



UNIVERSITY OF KWA-ZULU
NATAL

Artificial Intelligence in Science Education: A Study of Opportunities and Challenges in a South African University

A Thesis Submitted in Fulfilment of the Requirement for the Degree of Master's in
Computer Science Education

by

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ABSTRACT

The integration of Artificial Intelligence (AI) into education is reshaping teaching and learning worldwide, offering innovative solutions to enhance academic outcomes. This study explores the perceptions of undergraduate science students at the University of KwaZulu-Natal regarding the use of AI in science education, with a specific focus on its opportunities, challenges, and ethical and social implications. Guided by Social Constructivism and Machine Learning Theory, the study aimed to investigate the opportunities and challenges of incorporating AI into science education, how AI applications can personalise and enhance learning experiences, and the ethical and social considerations involved in AI use.

A mixed method approach was employed, combining quantitative data collected through structured questionnaires and qualitative data from semi-structured interviews. Participants were selected using purposive and convenience sampling. The results revealed strong student support for AI's potential to personalise learning, improve understanding of complex science content, and increase engagement. However, several challenges were identified, including limited access to digital infrastructure, concerns about over-reliance on AI, academic dishonesty, and data privacy risks.

Based on the findings, the study recommends improving institutional infrastructure, providing digital literacy and ethical AI use training, and integrating AI tools into science curricula in a balanced and supportive manner. These recommendations aim to ensure equitable access, promote critical thinking, and support responsible AI use in higher education. The study contributes to the growing body of research on AI in education by offering context-specific insights that can inform policy, curriculum development, and future research.

DECLARATION

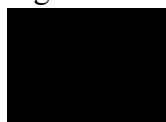
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LIST OF ACRONYMS

Acronym	Full Meaning
AI	Artificial Intelligence
AIEd	Artificial Intelligence in Education
ML	Machine Learning
NLP	Natural Language Processing
GANs	Generative Adversarial Networks
HEIs	Higher Education Institutions
UKZN	University of KwaZulu-Natal
SDG	Sustainable Development Goal
SDGs	Sustainable Development Goals
ICT	Information and Communication Technology
HCI	Human-Computer Interaction
AR	Augmented Reality
VR	Virtual Reality
ZPD	Zone of Proximal Development
CSIR	Council for Scientific and Industrial Research

AIED	Artificial Intelligence in Education (alternative abbreviation)
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Artificial Intelligence in Science Education: A Study of Opportunities and Challenges in a South African University

Keywords: Artificial Intelligence, Opportunities and Challenges, Science Education, Sustainable Development

CHAPTER ONE

1.1 INTRODUCTION

This chapter introduces the exploration of Artificial Intelligence (AI) in science education, with specific attention to its opportunities and challenges in the South African context. Although AI is rapidly transforming sectors such as health, business, and industry, its integration into education particularly in higher education institutions (HEIs) remains limited and underexplored. Existing studies often highlight AI's potential to support personalised and adaptive learning, but there is still a lack of empirical research examining how students in developing contexts perceive and engage with these technologies. This gap is particularly pronounced in South Africa, where persistent inequalities in digital access, infrastructure, and educational resources create unique challenges for equitable AI adoption. This study aims to investigate how AI can enhance science learning experiences, improve educational outcomes, and contribute to the achievement of sustainable development goals in higher education. In doing so, the research seeks to uncover both the opportunities such as personalised learning and increased engagement and the challenges, including ethical concerns around data privacy

This chapter will outline the research problem, emphasising the pressing need for equitable access to quality education amidst historical inequalities in South Africa. It will also detail the purpose of the study, highlighting the significance of understanding AI's role in transforming science education. Furthermore, it will present the research questions and objectives that guide this investigation, aiming to contribute valuable insights for policymakers and educators striving to harness AI responsibly in educational contexts. Through this comprehensive examination, we seek to illuminate both the transformative potential of AI in education and the challenges that must be navigated to realise its benefits effectively

1.2. BACKGROUND

Researchers have been exploring the manifold potential applications of Artificial Intelligence (AI) in various fields, recognising the pivotal role of education in individual and societal development. The concept of AI has evolved over time, with contemporary definitions emphasising its ability to tackle complex cognitive challenges akin to human intelligence, its widespread accessibility through smartphones and the internet, and its capacity to pinpoint

issues and devise solutions for the betterment of technology, individuals, and communities. The burgeoning popularity of generative AI tools like ChatGPT presents both new opportunities and challenges for higher education. While there exists considerable research on AI in higher education, there remains a pressing need for a holistic approach to leveraging AI for the transformation of Higher Education Institutions (HEIs) (Raza Beg & Mehndiratta, 2024).

According to (Wang, 2019), artificial intelligence (AI) encompasses machines' ability to emulate human-like thinking, learning, perception, and decision-making. (Marr, 2018) asserts that the fundamental aim of AI has always been to develop tools with human-like cognitive capabilities. AI has found widespread application in education as computing technologies have advanced, including intelligent tutoring systems, teaching robots, learning analytics dashboards, adaptive learning systems, and human-computer interactions (Chen & Hwang, 2022). The application of Artificial Intelligence (AI) to create new teaching-learning solutions is gaining speed and has the potential to completely revolutionise the educational system. Schools are starting to transition from traditional teaching methods to smart education to improve students' learning experiences (Ahmed, Taqi, & Farabi, 2021; Junejo1 & Rahoo, 2024)AI can transform education in South Africa and advance sustainable development by creating learning experiences to each student's specific needs. The fundamental focus of artificial intelligence in education (AIEd) is the creation of "computers which perform cognitive tasks, typically associated with human minds, particularly learning and problem-solving (p. 10)." (Chen, Hsu, Hsu, & Lien, 2023).

This research will explore the opportunities and challenges that AI presents to South African education, focusing on its contribution to Science Education students for quality education. The challenge lies in effectively using AI within South African higher education to significantly contribute to achieving quality education, amidst historical inequalities and socioeconomic disparities. Ensuring equitable access to quality education while integrating AI requires addressing ethical concerns such as data privacy and algorithmic bias, alongside the potential displacement of human educators. Additionally, resource limitations, including budget constraints and a shortage of educators, pose obstacles to implementing AI solutions effectively within the higher education sector in South Africa (Opesemowo & Adekomaya, 2024).

1.3. RESEARCH PROBLEM

According to (Opesemowo & Adekomaya, 2024), South Africa's higher education system is at a critical juncture, facing significant obstacles in meeting the United Nations' SDGs, including quality education, equity, and lifelong learning. The existence and potential of Artificial Intelligence (AI) present exciting solutions, but a persistent issue remains. South African higher education institutions effectively use and integrate AI technologies to address the multifaceted challenges of providing equitable access to quality education, promoting lifelong learning, and aligning with the SDGs in the South African socioeconomic and educational context. South Africa's higher education system has issues in providing access to quality education. Less fortunate populations frequently lack equal access to quality education. AI provides a potential solution, but the challenge is to successfully apply AI to overcome these inequalities.

Artificial intelligence (AI) has caused widespread disruption in a variety of areas, including higher education. Despite the increasing interest and use of AI in educational institutions, there is still a considerable gap in our understanding of its overall influence on Higher Education Institutions (HEIs) and the transformations they go through (Bhutto & Khaliq, 2025). From changing teaching methods to transforming organizational frameworks, the integration of AI into the field of education presents challenges as well as opportunities for institutions around the world. This study is guided by relevant learning and technology integration theories which explain how digital tools such as artificial intelligence can enhance or influence learning processes.

The lack of a holistic strategy to AI in higher education creates major challenges for the field of study. Without a comprehensive knowledge of the implications of AI on HEI change, educators and researchers may fail to fully realise AI's potential while risking unforeseen consequences. A holistic strategy to integrating AI in higher education is thus essential, not only for academic institutions but also for students, researchers, and politicians attempting to navigate the complicated environment of AI-driven change (Chandra & Feng, 2024).

This study set out to address the absence of a holistic strategy for integrating Artificial Intelligence (AI) into higher education, particularly in the field of science education in South Africa.

1.4. PURPOSE OF THE STUDY

Artificial Intelligence (AI) has emerged as a transformative force in education, offering opportunities to enhance student learning and institutional effectiveness. This study aims to explore the perceptions of undergraduate science students regarding the use of Artificial Intelligence (AI) in science education, with particular focus on the opportunities, challenges, and ethical considerations associated with its use. Artificial intelligence (AI) is being adopted and used increasingly frequently worldwide (Borenstein & Howard, 2021; Amah & Okesipe, 2025).

1.5. SIGNIFICANCE OF THE RESEARCH

Artificial intelligence (AI) stands at the forefront of driving innovation and growth across various sectors of life, including health, medicine, military, space, informatics, communication, industry, and notably, education (Goralski & Tan, 2020). Its profound development has significantly impacted educational practices, enhancing student learning, teacher effectiveness, and institutional decision-making processes (Hao & Demir, 2024)

Recognising the pivotal role of education in shaping the future of a country, it becomes imperative to expand education and research initiatives surrounding AI. In the era of AI, students hold dual roles as both users and potential developers of this technology. AI's integration into education spans across disciplines, where students utilise AI approaches for various purposes, from geographical positioning to financial data analysis, underscoring its relevance beyond computer science majors (Sijing & Lan, 2018).

Understanding how AI can enhance education is crucial for using its benefits effectively while addressing potential risks and challenges. By analysing the advantages and obstacles of AI in education, we can develop policies and practices to ensure its responsible and successful utilisation.

1.6. RESEARCH QUESTIONS

This section presents the research questions that guided the study. These questions were formulated based on the research problem and the purpose of the study. They aim to explore students' perceptions of the opportunities and challenges associated with the use of artificial intelligence in science education.

1.6.1. Primary Research Questions

What are the opportunities and challenges of incorporating AI into science education?

1.6.2. Secondary Research Questions

1. How can AI applications be used to personalise and enhance science learning experiences?
2. What are the ethical and social implications of using AI in science education?

1.7. RESEARCH OBJECTIVES

The research objectives provide clear direction for the study and outline what the research seeks to achieve. These objectives are aligned with the research questions and focus on examining both the benefits and challenges of artificial intelligence in science education.

1.7.1 Primary Objectives

To identify the potential benefits and challenges of using AI in science education.

1.7.2 Secondary Objectives

1. To examine how AI applications can be used to personalise and enhance science learning experiences.
2. To examine the ethical and social implications of using AI in science education, including issues of privacy, bias, and equitable access.

1.8. CONTEXT OF THE STUDY

This study is located in Durban, the University of KwaZulu-Natal at Edgewood Campus. This research focuses on the University of KwaZulu-Natal (UKZN) Edgewood Campus Artificial Intelligence (AI) in Science Education: A Study of Opportunities and Challenges due to several compelling reasons. The University of KwaZulu-Natal is known for its environmental education programs. Additionally, UKZN has a dedicated Centre for Artificial Intelligence Research, launched in partnership with the CSIR-Meraka Institute, which focuses on advancing AI research and its applications (Gleason N. , 2018).

1.9. STRUCTURAL OUTLINE

This study comprises seven chapters. The chapters are organised as follows:

In Chapter One, the background of the study and the research problem have been presented. The research objectives and questions have been acknowledged, and the significance of the study is argued.

In Chapter Two, the existing literature will be reviewed to identify the opportunities and challenges presented by Artificial Intelligence in higher education institution.

Thereafter there is Chapter Three, the theoretical framework that outline the two theories guiding the study.

In Chapter Four, the research methodology and methods will be explained. The use of an interpretive research paradigm, qualitative and quantitative research methodology will be justified. The sampling and research methods used will be discussed, including the ethical issues.

In Chapter Five, the characteristics of the participants and the data collected from each of the data generation tools used in this study are provided. Thematic analysis and inductive reasoning for the key findings will be discussed. A visualisation of the responses to each research question will be presented in tables and figures.

In Chapter Six, this chapter now moves beyond simply presenting the data and instead engages in a critical discussion of the findings in relation to the research questions, theoretical framework, and existing literature.

In Chapter Seven, this chapter presents a comprehensive summary of the research study, drawing together the key findings, theoretical insights, and implications discussed in previous chapters and provides a well-grounded conclusion based on the results of both the quantitative and qualitative data.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

This section reviews literature relevant to the scope of the study, focusing on the opportunities and challenges of Artificial Intelligence (AI) in science education at the University of KwaZulu-Natal. While AI has been widely acknowledged as a transformative force in education, most existing research is concentrated in developed contexts, with limited exploration of its impact in African higher education systems. This gap restricts our understanding of how AI can be equitably and effectively integrated in resource-constrained environments such as South Africa, where issues of access, infrastructure, and digital literacy continue to shape educational outcomes.

The aim of this literature review is therefore to critically examine existing theoretical and empirical studies on AI in education, drawing on Social Constructivism and Machine Learning Theory to frame how AI can personalise learning, foster collaboration, and address disparities in access. By situating this study within the global and local debates, the review highlights both the potential benefits of AI such as adaptive learning, improved engagement, and efficiency and the significant challenges, including ethical concerns, equity issues, and risks of over-reliance on technology. This gap in the literature motivates the present study's questions: by investigating undergraduate science students' perceptions, this research seeks to generate empirical, context-specific evidence that can inform how AI can be equitably integrated in South African higher education (see Research Questions 1–3). In particular, the study examines both pedagogical opportunities and ethical/social constraints to ensure findings directly address policy and curriculum concerns

The significance of this review lies in its contribution to shaping a holistic understanding of AI in higher education that aligns with Sustainable Development Goal 4 (Quality Education). By bridging the gap between global discourse and the South African context, it establishes a foundation for investigating how AI can be responsibly harnessed to enhance inclusive and equitable science education in universities.

