be employed to effectively integrate AI into teaching and learning in higher education institutions.

> *"To deal with the abuse of AI by learners in assessments lecturers should set high order questions and use case scenarios to provoke high order thinking. Lecturers can also use collaborative activities and presentations to assess learners"* P 2 Institution B.
>
> *"Case studies and Indigenous Knowledge Systems (IKS) should be prioritised in the assessments because AI is not yet strong in these areas"* P 1 Institution C.

Participants argued that AI can assist learners with straightforward and lower-order questions, but it is not capable of handling higher-order questions that require critical analysis, such as case studies and context-based questions grounded in Indigenous Knowledge Systems (IKS). This perspective is supported by Sweeney (2023), who contends that assessments should allow greater scope for analysis and critical thinking than essays typically provide. Moreover, assessments need to accommodate evolving learning styles shaped by technological innovation and social media. Various assessment methods exist, ranging from traditional closed examinations and essays to group work, literature reviews, project reports, multiple-

choice questions, long and short answers, open-ended questions, twenty-four-hour open-book examinations, presentations, videos and podcasts, role-playing, reflective statements, and viva voce. This demonstrates that lecturers have multiple options for designing assessments that can mitigate the misuse of AI by learners.

Participants also emphasized that higher education institutions should develop policies, ethical standards, and guidelines to govern the use of AI.

> *"Higher education institutions in Eswatini should embrace AI, because students are already using it. So they should come up with control measures. They should not run away from AI, because it has already landed"* P 1 Institution C.
>
> *"I think the first strategy is to regulate the use of AI e.g. allowing students to use it to a certain percentage like 20% use of AI and 80% from other sources"* P 5 Institution A.
>
> *"Challenges caused by AI in institutions could be mitigated by enacting MOET and institutional policy guidelines regulating the use of AI"* P 1 Institution A.
>
> *"Institutions should enact AI policies that should be operationalised through guidelines and procedures. Enacted policies should accommodate introduction of Turnitin that identifies plagiarised information from AI. Policy guidelines should also facilitate the setting of structures that are responsible for the usage of AI and ensuring that standards and ethics are followed"* P 2 Institution B.
>
> *"ESHEC as a regulatory board in the country should come up with standards of monitoring assessments in higher education institutions. They should have standards enhancing the use of AI in institutions e.g. ESHEC have 12 standards, so they need to enact another standard e.g. standard No…. that is addressing assessments so that it embraces and enhances the use of AI in institutions"* P 1 Institution C.

Participants' assertions that the use of AI in higher education institutions should be regulated through policies, guidelines, and standards are supported by the U.S. Department of Education (2023), which emphasizes the urgent need for policies in AI implementation. Heeg and Avraamidou (2023) advise curriculum developers to consider the seven key requirements that AI systems should meet according to the Ethics Guidelines for Trustworthy AI, established by the European Commission in 2018. This would ensure the fair, safe, and impartial application of AI in educational institutions. Participants believed that if AI were regulated through policies, standards, and ethical guidelines, its use would be both effective and productive in institutions.

Rabatseta et al. (2024) propose a framework for the use of AI in providing information services in the Fourth Industrial Revolution at the University of Limpopo libraries in South Africa. Sweeney (2023) argues that it is more practical and beneficial for universities to embrace emerging technologies such as AI rather than prohibit their use. The adoption of AI in education is further supported by the theory of technological innovation, which advocates for the reform of education through the use of technology (Han, 2020).

Participants also identified training for lecturers and learners on the use of AI as a key strategy for ensuring its effective integration into higher education institutions.

> *"Students and lecturers should be trained on the ethical usage of AI. Students can be taught to use AI to brain storm and generate ideas and then those ideas can be analysed and aligned to the context. Lecturers also need to be trained and capacitated. When AI is used it should be acknowledged"* P 1 Institution B.
>
> *"I think we need to be trained and capacitated so that we can use AI with understanding. Educators should be in-serviced by the government in the use of technology and AI. Capacitation and self will are important. In-service and pre-service training and willingness to change are important"* P 2Institution A.
>
> *"AI is supposed to be taught to learners under principles of teaching or Teaching Principles module to empower them with knowledge and skills of using AI effectively and productively"* P 5 Institution A.

Participants' views on training lecturers and students to promote the effective use of AI in higher education institutions are supported by authoritative sources. Liua et al. (2021) recommend that educational institutions establish a teacher education innovation base, create an innovative teacher training environment, and provide training for teachers and principals on AI and other emerging technologies. Rabatseta et al. (2024) further suggest that the University of Limpopo should offer training programs and workshops to help library professionals enhance their knowledge of AI technologies. This indicates that training both staff and students in higher education institutions can contribute to the effective use of AI in those institutions.

5. Conclusion

Based on the study's findings, it was concluded that participants had a limited understanding of AI. They primarily recognized it as encompassing Learning Management Systems, WhatsApp, and AI tools such as ChatGPT and GeoGebra. However, the literature

shows that AI is broader and also includes tools such as Intelligent Tutoring Systems, Educational Robots, Gradescope, Turnitin, Google Translate, and Chatbots.

The study further concluded that AI presents both benefits and challenges in higher education institutions. Key benefits include enabling students to access up-to-date information from cyberspace and supporting self-paced learning. AI also facilitates the use of innovative teaching and learning tools, consistent with Schumpeter's theory of technological innovation. Major challenges identified include the absence of AI policies, standards, and ethical guidelines within Eswatini's MOET, ESHEC, and higher education institutions. This has led to violations of assessment principles, academic dishonesty, and unethical conduct. Additionally, students and lecturers have not been adequately trained or oriented on the proper use of AI. The study concluded that it is necessary for MOET and institutions to regulate, rather than ban, the use of AI to ensure it effectively contributes to innovation in science education.

6. Recommendations

To facilitate the effective and productive use of AI in higher education, it is recommended that MOET and higher education institutions enact clear policy guidelines and ethical standards regulating its use. Institutions should also establish appropriate technological infrastructure, including both hardware and software, to support AI applications. ESHEC, as the education regulatory board, should develop compliance standards to regulate AI use in institutions and ensure that these standards are consistently implemented. Additionally, assessment methods should be revised to incorporate approaches such as case studies, practical projects, presentations, and open-book examinations that require creative and critical thinking, thereby reducing opportunities for misuse of AI. Finally, both students and lecturers should receive training on the proper and ethical use of AI in teaching and learning to ensure that its integration enhances educational outcomes and promotes innovation in science education.

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