Framework of the Study

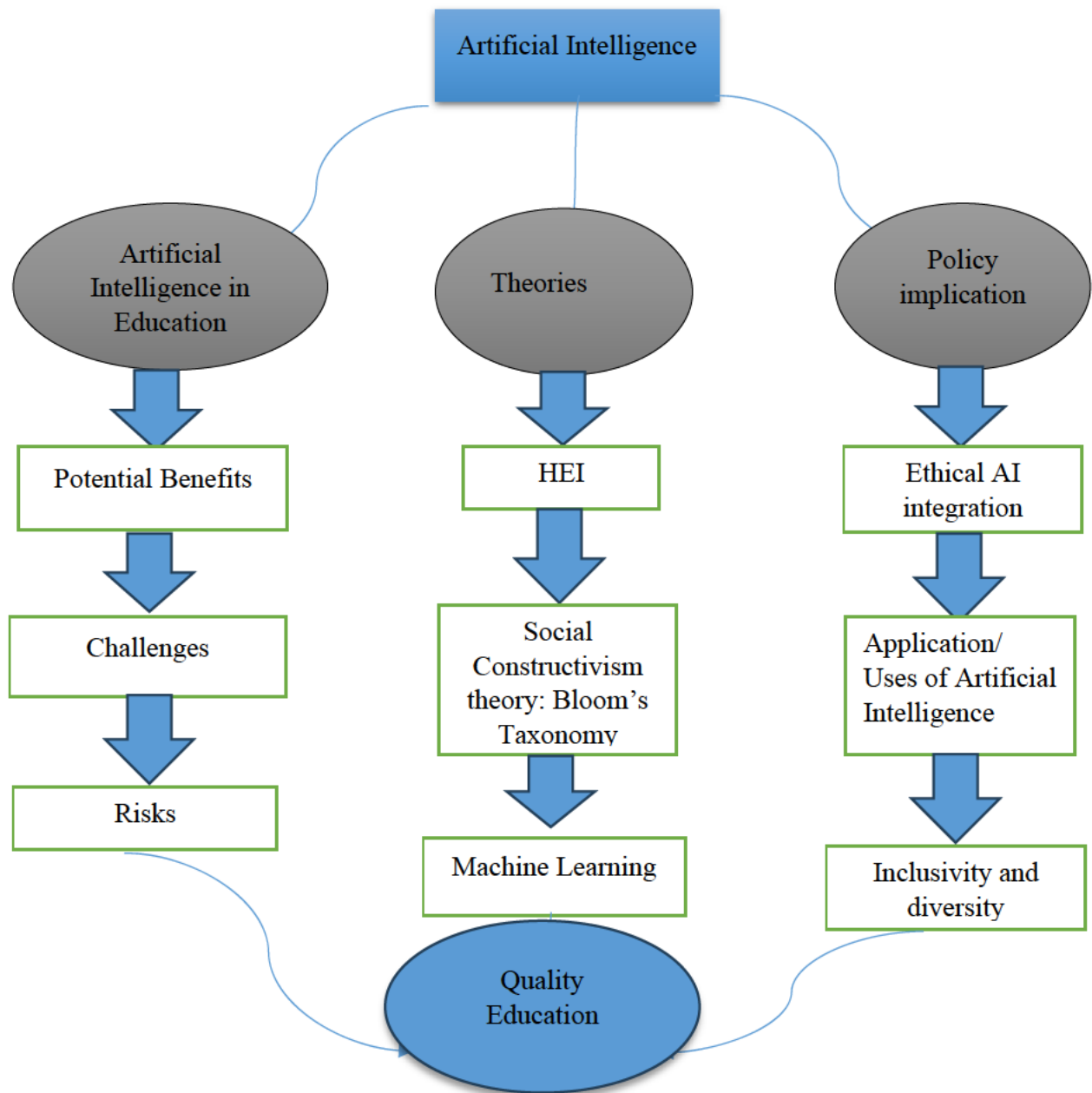


Figure 2. 1: Framework of the Study

Source: created by the author for this research purpose

The figure above (‘Figure 2.1: Framework of this Study’) visually outlines the conceptual and theoretical underpinnings that guide the research on the integration of Artificial Intelligence (AI) in science education. At its core, the framework connects key elements Artificial Intelligence, Education, Theories, and Policy Makers demonstrating how they interact to influence both the implementation and impact of AI in educational settings.

The conceptual aspect of the framework is anchored in the practical application of AI technologies within education, particularly focusing on how these tools support teaching and learning. It reflects a systemic view, where AI is not seen in isolation but in relation to broader educational structures, including curriculum, pedagogy, and access to digital infrastructure.

The theoretical foundations are rooted in two primary theories: Constructivism and Machine Learning. Constructivism supports the idea that learners construct knowledge through experiences, aligning well with AI's ability to provide interactive, adaptive, and student-centered learning environments. On the other hand, Machine Learning represents the computational backbone of AI, allowing educational tools to adapt based on student performance and data over time thus linking theory to practice.

Lastly, the inclusion of Policy Makers in the framework emphasises the need for governance, ethical guidelines, and equity-focused strategies when integrating AI in schools. Their role is crucial in shaping AI policies that ensure responsible use, safeguard student data, and promote inclusive access.

2.2.ARTIFICIAL INTELLIGENCE

Karthikeyan and Hie (2021) characterise artificial intelligence as the development of intelligent machines and computer programs to do activities that require human intelligence. They define it as a system that replicates the functions that a human may perform and further outline that AI makes uses of external data, such as big data, to achieve superior performance on assigned tasks. AI was previously only seen in science fiction and debates about technology's impact on the present world. However, technology has now become an integral part of our everyday lives. It has become a crucial function in many technical and other industries. Artificial intelligence has a tremendous impact on businesses such as manufacturing, healthcare, and supply chain management (Mogoale, 2025).

Table 2.1 highlights the varied definitions and interpretations of Artificial Intelligence (AI) across scholarly literature. It categorises AI into two broad perspectives: *acting humanly* and *acting rationally*. Some definitions, such as those by Haugeland (1989) and Bali (2017), describe AI as the effort to replicate human thought processes like decision-making and learning. Others, like Winston (1992) and Chakroun & Daelman (2018), view AI through a computational lens, focusing on the processes that allow machines to perceive, reason, and act.

Meanwhile, rationalist definitions by scholars like Poole et al. (1998) and Nilsson (1998) describe AI as the creation of intelligent agents or systems that exhibit intelligent behaviour,

not necessarily mimicking humans. Overall, table 2.1 illustrates the interdisciplinary nature of AI, combining cognitive science, computer science, and philosophy to understand and build systems capable of intelligent action.

2.2.1 Different dimensions of Artificial Intelligence

Table 2.1 presents a structured overview of the different dimensions of Artificial Intelligence (AI), highlighting how AI can be understood from both human-like and rational perspectives. The table categorises AI into four key approaches thinking humanly, thinking rationally, acting humanly, and acting rationally based on definitions from various scholars. This classification provides a foundational understanding of how AI systems are designed either to mimic human cognition and behaviour or to operate through logical and efficient decision-making processes, thereby illustrating the complexity and interdisciplinary nature of AI.

Thinking Humanly	Thinking Rationally
The exciting new effort to make computers think... machines with minds, in the full and literal sense (Haugeland, 1989). The automation of activities that we associate with human thinking, activities such as decision-making, problem-solving, learning...' (Bali, 2017)	The study of mental faculties through the use of computational models.' (Chakroun & Daelman, 2018) 'The study of the computations that make it possible to perceive, reason, and act.' (Winston, 1992)
Acting Humanly	Acting Rationally
'The art of creating machines that perform functions that require intelligence when performed by people.' (Kurzweil, 1990) 'The study of how to make computers do things at which, at the moment, people are better.' (Rich & Knight, 1991)	'Computational Intelligence is the study of the design of intelligent agents.' (Poole, et al., 1998) 'AI... is concerned with intelligent behaviour in artifacts.' (Nilsson, 1998)

Table 2. 1: Different dimensions of Artificial Intelligence

The study of artificial intelligence (AI) can be understood through four key dimensions. First, acting humanly focuses on creating machines that can perform tasks requiring human-like intelligence, such as decision-making and problem-solving, as emphasised by Haugeland (1989). Second, acting rationally highlights the goal of enabling computers to execute tasks where humans currently excel, as noted by Rich and Knight (1991). Third, computational

models of mental faculties explore how computational frameworks can simulate human cognitive processes like perception and reasoning, bridging psychology and computer science (Chakroun & Daelman, 2018). Finally, intelligent agents concentrate on designing systems that can operate autonomously and intelligently within their environments, adapting to new situations and learning from experiences (Poole & Katie, 1998). Together, these dimensions illustrate the complexity of AI, showcasing its dual objectives of replicating human thought and enhancing rational decision-making through intelligent agents and computational modelling.

McManis & Gunnewig (2012) highlighted how contemporary youth often dedicate significant time to their mobile devices, providing an opportunity for utilising AI applications for brief study sessions during their leisure time. Employing gesture recognition technology, AI assists in gauging students' engagement levels or comfort during lectures. With advancements, AI can now interpret facial expressions and hand movements to assess whether students struggle to grasp lecture content. In such cases, the system can dynamically adjust the course material to enhance comprehension (Ang & Wenlan, 2023; Garnier, 2025). Laanpere (2014) emphasised recent studies contributing to the ways AI can enhance learning opportunities and management systems. Researchers, such as Yousef and Mohammad (2024), assert that AI's increasing integration in education can mitigate the shortage of trained teachers and optimise educational efficacy, ultimately improving student learning outcomes.

To achieve Sustainable Development Goal 4, which aims to provide inclusive and equitable quality education and promote lifelong learning opportunities for all, equal access to learning is crucial. AI tools play a significant role in facilitating inclusive and equitable education by offering suitable learning opportunities to marginalised groups and communities, including individuals with disabilities, refugees, out-of-school children, and those living in remote areas. For example, telepresence robots enable learners with special needs to participate in classes from home or hospitals, ensuring continued education during crises or emergencies. By leveraging such technologies, inclusivity and widespread access to education can be enhanced (Brittle, 2023; UNESCO, 2017)

In his article, (Al-Emran & Ghobakhloo, 2025) describe the advantages of Artificial Intelligence in education, specifically highlighting Global Knowledge, Student Attendance Tracking, and Removing Barriers. Artificial intelligence systems facilitate language learning by translating educational content into the learner's language and adapting texts published in

other languages. This enhances access to educational resources and promotes rapid acquisition of knowledge. Moreover, AI streamlines student attendance tracking using sophisticated sensors, eliminating the need for manual attendance-taking by teachers. Additionally, AI technology removes barriers for learners with special needs by providing access to educational materials tailored to their requirements (Xue & Ghazali, 2026). This fosters their full and equitable participation in social life, ensuring inclusivity in educational environments. Visually impaired students benefit from text-to-speech systems, while hearing-impaired individuals utilise audio-to-text systems. Furthermore, individuals facing mobility impairments or illnesses can remotely participate in educational activities from home, preventing educational disparities.

AI can significantly enhance collaborative learning, particularly in computer-supported environments where learners are not physically co-located. Online asynchronous discussion groups play a pivotal role in facilitating collaborative learning experiences. AI systems equipped with machine learning and shallow text processing techniques monitor these discussion groups, providing valuable insights to teachers regarding learner interactions and engagement. Asynchronous online learning is often preferred for adult learners, who are typically non-traditional students balancing part-time enrolment with full-time employment and family responsibilities (Breazeal & Safinah, 2024)

Through a variety of means, AI can support personalising education. With the aid of AI, teachers will be able to focus more on pupils who are struggling in their classes. Teachers devote a significant amount of time to mundane and administrative duties, such as creating assignments. In addition to acknowledging the potential benefits of AI in education, it's crucial to address the challenges and ethical considerations associated with its widespread adoption. These include exacerbating educational inequalities due to the digital divide, concerns about data privacy and security, and the risk of algorithmic bias and discrimination (Lindner, Clemons, & McKibben, 2026). To mitigate these challenges, policymakers and educators must prioritise transparency, accountability, and inclusivity in AI implementation. This involves ensuring equitable access to technology, safeguarding data privacy, and regularly auditing algorithms for bias. Furthermore, integrating ethics education into the curriculum and providing training for educators can help students and teachers navigate ethical dilemmas associated with AI. By proactively addressing these issues, stakeholders can harness the potential of AI to enhance education while promoting equity, privacy, and inclusivity for all learners.

2.2.2 History of artificial intelligence

Figure 2.2.2 provides a brief overview of the historical development of Artificial Intelligence (AI), tracing its evolution from early philosophical ideas about intelligent machines to modern technological advancements. It highlights key milestones, such as the development of programmable computers in the 1940s, Alan Turing's foundational work in 1950, and the formal establishment of AI as a field during the Dartmouth Conference. The section further outlines how AI has progressed through different phases, including periods of rapid growth and decline, leading to the current era of machine learning and advanced applications. Overall, it demonstrates how AI has evolved into a transformative technology shaping various sectors, including education.

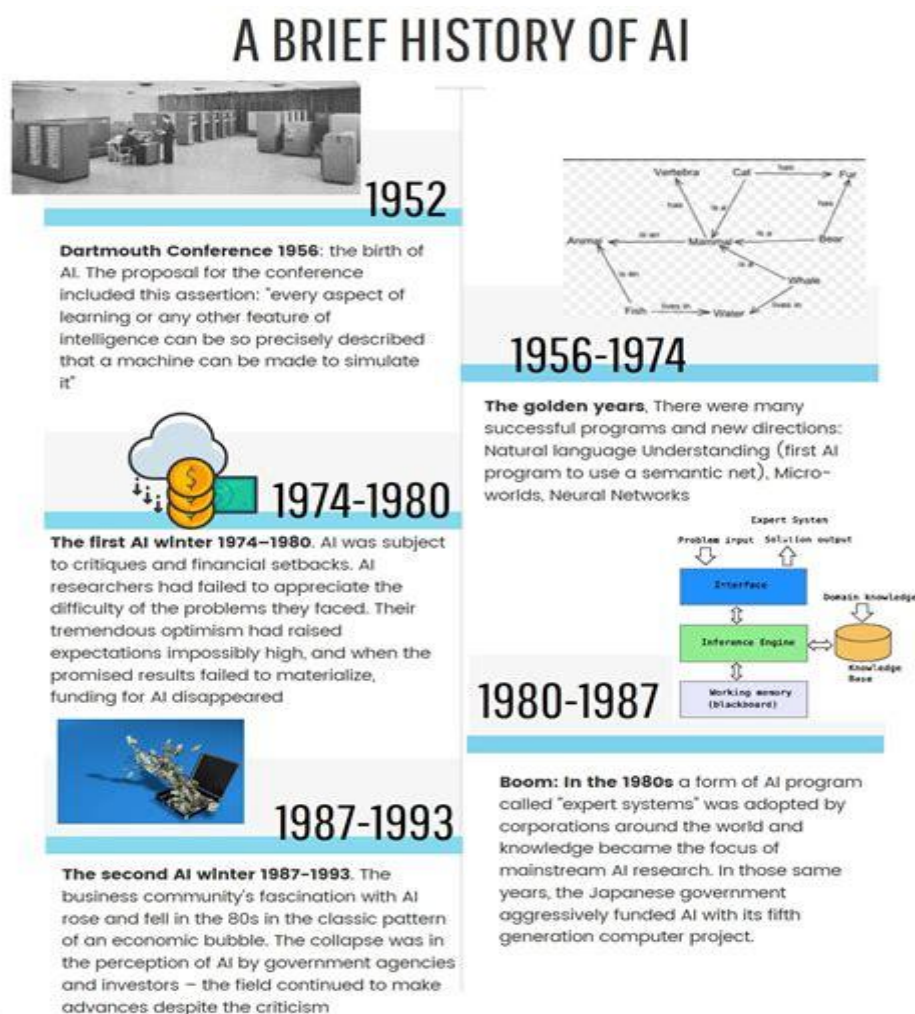


Figure 2. 2: A Brief History of Ai AR and VR

Source:vogue.com

The picture you included as Figure 1.1 in your research on "A Brief History of AI, AR, and VR - Vogue" likely represents a timeline or infographic detailing the key milestones and evolution of Artificial Intelligence (AI), Augmented Reality (AR), and Virtual Reality (VR).

Such a figure typically chronicles major developments in these fields, starting from foundational concepts and inventions to more recent technological advancements and applications.

For example, in the history of VR and AR, milestones include early inventions like Morton Heilig's Tele sphere Mask (the first head-mounted display in 1960), Ivan Sutherland's 1968 Sword of Damocles VR headset, Myron Krueger's 1970s artificial reality environments, and the coining of terms such as "virtual reality" by Jaron Lanier in the 1980s. The progression continues through the 1990s and 2000s with commercial VR systems, the introduction of augmented reality in 1990 by Tom Caudell, and breakthrough consumer devices like Google Glass and PlayStation VR, plus major software innovations and gaming applications like Pokémon Go in 2016.

Regarding AI, seminal papers such as Alan Turing's 1950 work and the development of AI as a concept likely appear early. The figure may also reference AI's role in driving the Fourth Industrial Revolution and its integration with AR and VR technologies. This combined timeline or graphic serves to visually and succinctly convey the intertwined development of AI, AR, and VR technologies, highlighting influential inventions, terminology origins, institutional milestones, and commercial breakthroughs that collectively map out their historical trajectories.

The history of artificial intelligence (AI) begins in antiquity, with myths, legends, and rumours of artificial entities endowed with intelligence or consciousness by master artisans. Philosophers who attempted to characterise the process of human thought as the mechanical manipulation of symbols laid the groundwork for modern artificial intelligence. This research resulted in the construction of the programmable digital computer in the 1940s, a machine based on the abstract basis of mathematical logic. This technology and the theories underlying it spurred a small group of scientists to seriously consider the potential of creating an electronic brain (Binder, 2024). The evolution of Artificial Intelligence (AI) has profound implications for education, transforming how teaching and learning occur. The historical trajectory of AI, from its theoretical underpinnings to practical applications, highlights its potential to enhance educational outcomes while also presenting challenges that need to be addressed.

AI's roots can be traced back to ancient myths, but its formal study began in the mid-20th century, notably with Alan Turing's introduction of the Turing Test in 1950. This test established a framework for evaluating machine intelligence. The 1956 Dartmouth Conference,

which marked the official birth of AI as a field, aimed to explore the simulation of human intelligence by machines (Jiang, 2024). These foundational concepts laid the groundwork for subsequent developments in AI, particularly in the realm of symbolic AI during the 1960s and 1970s, where early programs like ELIZA showcased natural language processing capabilities. However, the limitations of symbolic AI led to a decline in interest, known as the "AI winter." The resurgence of AI in the late 1980s and 1990s was driven by advancements in machine learning, particularly neural networks, which enabled systems to learn from data rather than relying solely on predefined rules. This shift has revolutionised fields such as image recognition and natural language processing, leading to significant milestones like IBM's Watson winning "Jeopardy!" and Google's Alpha Go defeating a Go champion.

2.2.3 Introduction of Artificial Intelligence in Education

Artificial Intelligence in Education (AIED), founded in the 1970s, focuses on researching, developing, and evaluating computer software to improve teaching and learning. AIED is connected to the long-term goal of obtaining feedback from students, assessing strengths and weaknesses, and personalizing education to an individual or group of learners. Furthermore, AI is likely to be utilised to investigate teaching and learning ideas (Arroyo, Royer, & Woolf, 2015; García-Martínez & Fernández-Batanero, 2023). While AI prioritises machine learning and human-like intelligence, education focuses on developing learning capacity and human intellect. AIED abilities contribute to closing this gap by giving strategies for more efficient and intelligent interactions with people, which improves educational outcomes. Researching and implementing existing AI-based solutions has improved the teaching and learning experience (Booi & Ntlabathi, 2026).

The integration of AI into education offers numerous opportunities for enhancing learning experiences. AI can personalise education by adapting content to individual students' needs, thereby improving engagement and understanding. For instance, intelligent tutoring systems can provide tailored feedback, while AI-driven analytics can help educators identify students who may be struggling and require additional support. Moreover, AI technologies can facilitate inclusive education by providing resources for marginalised groups. Tools such as telepresence robots enable students with disabilities to participate in classes remotely, ensuring continued access to education during crises. This aligns with Sustainable Development Goal 4, which emphasises inclusive and equitable quality education for all.

Looking to the future, the trends and innovations emerging from AI in education are both exciting and complex. Selwyn's 2021 paper, "The Future of AI in Education: Trends and

Predictions," provides insights into the long-term possibilities and potential impacts of AI technologies on the educational landscape. Holmes and Bialik's 2019 review of emerging AI technologies discusses the opportunities and challenges these innovations bring, highlighting the need for ongoing research and adaptation as AI continues to evolve (Almufarreh & Arshad, 2023).

Artificial Intelligence (AI) is reshaping education in transformative ways. One of its most significant impacts is on personalised learning. AI technologies can analyse students' performance and learning styles to tailor educational experiences, offering customised resources and feedback that address individual needs and enhance learning outcomes (Kaisara, Yakobi, & Atiku, 2026). This adaptability helps accommodate diverse learning paces and preferences, making education more effective and engaging.

2.2.4 Opportunities of Artificial Intelligence in Education

The use of AI in education has advanced significantly during the past 25 years (Roll & Wylie, 2016). Since the growth of computing and information processing tools, AI has been extensively applied in education. AI in education opens up new possibilities, difficulties, and opportunities for educational methods (Ouyang & Jiao, 2021). The goal of AI in education is to significantly improve educational methods through field tests and the creation of modular standard prototypes for statistical reasoning, data visualisation, and learning analytics (Alam, 2021)

One of the most important uses of AI in education is to provide each student with personalised learning support or help depending on their learning status, preferences, or other personal characteristics (Hwang, 2014;2023; Hwang et al.)AI in education also seeks to leverage AI to assist the teaching process, which is critical and where instructors' acceptance of AI is critical (e.g., by using educational data mining to predict student performance and by understanding and facilitating computer-supported collaborative learning through discourse analysis).But because AI is still a relatively new concept to instructors, they typically struggle to react appropriately and swiftly to the insights provided by AI-enabled apps. They are therefore less receptive to AI and less willing to adopt it. As a result, it is imperative that increase teachers' adoption of AI systems (Chen & Hwang, 2022).

AI is very powerful and can affect and significantly change various sectors of society, with the education sector being one of the most likely to be significantly affected by AI. Indeed, from

the many publications analysed, AI has been adopted and used in the education sector, where it contributed to improvements in different sectors (Chen, Chen, & Lin, 2020). In the future, AI will profoundly influence various aspects of life, including education, due to its pivotal role in teaching and learning. However, the current educational system has shortcomings, and research in blended learning and AI in education is fragmented. The true impact of AI on education remains uncertain, requiring further investigation (Holmes et al, 2021). Limited familiarity with AI technologies poses a challenge to their integration into educational settings (Alzubi, Nayyar, & Kumar, 2018), More review studies are needed to organise the literature, identify opportunities, and address challenges in AIEd. Unlike the past, the future of AI in education promises greater adaptability and scalability, with innovations like AI mentors aiming to overcome the limitations of traditional teaching methods (Strickroth et al 2013).

According to the 2018 Horizon research, experts predicted a 43% increase in the usage of AI in education between 2018 and 2022. Over the past three decades, there has been ongoing study into the use of AI in education. Researchers like McArthur, Lewis, and Bishary (2005) foresee a future where AI enables the customization of educational software for each learner. Currently, user-friendly games and software for adaptive learning are available. AI in education aims to make studying more convenient while safeguarding personal information. The integration of smart sensors and fitness trackers enriches learning experiences by combining online practices with real-time data sources (Owusu, Asitanga, & Aduku, 2026).

Figure 2.3 illustrates the various roles that Artificial Intelligence plays in education, highlighting key functions such as intelligent tutoring systems, automated grading, curriculum planning, edutainment and gamification, and administrative support. The figure demonstrates how AI supports both teaching and learning processes by enhancing personalisation, improving efficiency, and reducing the administrative workload of educators. Furthermore, it shows that AI contributes to creating more engaging and interactive learning environments while also streamlining institutional operations. Overall, Figure 2.3 provides a visual summary of how AI technologies are integrated into different aspects of education to improve learning outcomes and educational effectiveness.

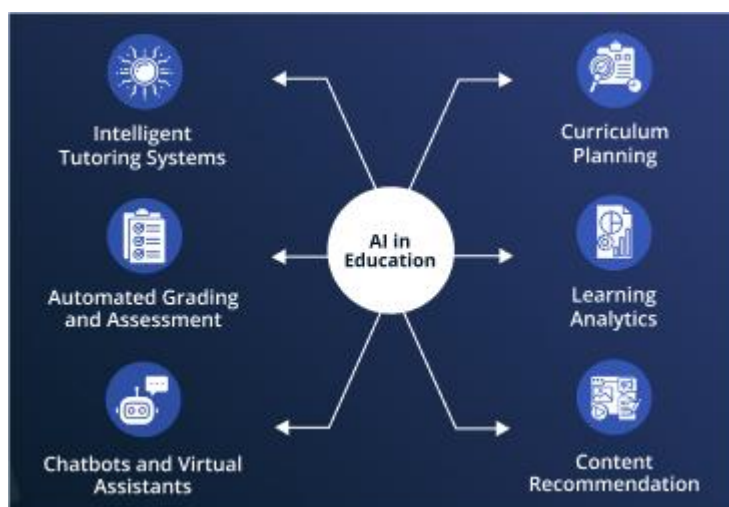


Figure 2. 3: Role of Artificial Intelligence in education
 Source: LeewayHertz

‘Figure 2.3’ highlights the roles that Artificial Intelligence play in education, AI has numerous uses in education, redefining the way students learn, teachers instruct, and educational institutions operate. Some popular AI uses in education include the ones on figure 2.3 above and explained in detail below.

Intelligent Tutoring Systems

AI-powered tutoring systems provide personalised, real-time feedback to students by analysing their responses as they engage with learning materials. These systems identify areas of difficulty and tailor explanations to enhance comprehension, allowing for an individualised learning pace (Lin & Huang, 2023). This approach not only helps bridge gaps in understanding but also empowers students to grasp complex concepts more effectively. Continuous interaction with AI fosters a dynamic learning environment that boosts student confidence and overall academic performance.

Automated Grading and Assessment

AI streamlines the grading process by analysing student work and delivering swift, consistent evaluations. This automation reduces the burden on educators, enabling them to focus on personalised guidance. By identifying patterns in student performance, AI helps educators pinpoint struggling students and pay more attention to them. The efficiency of AI ensures prompt feedback, enhancing the learning cycle and promoting equitable assessment, which ultimately cultivates effective collaboration between students and teachers (Lin & Huang, 2023).

Curriculum planning

AI assists in curriculum planning by analysing educational data to identify trends and gaps in learning outcomes. It can suggest updates and adjustments to curricula based on real-time insights and evolving educational standards. Additionally, AI can automate aligning curricula with specific learning objectives, ensuring that educational content remains relevant and up to date. This streamlining of curriculum planning allows educators to make data-driven decisions and allocate resources more effectively, ultimately improving the quality and relevance of education (Deshen, Harari, & Aharony, 2026).

Edutainment and gamification, and Administrative Support through AI

Edutainment and gamification are innovative educational approaches that leverage artificial intelligence (AI) to create interactive learning experiences, transforming traditional learning into an engaging and enjoyable process. By infusing game elements such as rewards and competition into educational content, these methods enhance student engagement and motivation, leading to improved retention and understanding of complex concepts. AI-driven edutainment and gamification tools captivate students' attention through immersive gameplay and interactive challenges, fostering an environment where learners actively participate in their learning journey (Cascella et al, 2023). These approaches align with contemporary educational trends that recognise the importance of making learning both informative and entertaining.

AI plays a crucial role in streamlining administrative tasks within educational institutions, automating processes like scheduling, resource allocation, and student enrolment. The integration of chatbots and virtual assistants helps manage routine inquiries, allowing lecturers to focus on more strategic and creative aspects of their responsibilities. By automating these administrative functions, AI contributes to a more efficient and responsive educational environment, ultimately improving the overall effectiveness of educational institutions. The combination of edutainment, gamification, and AI-driven administrative support represents a transformative shift in the educational landscape, paving the way for a more engaging, personalised, and effective learning experience for students (Ezinwa et al., 2024).

The use of AI in education presents a chance to overcome the physical constraints provided by national and international borders. Utilising other features of AI, such as language translation tools, enables students to study best within the context of their unique talents (Steele, 2026). Learning online or using web-based learning platforms makes the content accessible from anywhere in the globe. Artificial intelligence has invaded several aspects of the education sector or departments inside educational institutions. Artificial intelligence in education has had a significant impact, including increased efficiency, global learning, customised/personalised learning, better content, and increased effectiveness and efficiency in education administration, among other things. Artificial intelligence is still evolving, and new applications in education are emerging (Holmes & Ronghuai, 2021).

The widespread adoption of AI in education presents both opportunities and challenges. Key challenges include equity and accessibility issues, data privacy and security concerns, potential loss of human connection, algorithmic bias, and the digital divide. To mitigate these challenges,

policymakers and educators can implement strategies such as ensuring equitable access to AI tools, establishing robust data privacy protocols, emphasising the complementary role of AI and human educators, addressing algorithmic bias through transparency and accountability, and bridging the digital divide through infrastructure investments and alternative learning methods. By proactively addressing these challenges, stakeholders can maximise the benefits of AI in education while upholding ethical standards and promoting inclusivity.

2.2.6 Challenges Presented by Artificial Intelligence in Science Education

Figure 2.4 presents the key challenges associated with the integration of Artificial Intelligence in science education. While AI offers significant opportunities to enhance teaching and learning, its implementation is accompanied by several ethical, technical, and pedagogical concerns that may limit its effectiveness. The figure highlights these challenges, providing a visual overview of the barriers that need to be addressed to ensure the responsible and equitable use of AI in educational contexts.

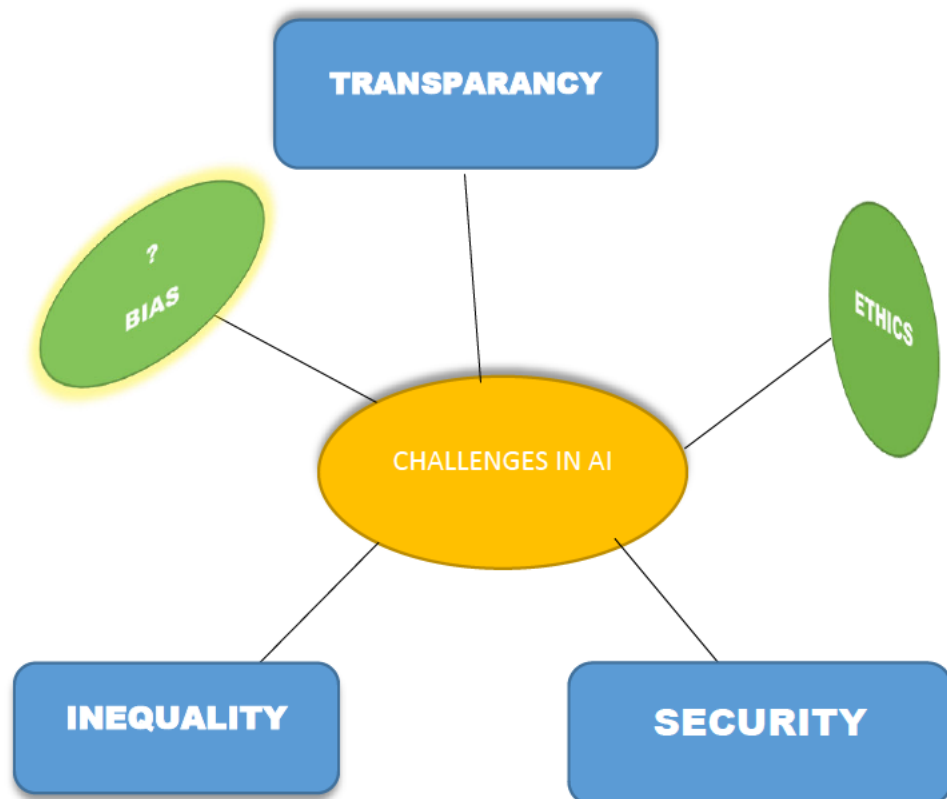


Figure 2. 4: Key challenges of Artificial Intelligence in Education

Source: created by the author for this research purpose

Figure 2.4 highlights the key challenges associated with the integration of Artificial Intelligence (AI) in education, succinctly capturing the multifaceted obstacles that educators, students, and institutions face. Central to these challenges are ethical concerns, including data privacy and the responsible use of sensitive student information, as AI systems often lack transparency in how they process and utilise data. Algorithmic bias is another significant issue, where AI models can perpetuate existing inequalities by producing unfair outcomes for marginalised groups. Additionally, access and infrastructure limitations, such as unreliable internet, lack of digital devices, and insufficient institutional support, create a digital divide that hinders equitable AI adoption, particularly in under-resourced educational environments.

Beyond technical and ethical issues, Figure 2.4 also emphasises practical challenges like academic dishonesty, where easy access to AI-generated content may encourage plagiarism and reduce genuine learning engagement. Over-reliance on AI tools risks diminishing students' critical thinking and independent problem-solving skills, altering traditional teacher-student dynamics. Figure 2.4 also highlights the need for enhanced teacher training and digital literacy to ensure effective and responsible AI use in classrooms. Finally, social implications such as reduced face-to-face collaboration, cultural relevance, and inclusivity challenges underscore the importance of balancing AI integration with human interaction and context-sensitive approaches to foster meaningful and equitable learning experiences.

Artificial intelligence (AI) can improve every aspect of the African social structure. However, there are certain concerns about the adoption and usage of AI applications in African society. These concerns include policy from the government, the lack of adequate infrastructure and network connectivity, ethics, programming, data integration, user attitude, and skill acquisition. While AI can open numerous opportunities, as described in this paper, it can also be a disruptive technology, deepening existing inequities and divides as the disadvantaged and underprivileged population is more likely to be excluded from AI-powered education. As a result, a new kind of digital divide has emerged: a divide in the application of databased information to inform intelligent decision making (Thomas, Chiu, Zhou, Chai, & Cheng, 2023).

A study by The Centre for Academic Integrity found that almost 80% of college students admit to cheating at least once. Now, it has become inevitable for academicians to look for ways through which the negative effects of AI can be minimised so that maximum benefits can be achieved. This can only be possible when awareness increases and the issues and challenges are studied deeper (Celik & Dindar, 2022; Muhammad, Saba, & Syeda, 2024) The fundamental

issues in general education are faced by Artificial Intelligence in Education (AIEd), such as how to meet learners' requirements and how to provide learners with the ability to take responsibility for their own learning. Although Artificial Intelligence in Education incorporates cutting-edge computing and information-processing techniques into education, it does not ensure positive educational outcomes or a high level of learning quality (Castaneda & Selwyn, 2018).

Different research teams have carried out a few systematic reviews to highlight the issue with AIEd, namely the disconnect between AI methods and theoretical foundations, which has a significant impact on the outcomes of AI implementations in education (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019), for instance, found that there was a lack of critical thought on the theoretical, pedagogical, and ethical issues associated with the introduction of AI applications in higher education after analysing 146 pieces of research on the subject.

The integration of artificial intelligence (AI) in education for sustainable development in South Africa faces several key challenges that must be addressed, including a lack of adequate infrastructure and resources to effectively implement AI technologies, which can exacerbate existing inequalities in educational access and quality (Akgun & Greenhow, 2022). Algorithmic bias in AI systems that can perpetuate unfair educational outcomes, particularly for marginalised groups, undermining the goal of inclusive education.

Absence of comprehensive national policies to guide the use of AI in educational settings, leading to inconsistent practices and ethical dilemmas; insufficient teacher training and support to utilise AI tools effectively, resulting in underutilization of these technologies; disparities in access to AI-enhanced educational resources, which can widen the educational gap between different socio-economic groups, contradicting the principles of sustainable development; and the need for cultural and contextual adaptations of AI applications to ensure they are relevant and appropriate for the diverse educational needs of South African learners. Addressing these challenges is crucial to harness the potential of AI in transforming education and contributing to sustainable development goals in South Africa, requiring collaboration among policymakers, educators, and stakeholders to create an inclusive, equitable, and effective educational environment that leverages AI's capabilities while mitigating its risks (Stahl & Wright, 2020).

2.2 Artificial Intelligence Applications widely used by students.

Table 2.2 provides a concise overview of commonly used Artificial Intelligence (AI) applications by students and their main functions. It highlights how tools such as ChatGPT, QuillBot, Grammarly, Google Translate, and WOMBO Dream support academic tasks like writing, paraphrasing, grammar correction, translation, and creative content generation. Overall, the table shows how AI enhances students' productivity, learning efficiency, and creativity in their academic work.

AI Application	Main Function	How Students Use It
ChatGPT (Open AI)	Natural language processing & text generation	Writing assistance, summarizing, research support, idea generation, grammar/stylistic corrections
QuillBot	Paraphrasing & writing enhancement	Rephrasing sentences, improving clarity, summarizing, synonym suggestions, quick writing help
Grammarly	Grammar & style correction	Correcting grammar, spelling, and improving academic writing
Google Translate	Translation & multilingual support	Translating terms, understanding texts in different languages
WOMBO Dream	AI art generation (creative tool)	Visualizing abstract concepts, creating educational illustrations, enhancing creativity in projects

Table 2. 2: A concise overview of the Artificial Intelligence (AI) applications most widely used by students

Table 2.2 highlights the most widely used Artificial Intelligence applications among students, showing how they support both academic and creative learning. Tools like ChatGPT and QuillBot are primarily used for writing assistance, paraphrasing, and idea generation, helping students improve clarity and save time. Grammarly ensures academic work is polished by correcting grammar and style, while Google Translate bridges language barriers, making texts accessible across different languages. On the creative side, WOMBO Dream allows students to generate visuals that simplify abstract concepts and enhance projects. Collectively, these tools demonstrate how AI is being integrated into students' daily academic practices to improve productivity, creativity, and learning outcomes (Akanda & Talukder, 2026).

Chat Generative Pre-Trained Transformer

ChatGPT, known as Chat Generative Pre-Trained Transformer, is an AI-driven natural language processing tool developed by Open AI. It employs regression language modelling techniques to accurately predict subsequent words in a sentence, drawing from its access to vast amounts of data and billions of parameters (Taecharungroj, 2024). This tool enables the automatic generation of text based on user input, aiming to comprehend natural language and

provide meaningful responses to user queries. However, it's important to note that while ChatGPT has been trained on extensive data, its models are only familiar with information up to the year 2021, potentially limiting their awareness of events occurring after that time (Fitria, 2024).

According to (Mlambo, 2024) ChatGPT is hailed as a cutting-edge innovation with the potential to greatly benefit higher education. It is described as the largest language model capable of generating responses within seconds based on user prompts (Strzelecki, 2023; Mlambo, 2024). ChatGPT serves as a valuable tool for enhancing writing skills in higher education, as it can generate text, summarise data, and create outlines, thereby saving time and improving work quality. Moreover, it can identify grammatical and stylistic errors, enhancing the clarity and comprehension of written content (Al-Emran & Ghobakhloo, 2025). Additionally, ChatGPT aids students in developing research skills by providing information, suggesting new research avenues, and facilitating a deeper understanding and evaluation of topics (Kasneci et al, 2023).

Khalil (2023) investigated the effectiveness of plagiarism detection techniques in identifying essays generated with ChatGPT. Their findings revealed that 40 out of 50 assessed essays had a similarity score of 20% or lower, indicating a high level of originality. In a separate study, Susnjak (2022) conducted an experiment to assess ChatGPT's ability to engage in critical thinking beyond mere knowledge retrieval. The results demonstrated a high degree of accuracy, logical coherence, and exactness in ChatGPT's responses. Conversely, Dowling & Lucey (2023) noted limitations in ChatGPT's capability, particularly in literature synthesis and developing suitable testing frameworks within the context of finance research. While ChatGPT offers advantages for idea generation and data identification, concerns remain about its application in educational settings, particularly regarding plagiarism and academic integrity in the creation of reports and essay.

WOMBO Dream Artificial Intelligence

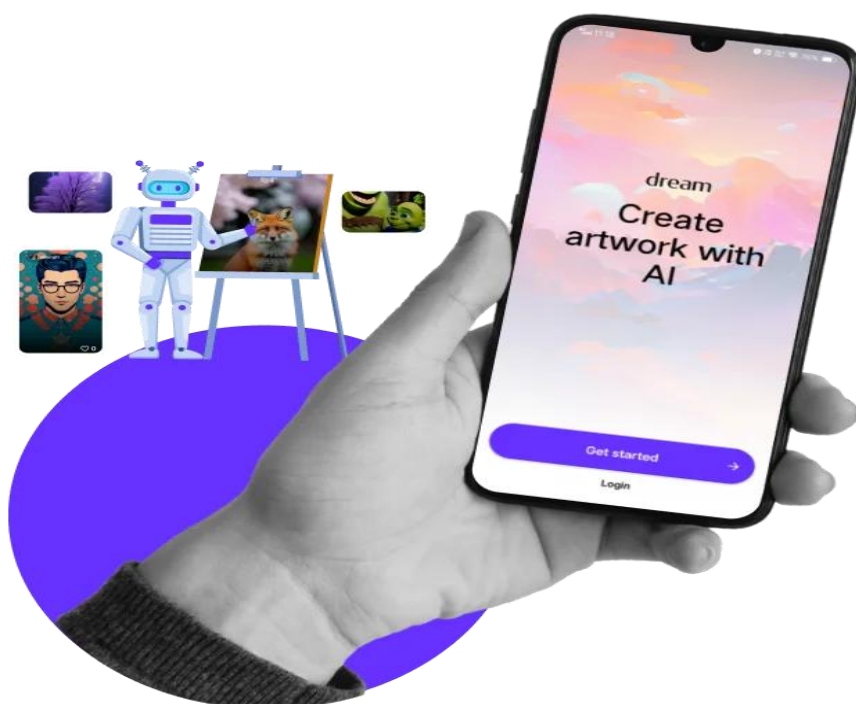


Figure 2. 5: Wombo Dream AI Art Generator

Source: [Concetto Labs](#)

Figure 2.5 shows a user interacting with the Wombo Dream AI Art Generator app on a smartphone, visually representing how artificial intelligence can be harnessed creatively in educational and everyday contexts. The image was included in your research to demonstrate a practical example of AI's expanding role beyond traditional learning tools, highlighting its potential to foster creativity and engagement through user-friendly AI applications.

This picture was used to illustrate the accessibility and innovative capabilities of modern AI technologies, where users can easily create unique artworks by providing simple text prompts. This aligns with the study's broader theme of AI's transformative impact, showing that AI not only supports personalised and adaptive learning in science education but also opens new avenues for creative expression and interactive experiences. By including figure 2.5, we emphasise the diversity of AI applications, reinforcing the importance of integrating AI meaningfully across educational disciplines to enhance student engagement and skill development.

According to (Fitria, 2024), WOMBO Dream is an AI-driven application designed to generate novel images by combining text and image guidelines provided by the user. This AI-powered art generator empowers users to craft personalised and distinctive artwork by employing a

blend of generative adversarial networks (GANs) and style transfer algorithms. Users simply need to provide a concise textual description of their desired creation, prompting the AI to generate a bespoke artwork that aligns with their vision. This serves as a prime example of how AI can enrich human creativity and expression. Moreover, WOMBO Dream holds potential as an educational tool, offering the capability to create visuals that elucidate complex scientific concepts or historical events. Such visuals could enhance student comprehension by presenting intricate ideas in a captivating and memorable manner. Furthermore, WOMBO Dream could facilitate the development of interactive learning activities, such as image-based quizzes or games, thereby fostering engaging and immersive learning experiences. Lastly, it could serve as a creative platform for children, empowering them to unleash their imagination and express themselves through the creation of unique and imaginative graphics (Yang, 2025).

QuillBot's Artificial Intelligence

According to Fitria (2022), Quillbot is described as an AI-driven writing tool aimed at aiding students in enhancing their writing proficiency. Utilising AI technology, Quillbot scrutinises text and offers suggestions for enhancements, including adjustments to grammar, clarity, and style. Additionally, it can summarise text and generate new content upon request. Quillbot's versatility extends to various writing tasks such as essay writing, composing emails, and crafting social media posts. Widely recognised as a free paraphrasing tool, Quillbot utilises AI to provide paraphrasing suggestions, as noted by (Dale, 2020). This tool automatically alters, adds, or removes words to produce entirely new sentences. By helping in paraphrasing tasks, Quillbot serves as a solution for learners facing time constraints, as highlighted by (Kasneci & Bannert, 2023). This application has been trusted to help students, writers, bloggers, teaching staff, etc.

Using QuillBot paraphrasing tools has various advantages, the first of which is that it saves time when writing. QuillBot's paraphrasing tool uses cutting-edge artificial intelligence to recreate a sentence, paragraph, or article. QuillBot can help users improve their writing quickly by deleting unnecessary words and supporting them in delivering a clear message. Second, QuillBot assists in discovering the appropriate synonyms. QuillBot includes a built-in thesaurus that allows users to easily change individual words to get the right term every time. Finally, it improves clarity and purpose. The writing styles in QuillBot allow users to write in their favourite style. They will immediately acquire the results they require, whether for

grammar, simplicity, or originality. Fourth, it has a large vocabulary. QuillBot's Word Flipper enables users to swiftly change more (or less) words (Basori, 2021).

In reviewing the literature on Artificial Intelligence (AI) in education, this study distinguishes between leading studies and supporting studies. Leading studies refer to research that directly examines the use of AI in educational contexts, particularly focusing on students' perceptions, opportunities, challenges, and ethical considerations associated with AI in teaching and learning. These studies are central to this research because they provide empirical evidence and theoretical insights that closely align with the focus of this study. Therefore, they are discussed in greater depth, including their research context, methodology, and key findings, to enable a clearer understanding of how AI is currently being integrated into educational environments.

Supporting studies, on the other hand, provide broader contextual information on the development and application of AI technologies in education globally. These studies discuss general AI tools such as intelligent tutoring systems, chatbots, and other AI-driven technologies that support learning processes. While they may not directly focus on students' perceptions, they contribute to understanding the wider landscape of AI in education and help contextualise the relevance of this study.

Furthermore, this literature review considers both international and South African studies to highlight similarities and differences in the adoption of AI in educational settings. International studies provide insight into global trends and advancements in AI-driven education, while South African studies help contextualise the discussion within the local higher education environment. By distinguishing between leading and supporting studies, this review provides a clearer framework for evaluating existing research and identifying the gap that the current study aims to address.

CHAPTER THREE

THEORETICAL FRAMEWORK

3.1 INTRODUCTION

The integration of Artificial Intelligence (AI) in science education presents both promising opportunities and significant challenges, as highlighted in the comprehensive literature review. While AI holds immense potential to personalise learning and enhance educational outcomes, gaps remain in understanding how these technologies align with established educational theories and how they can be effectively implemented in the South African higher education context. This study addresses this gap by grounding its investigation in two prominent educational frameworks: Social Constructivism and Machine Learning Theory.

Social Constructivism, as discussed in the literature, emphasises the active, collaborative construction of knowledge through social interaction and scaffolding within the learner's Zone of Proximal Development (ZPD). This theory aligns well with AI's ability to function as a learning scaffold, supporting personalised and contextualised learner engagement. Meanwhile, Machine Learning Theory offers insight into how AI systems adapt dynamically to individual learners' needs by analysing data to provide tailored feedback and resources, thereby enhancing personalised learning experiences.

By explicitly linking these theoretical perspectives to the mixed-methods research approach employed, this framework guides both the interpretation of student experiences and the evaluation of AI's pedagogical impact in science education. The social constructivist lens supports the qualitative exploration of learners' social interactions and cognitive development, while machine learning theory informs the quantitative analysis of adaptive AI tools fostering personalised learning. Together, these theories provide a comprehensive foundation for investigating how AI can be ethically and effectively integrated to transform science education, addressing the study's aims to explore AI's opportunities, challenges, and ethical-social implications within a resource-constrained higher education setting.

Social Constructivism, rooted in the work of Lev Vygotsky, posits that knowledge is constructed through social interactions and collaborative efforts. This theory emphasises the importance of active engagement, where learners create and analyse their own understanding based on prior knowledge, personal perspectives, and cultural contexts. Central to this approach

is the concept of the Zone of Proximal Development (ZPD), which highlights the role of guidance from more knowledgeable others in helping learners achieve tasks beyond their current capabilities. In this context, AI tools such as ChatGPT serve as scaffolds within the ZPD, providing personalised support that gradually diminishes as students develop their skills. This interaction not only fosters critical thinking but also empowers students to take ownership of their learning journey (Nayak & Nayak, 2026).

On the other hand, Machine Learning Theory focuses on the ability of AI systems to learn from data and adapt to individual needs. This approach utilises algorithms to analyse student interactions with educational resources, thereby delivering personalised feedback and instruction tailored to each learner's strengths and weaknesses. As a subset of artificial intelligence, machine learning enhances educational environments by facilitating ongoing, iterative learning experiences that respond dynamically to student progress. This adaptability not only promotes engagement but also helps educators gain insights into student comprehension and instructional effectiveness.

Together, these frameworks underscore the potential of AI to promote personalised, interactive, and adaptive learning experiences in science education. By integrating social constructivist principles with machine learning capabilities, educators can create enriched learning environments that support collaborative knowledge construction while addressing individual learner needs. This theoretical foundation sets the stage for exploring how AI technologies can be effectively implemented to enhance educational outcomes and prepare students for success in an increasingly complex world.

3.2 SOCIAL CONSTRUCTIVISM

According to social constructivism, a theory of learning, knowledge is most effectively acquired through active engagement in creating and analysing one's own understanding (Mascolo & Fischer, 2005; Umar, 2023). Social constructivism informs both the design of the research instruments and the interpretation of the data in this study. The theory emphasises that knowledge is constructed through interaction, collaboration, and guided learning. In the context of this research, AI tools such as ChatGPT are conceptualised as digital scaffolds that support learners within their Zone of Proximal Development (ZPD) (Rachel, 2024).

Vygotsky's social constructivism emphasises the role of social interaction in learning processes, utilising concepts such as the Zone of Proximal Development (ZPD), inter-subjectivity, and enculturation. The ZPD delineates the gap between a learner's current level of

development and their potential level with guidance (Permatasari & Nurdin, 2024). AI tools can act as scaffolds within the ZPD, offering support that diminishes as students' competence increases. For instance, ChatGPT aids students in formulating questions, gradually reducing assistance as their skills develop, ultimately empowering them to generate complex queries independently (Rachel, 2024). Figure 1 illustrates Vygotsky's concept of the ZPD and the role of technology in scaffolding learning experiences.

During the data analysis phase, responses will be coded using themes derived from social constructivist principles. These included learner interaction with AI, scaffolding and academic support, collaborative learning processes, and the development of independent learning skills. This approach will allow the researcher to analyse whether AI functions as a learning partner that facilitates knowledge construction.

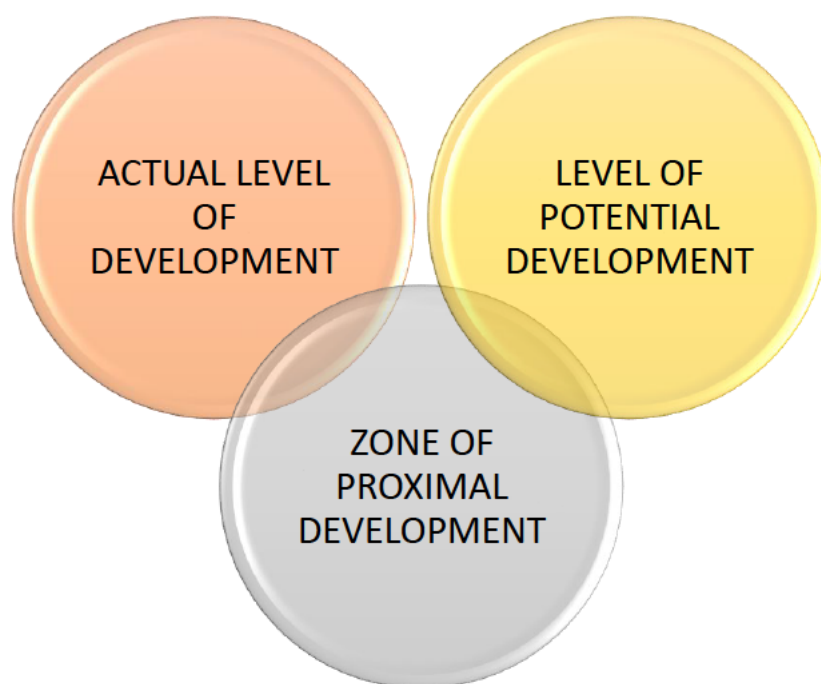


Figure 3. 1: Model of Vygotsky's zone of proximal Development

Source: created by the author for this research purpose

Figure 3.1 illustrate what Vygotsky stated that learners should be taught in the Zone of Proximal Development. A good teacher identifies a learner's ZPD and helps them stretch beyond it. Then the teacher gradually withdraws support until the learner can perform the task unaided. Scaffolding is the temporary support that a teacher gives a learner to do a task. The idea of figure 3.1 is to outline that student could use technology tools (AI systems) as "learning partners" to help them explore and make sense of new information.

Social constructivism highlights the significance of social interaction and context in learning. AI systems, such as chatbots or virtual assistants, can facilitate collaboration and adapt to individual learner needs. By providing personalised feedback and interactive learning experiences, AI supports active engagement and the construction of meaning in education.

3.3 MACHINE LEARNING THEORY

Learning as a generic process is about acquiring new, or modifying existing, behaviours, values, knowledge, skills, or preferences. Personal learning theories, including behaviourism, cognitivism, constructivism, experientialism, and social learning, describe how humans learn. Machines rely on data, while humans learn via experience. Machine learning (ML) is a type of artificial intelligence that allows computers to learn independently. The goal is to improve computer actions to achieve greater accuracy. Accuracy is assessed by the number of correct results (Jafar Alzubi et al , 2018; Binder, 2024)). Machine learning focuses on knowledge discovery, which involves interpreting "training data" to generate meaningful patterns and organised information. Machine learning can provide recommendations for students when selecting classes and universities. The system uses student achievements, aspirations, and preferences to match them with optimal institutions for their development. Additionally, this technology can provide educators with insights into student comprehension of concepts (Chen, Chen, & Lin, 2020). Machine learning, a subset of artificial intelligence, enables computers to learn from data and experiences without being explicitly programmed (Jaswanth, Geethashree, & Nagaraja, 2026).

Machine learning

Figure 3.2 illustrates the concept of Machine Learning, showing how Artificial Intelligence systems learn from data to improve their performance over time. The figure demonstrates the process through which data is input into an algorithm, which then analyses patterns and generates outputs or predictions. It highlights the adaptive nature of machine learning, where systems continuously refine their responses based on new data. Overall, Figure 3.2 provides a visual representation of how machine learning underpins AI applications, particularly in enabling personalised and data-driven learning in educational contexts.



Figure 3. 2: Machine Learning Source Manish Barthwal

Figure 3.2 above shows the different roles of machine learning

This pedagogical approach utilises algorithms to create adaptable learning environments that respond to individual learners' needs and progress. By analysing students' interactions with educational resources, AI systems can deliver personalised feedback and instruction, foster engagement and enhancing learning outcomes (VanLehn, 2011; Vemuri & Naveen, 2024). Machine learning pedagogy aims to provide ongoing, iterative learning experiences tailored to each student's unique strengths and weaknesses (Sanusi & Tukiainen, 2023), thus contributing to the advancement of education in South Africa This revised version aims to maintain the clarity and comprehensiveness of the theoretical framework while enhancing conciseness and coherence. It consolidates redundant explanations, provides a more streamlined discussion.

A very significant application of machine learning in personalised learning is through intelligent tutoring systems. These systems utilise data from student interactions to provide tailored feedback and resources. For instance, if a student struggles with a specific concept, the system can offer additional practice problems or alternative explanations suited to their learning style. This adaptive approach not only helps students grasp difficult material but also fosters a sense of autonomy in their learning journey. As noted in the article, the integration of such technologies can transform traditional educational methods into more dynamic and responsive learning environments, particularly in South Africa's higher education landscape, where equitable access to quality education remains a challenge (Kurilovas, 2019).

According to Sanusi and Tukiainen (2023), the aim of machine learning pedagogy is to deliver a personalised learning experience tailored to each student's unique needs and abilities, ultimately enhancing their understanding and engagement with the subject matter. This pedagogy is characterised by its iterative nature, continually adapting feedback and instruction based on students' interactions with the system. This dynamic approach enables students to progress at their own pace. Additionally, machine learning pedagogy provides valuable insights into students' learning processes, aiding teachers in their instructional strategies. It's important to note that AI, as defined by Russell (2010), encompasses the simulation of human intelligence by machines, allowing them to perform tasks such as communication, memory, reasoning, and learning.

Social Constructivism emphasises the role of social interaction and collaboration in learning, suggesting that AI tools can act as scaffolds to support student development within the Zone of Proximal Development (ZPD). On the other hand, Machine Learning pedagogy utilises algorithms to deliver personalised learning experiences tailored to individual student needs, fostering engagement, and enhancing learning outcomes. Both theories underscore the potential of AI in education to promote personalised, interactive, and adaptive learning experiences aligned with student-centered approaches.

CHAPTER SUMMARY

Table 3.1 summarises the theoretical framework by comparing the two key theories guiding this study, namely Social Constructivism and Machine Learning Theory. It highlights their core principles, differences, and relevance to the use of Artificial Intelligence in education, demonstrating how each theory contributes to understanding personalised learning and student engagement.

Aspect	Social Constructivism	Machine Learning Theory
Focus	Learning as a social process where knowledge is built through interaction and collaboration	Learning through algorithms that adapt based on data and patterns
Key Concept	Zone of Proximal Development (ZPD) – learners progress with guidance and scaffolding	Data-driven adaptation – systems learn from student input to personalise feedback
Role of AI	Acts as a scaffold or learning partner, supporting learners until they gain independence	Functions as a personalised tutor, providing customised learning pathways
Nature of Learning	Human-centered, collaborative, and context-based	Technology-centered, automated, and adaptive
Contribution to Education	Enhances critical thinking, collaboration, and meaning-making	Provides personalised instruction, identifies weaknesses, and improves efficiency
Limitation	May undervalue the technological side of adaptation and automation	May neglect the importance of social interaction and human context in learning

Table 3. 1: Comparison of Theoretical Frameworks: Social Constructivism and Machine Learning Theory

Table 3.1 compares the two theoretical frameworks underpinning the study, Social Constructivism and Machine Learning Theory, by highlighting their distinct focuses and contributions. Social Constructivism emphasises learning as a social and interactive process, where knowledge is constructed through collaboration, guidance, and scaffolding within the Zone of Proximal Development. In this view, AI serves as a supportive tool that facilitates interaction and gradually reduces assistance as learners gain independence.

In contrast, Machine Learning Theory explains how AI systems function by analysing data patterns and adapting instruction to individual needs, offering personalised feedback and tailored learning pathways. While Social Constructivism stresses the human-centered, collaborative aspect of learning, Machine Learning Theory underscores the technological, data-driven adaptability of AI. Together, they provide a comprehensive foundation for

understanding how AI can simultaneously support social knowledge construction and personalise learning experiences.

CHAPTER FOUR

RESEARCH METHODS AND METHODOLOGY

4.1 INTRODUCTION

This chapter outlines the research methodology employed to investigate the opportunities, challenges, and ethical implications of integrating Artificial Intelligence (AI) into science education at the University of KwaZulu-Natal, Edgewood Campus. Despite growing interest in AI's role in education, there remains a research gap in understanding how AI impacts science students in the South African higher education context, particularly in terms of equitable access, personalised learning, and ethical considerations. This study aims to fill this gap by comprehensively exploring students' perceptions and experiences with AI technologies in science education, providing valuable insights to inform policy, curriculum design, and ethical guidelines.

Given the complex nature of the research questions, which involve both quantifiable trends and nuanced personal experiences, a mixed-methods approach was adopted. This approach integrates quantitative data collected via structured questionnaires to capture general patterns and attitudes, alongside qualitative data from in-depth interviews to gain rich, contextualised understanding of student views, concerns, and lived experiences. By combining these methods, the study ensures a holistic and credible analysis of how AI is shaping science education at the university, facilitating both breadth and depth in addressing the research objectives (Creswell & Clark, 2017).

The chapter outlines the research paradigm (interpretivism), the research design (explanatory sequential), and details the sampling procedures, data collection tools, and data analysis techniques used in both phases of the study. It also addresses important ethical considerations, ensuring the study adheres to the principles of integrity, confidentiality, and respect for participants. By combining statistical evidence with personal narratives, the methodology employed in this study aims to provide a nuanced and comprehensive exploration of how AI is shaping science education in a higher education context (Opoku & Ahmed, 2016).

4.2 RESEARCH PARADIGM

This study is guided by the pragmatic research paradigm, which provides the philosophical foundation for the use of mixed methods. Pragmatism focuses on research problems and allows the integration of qualitative and quantitative approaches to gain a comprehensive understanding of the phenomenon under investigation.

The study employs a mixed methods approach to explore both measurable patterns and students' experiences regarding the use of Artificial Intelligence in higher education. The quantitative component uses structured questionnaires to collect numerical data, which is analysed statistically to identify trends, patterns, and relationships among variables. The qualitative component uses semi-structured interviews to explore students' perceptions, experiences, and interpretations, reflecting the interpretivist principle that reality is socially constructed and multiple realities exist (Mohajan, 2018; Chatzichristos, 2025; Saunders & Lewis, 2009).

The integration of quantitative and qualitative data provides a more complete understanding of the research problem. While quantitative data allows for generalisation of patterns, qualitative data provides contextual depth and insight into participants' subjective experiences. The pragmatic paradigm enables this methodological pluralism, ensuring alignment between the research philosophy, design, and methods.

By combining qualitative and quantitative approaches, the study maintains methodological rigor and effectively investigates the opportunities and challenges associated with the use of Artificial Intelligence in higher education institutions (Creswell & Poth, 2016; Abdulrahman & Al-Zahrani, 2024).

4.3 RESEARCH DESIGN

The research design is described by Kumar (2018) as a proposed study plan, which has been thought through and can be communicated to others. It involves the methods used for collecting data from participants, selection of participants, data analysis and communication of the findings. Likewise, Augustyn (2014) defines a research design as a plan of how the research is going to be conducted, who or what is involved and where and when the study will take place. An explanatory sequential mixed methodology approach is used for this research study since the aim of the research is to gain a comprehensive understanding of the opportunities and challenges presented by Artificial intelligence on the science education students in the University of KwaZulu-Natal. According to Creswell (2013), the aim of this design is to study

a problem by exploring it first through qualitative data collection and analysis. Thereafter, the results are used to develop the instrument/s for an experiment, which is then followed by a third quantitative phase.

The study introduces the rationale for choosing a mixed-methods approach, particularly in the context of exploring how Artificial Intelligence (AI) is used and experienced in science education. The complexity of the research topic which involves both measurable trends and personal insights requires a design that can capture the breadth of quantitative data and the depth of qualitative feedback. The explanation sets the stage for why a sequential design is most appropriate: starting with broad-based data collection questionnaires to identify patterns, followed by interviews to explore and explain those patterns in greater detail.

Figure 4.1: An Explanatory Sequential Mixed Method visually presents this process. It shows how the research unfolds in two distinct but connected phases. First, quantitative data is collected and analysed, revealing key themes or areas of interest. Then, based on these results, qualitative interviews are conducted to gain deeper insights into students' experiences and perceptions. The figure 4.1 also demonstrates how the two datasets are connected where the findings from the quantitative phase directly inform the focus of the qualitative phase.

An Explanatory Sequential Mixed Method

Figure 4.1 illustrates the explanatory sequential mixed methods design adopted in this study. It shows how the research begins with the collection and analysis of quantitative data, followed by qualitative data to further explain and elaborate on the initial results. This approach enables a deeper understanding of the findings by combining numerical trends with detailed participant insights.

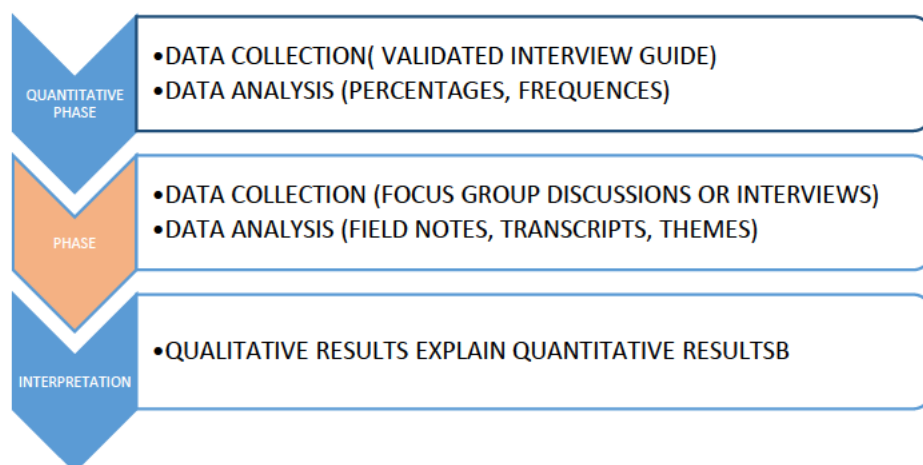


Figure 4. 1: An Explanatory Sequential Mixed Method

Source: created by the author for this research purpose

The discussion transitions into the specifics of implementation such as the sampling techniques, tools used for data collection (questionnaires and interviews), and methods of analysis (statistical analysis for quantitative data and thematic coding for qualitative responses). This continuation helps the reader understand how the research design was operationalised and how the sequential process strengthens the study's validity by ensuring both phases are meaningfully integrated (Gleason N. , 2018; Christiana & Olasumbo, 2024).

Research employing mixed methods seeks to gain a deeper understanding of a subject by integrating both quantitative and qualitative research methodologies (George, 2022; Padmaja, 2024). A mixed method approach is a research design that combines both quantitative and qualitative methods. Quantitative research involves the collection and analysis of numerical data using statistical methodologies. The goal is to generate objective, empirical data that can be measured and expressed in numerical form. Quantitative research is frequently used to test hypotheses, discover trends, and make predictions. In contrast, qualitative research captures non-numerical data like words, images, and sounds.

The emphasis is on investigating subjective experiences, opinions, and attitudes, frequently through observation and interviews. The goal of qualitative research is to generate rich and detailed descriptions of the phenomenon under study, as well as to discover new insights and interpretations. (Cohen, Manion, Morrison, & Creswell, Statistical power analysis for the behavioral sciences., 2018).

As a result, for this study, an explanatory sequential mixed method design was adopted. This method involves the researcher to conduct quantitative research first, analyse the results, and then build on the findings using qualitative research to explain them more thoroughly (Creswell J. W., 2014; Chatzichristos, 2025) . The explanatory sequential mixed method research design and the action research methodology adopted in this study were used to address the following research questions:

1. What are the opportunities and challenges of incorporating AI into science education?
2. How can AI applications be used to personalise and enhance science learning experiences?
3. What are the ethical and social implications of using AI in science education?

Questionnaires and interviews were used to collect data in this research, a list with questions was given to students at the University of KwaZulu-Natal Edgewood Campus to find out the challenges and opportunities that AI has presented on their education and find how it has improved their learning. Semi structured questionnaire was used as there were open-ended and closed-ended questions and the interview. The interviews took approximately 1 hour. Open-ended questions allowed students to respond as they like, they were not given specific categories or other answers to choose from.

An interview is a conversation between the researcher and the respondent. However, it is different from an everyday conversation in that the researcher is the person who sets the agenda and asks the questions. It is a structured and focused conversation where the researcher has in mind particular information that he or she wants from the respondent and has designed questions to be answered (Bertram & Christiansen, 2014; Junnier, 2024). In this research, to collect data structured interviews were used where the researcher used an interview schedule, which is a set of questions in a predetermined order. Most of the questions required open-ended responses where the students expressed their opinions or impressions or were asked to supply some information that will be essentially different from other students' answers.

The research was conducted in compliance with the university's ethical guidelines. This means that the participant was given informed consent forms, and their confidentiality and anonymity was maintained. The study is also be structured to reduce any possible risks or harm to the participants.

4.4 LOCATION AND POPULATION OF THE STUDY

This study is located in Durban, the University of KwaZulu-Natal at Edgewood Campus. The targeted population for this research is students who are doing third year and major in Natural Science and Technology Discipline at Edgewood Camps. The reason for choosing third year students at Edgewood Campus who are doing Natural Science and Technology is that third-year students in Natural Science and Technology are familiar with the use of Artificial Intelligence powered tools like the PHeT simulations, students in Natural Science and Technology disciplines often have experience with technology-related coursework and tools. This familiarity with technology can make them more receptive to learning about and engaging with AI applications in education. As future professionals in STEM fields, these students may directly encounter AI technologies in their careers (Lin, Yu, & Shih, 2021).

The convenience of selecting third-year Natural Science and Technology students at Edgewood Campus stems from several practical considerations. These students are readily accessible on campus, facilitating easier recruitment and data collection processes for the research. Given their advanced level of study, these students are likely to be more engaged and motivated participants. Their academic maturity allows for deeper discussions and insights regarding AI in education. The experiences of these students with technology and AI tools make them ideal candidates for providing valuable feedback on the effectiveness and applicability of AI applications in their educational journey. In summary, targeting third-year students at Edgewood Campus not only aligns with the research objectives but also enhances the feasibility and relevance of the study.

This research focuses on the University of KwaZulu-Natal (UKZN) Edgewood Campus due to several compelling reasons. The University of KwaZulu-Natal is known for its environmental education programs, aligning well with my research focus on the quality education with regards to the opportunities and challenges of Artificial Intelligence on students. Additionally, UKZN has a dedicated Centre for Artificial Intelligence Research, launched in partnership with the CSIR-Meraka Institute, which focuses on advancing AI research and its applications (Gleason N. , 2018).

The university also has a strong commitment to sustainability, as evidenced by the Sustainable and Resilient City Initiatives research group, which explores ways to make cities more sustainable. Furthermore, the university has ongoing projects related to environmental sustainability and community enhancement, which could provide valuable insights for this research (James, 2014; Christiana & Olasumbo, 2024). The use of students of Edgewood

Campus allowed the researcher to gather a wide range of perspectives on the challenges and opportunities presented by AI, enriching the research and providing a more comprehensive understanding of the topic.

4.5 DATA COLLECTION METHODS

This research is exploring and investigating the opportunities and challenges presented by Artificial Intelligence on Science Education students in the University of KwaZulu-Natal, the utilization of qualitative interviews and quantitative questionnaires as data collection methods provide a comprehensive approach to gather insights from students at the University of KwaZulu-Natal, Edgewood.

The decision to use a mixed methods approach specifically; an explanatory sequential design was driven by the nature of the research questions and the need to explore both the measurable and contextual aspects of AI integration in science education. Quantitative data, collected through structured questionnaires, enabled the researcher to identify general trends and student perceptions regarding the use of AI tools in learning environments. However, understanding students' attitudes, concerns, and personal experiences required a more nuanced approach that could not be captured through numerical data alone.

By following the quantitative phase with qualitative interviews, this mixed-methods approach allowed for triangulation validating and deepening the interpretation of findings. For instance, where the questionnaire indicated a certain percentage of students viewed AI positively, the interviews helped explain why they felt that way, and under what conditions. This combination of methods enriched the study by providing both a broad overview and detailed insight, ultimately enhancing the reliability and depth of the research. The explanatory sequential design also ensured that the qualitative phase was directly informed by the quantitative results, creating a coherent and logically structured research process.

To collect meaningful and reliable data, two primary instruments were developed: a questionnaire for the quantitative phase and an interview guide for the qualitative phase. The questionnaire was designed to capture students' awareness, usage, and perceptions of AI tools in science education. It included both closed-ended questions using a Likert scale (e.g., strongly agree to strongly disagree) and categorical response options (e.g., yes, no, unsure). The questionnaire covered topics such as the effectiveness of AI in learning, personalisation of learning experiences, ethical concerns, and access to AI tools. The structure allowed for

efficient data collection from a larger sample while maintaining clarity and consistency in responses.

The interview guide, on the other hand, consisted of open-ended questions that encouraged participants to elaborate on their personal experiences, opinions, and challenges related to using AI in science education. The guide was flexible, allowing the interviewer to probe further based on participants' responses. Questions focused on areas such as the role of AI in learning complex science concepts, concerns about data privacy and academic honesty, and the usefulness of AI in personalised study routines.

Both instruments were reviewed for content validity and clarity through pilot testing and consultation with academic supervisors, ensuring that the questions were aligned with the study objectives and accessible to participants.

Summary of Mixed Methods Approach and Instrument Design

Table 4.1 provides a summary of the mixed methods approach and the instruments used in this study. It outlines how both quantitative and qualitative data collection methods are integrated, specifying the tools (such as questionnaires and interviews), their purposes, and how they contribute to addressing the research questions.

Aspect	Description
Approach Used	Mixed Methods – <i>Explanatory Sequential Design</i>
Reason for Mixed Method	To capture both broad patterns (quantitative) and in-depth insights (qualitative) related to students' experiences with AI in science education.
Quantitative Phase	Structured questionnaire administered to a larger sample to identify trends and measure perceptions of AI use in learning.
Qualitative Phase	Interviews conducted with selected participants to explore personal views and explain patterns identified in the questionnaires.
Value of Mixing Methods	Enhances validity through triangulation; provides both statistical and narrative data to inform findings.
Questionnaire Design	Included Likert-scale and categorical questions covering awareness, effectiveness, ethical concerns, and personalisation of AI in education.
Interview Guide Design	Open-ended questions exploring deeper themes such as student engagement, ethical issues, AI as a learning scaffold, and personalised learning experiences.
Instrument Review	Tools were piloted and reviewed for clarity and alignment with research objectives; feedback was incorporated from academic supervisors.

Table 4. 1: Summary of Mixed Methods Approach and Instrument Design

This table provides a concise summary of the mixed-methods approach and the design of research instruments used in the study. It outlines the rationale for employing an explanatory sequential design, where quantitative data collection (via questionnaires) was followed by qualitative data collection (via interviews) to gain a comprehensive understanding of students'

experiences with AI in science education. The table also highlights how each instrument was purposefully designed questionnaires to identify broad trends and interviews to explore individual insights. Overall, the summary reflects a structured, well-justified methodological approach aimed at ensuring both depth and validity in the research findings.

4.5.1 Qualitative Data Collection Method

Qualitative interviews were conducted with seven students at University of KwaZulu-Natal on their experiences and views of using Artificial Intelligence towards academics. In the interviews I was finding out the knowledge students have on Artificial Intelligence, do they believe that the use of AI can improve the quality of Education in South Africa, what opportunities and challenges does AI presents them and the ethical issues associated with the use of AI. In engaging with the students, this improves the quality of my study by providing valuable guidance, feedback, resources, and collaborative opportunities, ultimately enhancing the rigor, relevance, and credibility of my research. The interviews were face-to-face and there were two students who were not available for face-to-face, and we had a zoom meeting. Each interview took approximately one hour. Interviewing students enabled me to get different perspectives/views on the use of Artificial Intelligence in Education.

4.5.2 Quantitative Data Collection Method

Questionnaires were used in this research to collect quantitative standardised responses from 39 students from Edgewood Campus who were involved in the study to gather structured data on their knowledge on Artificial Intelligence. Semi structured questionnaire was used as there were open-ended and closed-ended questions. I used semi-structured questionnaire with both open-ended and closed-ended questions in this research it offers flexibility, depth, and diversity in data collection. I used questionnaires as they allow for generalising findings and offer standardised data collection, efficiency in reaching many participants, anonymity for more honest responses (Young, 2016). I gave questionnaires to 39 students who are my participants. The questions were formulated to be clear, concise, specific, and directly aligned with the research objectives of the study. This approach aimed to enhance respondents' understanding of the questions and maintain a manageable length for the questionnaire.

The research instruments were pilot tested by administering two questionnaires to one master's student and one Ph.D. student. This process aimed to evaluate the effectiveness and clarity of the questions, ensuring that they adequately captured the intended information and elicited meaningful responses from participants. I had one interview with a master's student. There are

few questions that need to be rephrased for better understanding for participants, and few questions were added for the interview.

4.6 SAMPLING

Sampling involves deciding which people, settings, events, or behaviours to include in the study (Bertram & Christiansen, 2014). Researchers must determine how many people, organizations, or things (such as schools) will be observed. There are two types of sampling: random sampling (also known as probability sampling) and purposive sampling (sometimes known as non-probability sampling, though this term is also used in another context, which is why we avoided using it here). Both sample methods can be stratified. Random sampling means that every member of the population to be studied has an equal chance of being included in the sample (Sharma L. R., 2023). The very pragmatic convenience sampling method is a third sampling methodology, (Bertram & Christiansen, 2014; Palakshappa & Rischall, 2024).

In this research random sampling method was used, students from University of KwaZulu-Natal, Edgewood were interviewed to find out their views on the opportunities and challenges presented by Artificial Intelligence in South African Education. The participants of this research were third year students who major in Natural Science and Technology in the intermediate phase at Edgewood Campus. These students are familiar with the use of Artificial Intelligence powered tools. The students who were selected to participate in the study were randomly selected from the group of students who are doing Natural Science and Technology.

The recruitment of participants for the study on Artificial Intelligence in Science Education was conducted through a systematic approach utilising existing communication channels among students. Since the target participants are third-year students in Natural Science and Technology, a WhatsApp group dedicated to this cohort was leveraged. This group served as an effective platform for disseminating information quickly. A link to the study's participation form or an invitation to express interest in participating was shared in the group. This method encouraged immediate engagement and allowed students to respond at their convenience. An online form was created where students indicated their willingness to participate. This form collected basic information such as name, contact details. Once students' express interest, follow-up messages was sent to provide further details about the study, including what participation entails (interviews and questionnaires) and any ethical considerations. The sample size was carefully selected to ensure representation from various perspectives and experiences, thereby facilitating a comprehensive understanding of how the use of Artificial Intelligence affect the students in the University of KwaZulu-Natal in the Science discipline.

The synthesis of the theoretical framework and literature review contributed to the formulation of the questions for interview and questionnaire components (Creswell, 2014; Cohen, Manion, & Morrison, 2018). The question for a structured interview addresses the opportunities and challenges that Artificial Intelligence presented in Science Education in the University of KwaZulu-Natal. These structured interview questions were designed to comprehensively explore various aspects of the use of Artificial Intelligence (AI). They cover the role, opportunities, and challenges of AI in education, as well as the familiarity with AI-based educational platforms and the ethical considerations surrounding AI usage. By addressing these questions, interviewees provided insights into the current state and potential implications of AI in higher education, contributing to a deeper understanding of this rapidly evolving field.

The questions on the effect of Artificial Intelligence in science education, does the Artificial Intelligence improve the quality of education in South Africa and what are the advantages and disadvantages. These questionnaire questions were developed to explore students' perspectives on the use of Artificial Intelligence (AI) in education. They cover various aspects such as the definition and application of AI in education, the frequency of AI usage, its impact on learning experiences, and its potential to personalise curriculum and enhance collaboration (Kusmawan & Rahman, 2025). Additionally, the questions address whether AI aids in reducing time spent on routine tasks, its influence on critical thinking and creativity, and its role in promoting quality education. Lastly, the questionnaire probes whether students perceive AI usage as productive. These questions were constructed to gather comprehensive insights into students' experiences and perceptions regarding AI in education.

4.6.1 Sample size

In research, sample size refers to the number of people or items chosen as a sample. The sample size matters because it influences the accuracy and dependability of the results. Sample size determination is one of the key components of research methodology to draw inferences precisely about the population (Sharma & Suresh, 2024). In this research, students from University of KwaZulu-Natal, Edgewood Campus were interviewed to find out their views on the opportunities and challenges presented by Artificial Intelligence in Science. A total of 39 students completed the questionnaire and 7 students participated in semi-structured interviews. The questionnaire sample ($n = 39$) represents approximately 32% of the accessible population (122 third-year Natural Science and Technology students at the Edgewood Campus). The interview sample ($n = 7$) was chosen to achieve depth of insight via purposive sampling,

following common practice in mixed-methods studies where 5–10 interviews provide sufficient thematic saturation.

Sample Population for the study

Table 4.2 presents the sample population for the study, outlining the participants involved in the research. It provides details on the number of respondents, their characteristics, and how they were selected, thereby giving context to the data collected and ensuring the study's findings are appropriately understood.

Location	Pinetown- University of KwaZulu-Natal Edgewood Campus
Total population	122
Based on research	60%-70%
Sample size Questionnaire	39
Sample size interviews (30%)	7
Target participants Questionnaire	39

Table 4. 2: Sample Population for the study

4.6.2 Data Analysis

Data analysis (Phase one)

Quantitative data analysis comprises two primary stages. Initially, data preparation is conducted, followed by the actual analysis (Cohen, Manion, & Morrison, 2018; Creswell, 2014). The analysis follows the seven stages of the mixed data analysis process: data reduction, display, transformation, correlation, consolidation, and comparison from both qualitative and quantitative sources (Tashakkori, Johnson, & Teddlie, 2020; Tashakkori & Teddlie, 2003; Leech & Onwuegbusie, 2010). During data preparation, the information is cleaned, coded, and then inputted into statistical analysis software. This process involves identifying and rectifying omissions, errors, and ambiguities in the responses.

The data collected in this study were analysed using thematic analysis. Thematic analysis is a widely used qualitative method that involves identifying, analysing, and interpreting patterns or themes within the data (Braun & Clarke, 2006). This approach was selected because it allows

the researcher to systematically organise and interpret participants' responses in relation to the research objectives.

The data analysis process followed several stages.

Stage 1: Data familiarisation

The first step involved carefully reviewing all the collected data. The researcher read through the responses multiple times to gain a comprehensive understanding of the participants' perspectives. This stage allowed the researcher to become familiar with the data and identify initial patterns related to the use of AI tools in education.

Stage 2: Initial coding

During this stage, meaningful segments of the data were identified and labelled with codes. Coding involved assigning descriptive labels to specific responses that related to key aspects of the research questions. These codes represented ideas such as learners' experiences with AI tools, perceived benefits of AI in learning, challenges encountered when using AI technologies, and the role of AI in supporting academic tasks.

Stage 3: Development of categories

After the initial coding process, similar codes were grouped together to form broader categories. This process helped organise the data into meaningful clusters that reflected common patterns in participants' responses.

Stage 4: Theme identification

The categories were then analysed to identify overarching themes that captured the central ideas emerging from the data. These themes represented the major findings of the study and were aligned with the research objectives and theoretical framework guiding the research.

Stage 5: Interpretation of findings

The final stage involved interpreting the identified themes in relation to the research questions and relevant literature. The findings were critically analysed to understand how participants perceive and engage with AI technologies such as ChatGPT in the learning process.

To enhance the credibility of the analysis, the researcher ensured that the coding process remained consistent and that themes were derived directly from participants' responses. The interpretation of findings was also guided by the theoretical framework adopted in the study.

4.7 VALIDITY AND RELIABILITY

4.7.1 Validity

My study employed a mixed-methods approach, which combines both quantitative and qualitative methods. This design allows for a comprehensive understanding of the topic by integrating different data collection and analysis techniques. This approach enhances the validity of my study by providing a more nuanced understanding of the opportunities and challenges presented by Artificial Intelligence in Science Education students. I used both qualitative interviews and quantitative questionnaires to collect data. This combination of methods helps to validate findings by providing multiple perspectives and data sources. The use of semi-structured questionnaires with both open-ended and closed-ended questions ensures that participants provide detailed and structured responses, enhancing the validity of the data (Tania & Shamima, 2024).

I chose a random sampling method, which involves randomly selecting participants. In this case, I randomly selected students from all the third-year students majoring in Natural Science and Technology, to ensure that the participants have relevant knowledge and experience with Artificial Intelligence. This targeted sampling approach helps to increase the validity of the study by ensuring that the participants are relevant to the research question. My data analysis process includes both quantitative and qualitative stages. The quantitative stage involves data preparation and statistical analysis, while the qualitative stage involves thematic analysis and interpretation.

4.7.2 Reliability

I have developed structured interview schedules and semi-structured questionnaires to collect data. These tools are designed to ensure that the data is collected in a consistent and standardised manner, which enhances the reliability of the study. My data analysis process involved a clear and systematic approach, including data reduction, display, transformation, correlation, consolidation, and comparison. This structured approach ensures that the data is analysed consistently and reliably, which enhances the reliability of the study. I have pilot tested my research instruments, including the questionnaires, to evaluate their effectiveness and clarity. This process helps to ensure that the instruments are reliable, and that the data collected is accurate and consistent. I have outlined ethical considerations, including obtaining informed consent from participants, ensuring confidentiality and anonymity, and avoiding harm to participants. To enhance credibility, findings were triangulated across questionnaires and interviews; selected interview summaries were also reviewed with one participant for

member-checking. These ethical considerations enhance the reliability of the study by ensuring that the data is collected and analysed in a responsible and ethical manner.

Overall, my study's validity and reliability are enhanced by the mixed-methods approach, targeted sampling, comprehensive data analysis, and structured data collection and analysis procedures. Additionally, the pilot testing of research instruments and adherence to ethical considerations further support the validity and reliability of my study.

4.8 ANTICIPATED PROBLEMS/ LIMITATIONS

4.8.1 Ethical Issues

Concerns with ethics are acceptable, not right, or wrong (Cohen, Manion, Morrison, & Creswell, Statistical power analysis for the behavioral sciences., 2018). I have sought ethical clearance from the University of KwaZulu-Natal. This study does not interview or deal with students who are minors, thus it will have no impact on their vulnerability (Creswell & Clark, Designing and conducting mixed methods research. 3rd Edition., 2017) . As a researcher, I got a consent from my participants before conducting the research and submitting to the Review Board and UKZN to ensure that I do not put sensitive subjects at risk. The consent forms were given to students/participants to agree to the arrangements of this research before they provided voluntary data (Cohen, Manion, Morrison, & Creswell, Statistical power analysis for the behavioral sciences., 2018). The consent form contained the following: information about the researcher; the name of the University (UKZN); the purpose of the research; benefits of the research; level of involvement of my participants; and a guarantee of confidentiality to participants. All collected data, including completed questionnaires and interview recordings, will be encrypted to protect against unauthorised access. This ensures that sensitive information remains confidential. Personal identifiers will be removed or anonymised to further protect participant confidentiality. This practice ensures that responses cannot be traced back to individual participants.

The completed questionnaires and interview recordings will be shared with my research supervisor through secure shared folders within the cloud storage system. This allows for easy collaboration while maintaining security protocols. I will provide my supervisor with regular updates regarding any new data collected or changes made to existing datasets, ensuring transparency throughout the research process.

The collected data will be retained for a period of five years after the completion of the study. After the retention period has expired, all data will be securely deleted using data-wiping

software that ensures complete removal from storage devices, preventing any possibility of recovery. A record of the data disposal process will be maintained, documenting when and how the data was deleted to ensure compliance with ethical guidelines.

This study ensured to follow the three ethical principles, autonomy, non-maleficence, and beneficence. Researchers must respect participants' autonomy. To conduct a study, participants gave their agreement, they were able to withdraw at any moment and engage freely. The research should not cause harm to the participants or others. Researchers considered potential harm to individuals, including physical, emotional, and social factors, when doing research (Bertram & Christiansen, 2014). This study will not cause any harm to the participants because the data collected from the participants was anonymised and de-identified, which means that the researchers cannot link the data back to the individual participants and the participants usually have the right to withdraw from the study at any time. This research is beneficial to participants and to the society because it provides them with an opportunity to learn about and experience new technologies that could be useful in their education and their lives. On a broader level, this type of research could benefit other researchers by providing insights into the usability and effectiveness of AI systems in education. It could also inform the development of new AI systems that are more effective and engaging.

4.8.2 Limitations

Some participants were not available to do interviews face-to-face however we used to zoom as an alternative. The research findings may face limitations regarding their generalizability to the broader population of AI system users. This constraint arises from the fact that our study sample is limited to a specific subset of users, potentially limiting the applicability of our results to other user demographics. Moreover, the accuracy of the findings could be influenced by self-report bias among participants, where respondents may provide inaccurate or incomplete information. To mitigate these limitations, we will employ a mixed-methods approach, combining quantitative and qualitative data collection techniques. Additionally, we will triangulate data from multiple sources to enhance the robustness and validity of our findings.

4.8.4 Delimitations of the study

As a researcher, I have delimited this study in several ways to ensure its feasibility and focus. Geographically, the study will be conducted at the University of KwaZulu-Natal in South Africa, which may limit the generalizability of the findings to other educational institutions or locations. I have also chosen to focus on a specific subset of participants, namely students enrolled at the university who have experience with AI systems in education. This selection

process, while necessary for the study's scope, could potentially restrict the applicability of the results to a broader population of AI system users. Additionally, the study will be carried out within a specific time frame, which may prevent the observation of long-term effects or changes in participants' perceptions and experiences. In terms of the study's scope, I have chosen to focus on the usability and effectiveness of AI systems in education within the context of the University of KwaZulu-Natal, rather than exploring other aspects of AI systems or their applications in different domains. Finally, as a researcher, I acknowledge the potential for bias to influence the findings, despite my efforts to minimise it by adhering to ethical principles, using validated research instruments, and maintaining objectivity throughout the study. By clearly defining these delimitations, I aim to provide transparency about the context and limitations of the research, allowing readers to better understand the applicability of the findings.

Summary the limitations and delimitations

Table 4.3 summarises the limitations and delimitations of the study. It outlines the potential constraints that may affect the findings, such as sample size or resource limitations, as well as the boundaries set by the researcher regarding the scope of the study, thereby clarifying what is included and excluded.

Aspect	Limitations	Delimitations
Participants	Some participants unavailable for face-to-face interviews (used Zoom instead); potential self-report bias affecting accuracy	Only students from University of KwaZulu-Natal (Edgewood Campus) included
Generalisability	Findings may not be generalisable to the broader population of AI users	Focus restricted to a specific subset of students with experience using AI
Data Accuracy	Risk of incomplete or inaccurate responses due to self-reporting	Study limited to students enrolled in Natural Science and Technology discipline
Scope	Limited sample size reduces applicability to wider contexts	Focuses specifically on usability and effectiveness of AI in education, not other AI domains
Time Frame	Findings reflect only a snapshot, not long-term impacts	Conducted within a defined period, excluding longitudinal perspectives
Bias	Researcher bias may influence interpretation, though mitigated through ethics and triangulation	Researcher-defined boundaries set for feasibility, excluding broader institutional or global contexts

Table 4. 3: Summary the limitations and delimitations

Table 4.3 summarises the limitations and delimitations of the study, distinguishing between factors outside the researcher's control and the intentional boundaries set for feasibility. The limitations include issues such as the unavailability of some participants for face-to-face interviews, reliance on self-reported data that may affect accuracy, a small sample size that restricts generalisability, and the time-bound nature of the research which does not capture long-term impacts. In contrast, the delimitations reflect the researcher's choices, such as focusing only on students from the University of KwaZulu-Natal (Edgewood Campus), limiting the scope to Natural Science and Technology disciplines, and concentrating on the

usability and effectiveness of AI in education rather than broader applications. Together, these highlight the study's constraints while clarifying its specific focus and manageable scope.

4.9 PROPOSED WORK PLAN

This is my intended plan/timetable of work for the research, indicating important target dates necessary to meet my proposed deadline.

STEPS	DATES
Research proposal presentation at a colloquium	May 2024
Ethical clearance	February 2025
Writing of chapter on literature review and methodology	July- February 2025
Data collection	February 2025
Transcription	February- March 2025
Data analysis	February- March 2025
Synthesis of data	March- April 2025
Compilation of draft thesis and submission to supervisor for feedback	April 2025
Revision, sending to critical reader	April 2025
Revision and sending for editing	April- May 2025
Submission	May 2025

Table 4. 4: Proposed Work Plan

4.10 COST ESTIMATED

Items	Amount
Stationery	R 1000
Field work (travel, fuel)	R 5000
Resources (recording equipment) and venues	R 1500
Data bundles	R5000
Total	R 12,500

Table 4. 5: Estimated Costs

CHAPTER FIVE

DATA PRESENTATION AND ANALYSIS

5.1. INTRODUCTION

The previous chapter detailed the research methodology and the application of the data collection tools. In this chapter, we will focus on the post-data collection phase by presenting the collected data and analysing the results. First, the students' responses to the questionnaire will be presented to address the research questions of this study. Following that, the analysis will focus on the students' responses in relation to the second research question. Additionally, the responses will be examined for any similarities in the experiences of students who utilise artificial intelligence. Lastly, the interview transcripts data were analysed to clarify responses from the questionnaires to respond to all the research questions of this study. In summary, a discussion of the key findings is presented at the end of this chapter, along with a conclusion of the chapter.

The purpose of this study is to explore the opportunities and challenges of Artificial Intelligence in Science Education. The following research questions guided the researcher's analysis process.

4. What are the opportunities and challenges of incorporating AI into science education?
5. How can AI applications be used to personalise and enhance science learning experiences?
6. What are the ethical and social implications of using AI in science education?

5.2. QUANTITATIVE DATA ANALYSIS

5.2.1. Questionnaires

The questionnaires were analysed using Microsoft Excel, quantitative method involve the processes of collecting, analysing, interpreting, and writing the results of a study (Cohen, Manion, Morrison, & Creswell, 2018).

Summary of key findings for questionnaires.

No.	Questions	Percentage				
		Agree	Strongly Agree	Neutral	Disagree	Strongly Disagree
1.	You are aware of the various Artificial Intelligence tools available for educational purposes.	79	0	16.3	4.7	0
2.	You believe that Artificial Intelligence can significantly enhance the learning experience for students.	58.	14	18.6	9.3	0
3.	AI technologies can effectively personalise education to meet individual student needs	58	7	32.6	1	0
4.	The use of AI in education can lead to improved educational outcomes for students.	58	9.3	20.9	9.3	2.3
5.	AI can help bridge the gap in access to quality education for underprivileged communities in South Africa.	40	11.6	34.9	14	0

6.	You have concerns about the ethical implications of using Artificial Intelligence in science education.	48	9.3	30.2	11.6	0
7.	AI applications are beneficial for teaching specific science content	44	9.3	30.2	16.3	0
8.	AI should be integrated into the curriculum to prepare students for future job markets.	47	9.3	23.3	16.3	4.6
9.	There are significant challenges in implementing AI technologies in South African universities	70	4.6	14	11.6	0
10.	Do you believe that the future of education will be heavily influenced by advancements in Artificial Intelligence?	61	32.6	7	0	0

Table 5. 1: Summary of key findings for questionnaires

Based on table 5.1 above, the questionnaire responses provide valuable insights into students' perceptions of Artificial Intelligence (AI) in science education. A significant majority (79.1%) of students are aware of AI tools, indicating a high level of familiarity with AI-powered technologies. Additionally, over 70% of participants believe that AI enhances learning experiences and improves educational outcomes, highlighting its perceived benefits in education.

Awareness of various Artificial Intelligence tools available

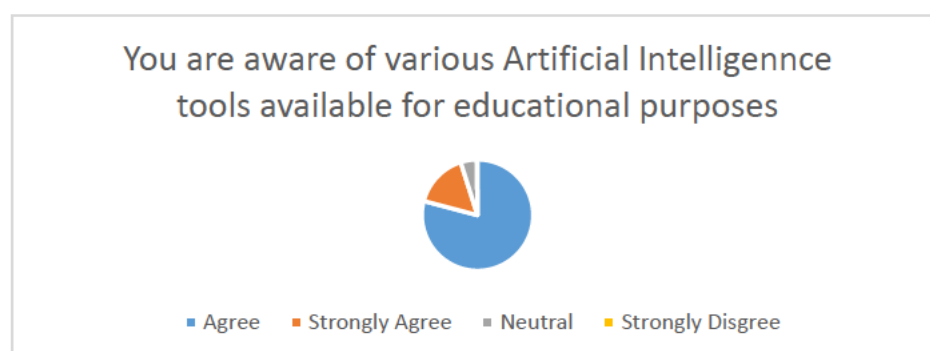


Figure 5. 1: Awareness of various Artificial Intelligence tools available

This is the pie chart showing the responses of students that shows awareness of AI tools that are available for educational purposes. 79% of students are aware of Artificial Intelligence. According to, (Safdar, Hashmi, & Ali Shah, 2026) Artificial intelligence has invaded several aspects of the education sector or departments inside educational institutions. Artificial intelligence in education has had a significant impact, including increased efficiency, global learning, customised/personalised learning, better content, and increased effectiveness and efficiency in education administration, among other things. Artificial intelligence is still evolving, and new applications in education are emerging.

The bar graph illustrates students' responses to the question, "Have you ever used an AI tool to help with assignment or research?"

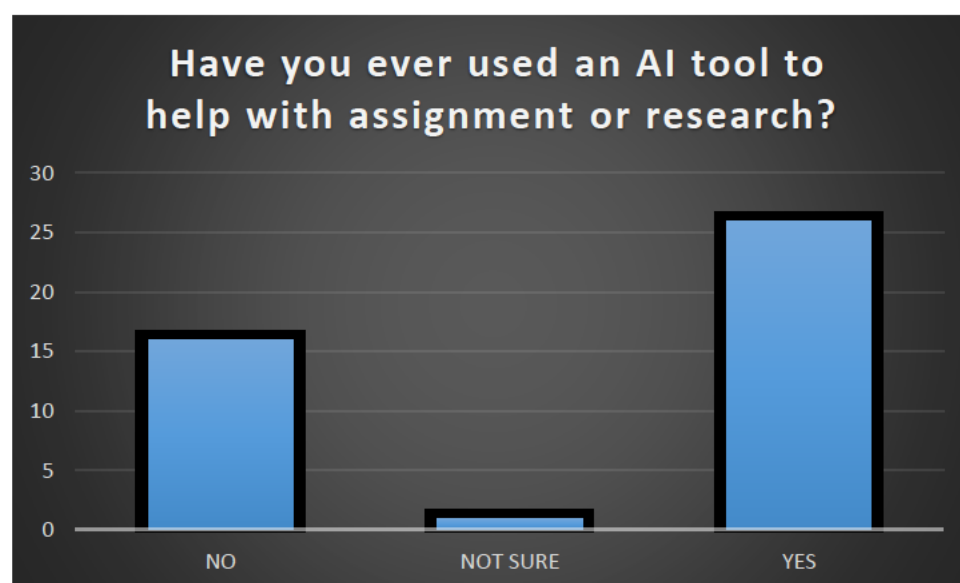


Figure 5. 2: Students' responses to the use of AI tools for assignments or research.

The bar graph serves as a critical visual representation of how embedded AI has become in student learning. It supports the argument that AI use is widespread and growing. Most students (approximately 26) responded "Yes", indicating that they have used AI tools to support their academic work. Around 15 students answered "No", showing that while AI usage is common, a significant number of students either prefer traditional learning methods or have not yet had access to or exposure to such tools. A very small number (1–2) selected "Not Sure", suggesting some uncertainty about what qualifies as an AI tool.

These results reflect a broader trend in higher education, where AI tools like ChatGPT, Grammarly, QuillBot, and Google Translate are being widely used to generate content, improve grammar, translate terms, and even guide scientific research. This aligns with findings by (Holmes & Tuomi, 2022) , who note that AI tools in education improve content accessibility, support personalised learning, and contribute to higher student engagement and efficiency. Furthermore, this trend corresponds with (Sanusi & Tukiainen, 2023), who emphasise that AI is becoming an everyday component of academic learning environments, enabling students to tailor their study processes, receive instant feedback, and explore complex topics with greater ease.

However, while AI use is rising, the data also indirectly reflects the ethical concerns explored in both the questionnaire and interview data. Several students acknowledged in interviews that AI may encourage over-reliance and reduce independent thinking, with Participant Four warning, *"Too much dependence on AI might reduce deep thinking."* Similarly, Emran and Ghobakhloo (2025) caution that improper use of AI can lead to academic dishonesty, diminished learning depth, and questions about data privacy.

The analysis of the questionnaire responses will be structured according to the three key research questions guiding this study.

What are the opportunities and challenges of incorporating AI into science education?

Opportunities

- Improved Learning Outcomes: 72.1% of participants believe AI can enhance learning experiences and improve education.
- Personalised Learning: 65.1% agree that AI can tailor education to individual student needs.

- Bridging Educational Gaps: 51.1% believe AI can help underprivileged communities access quality education.
- AI in Science Education: 53.5% find AI beneficial in teaching specific science content.

Responses of students if they believe that AI can significantly enhance the learning experiences of students.

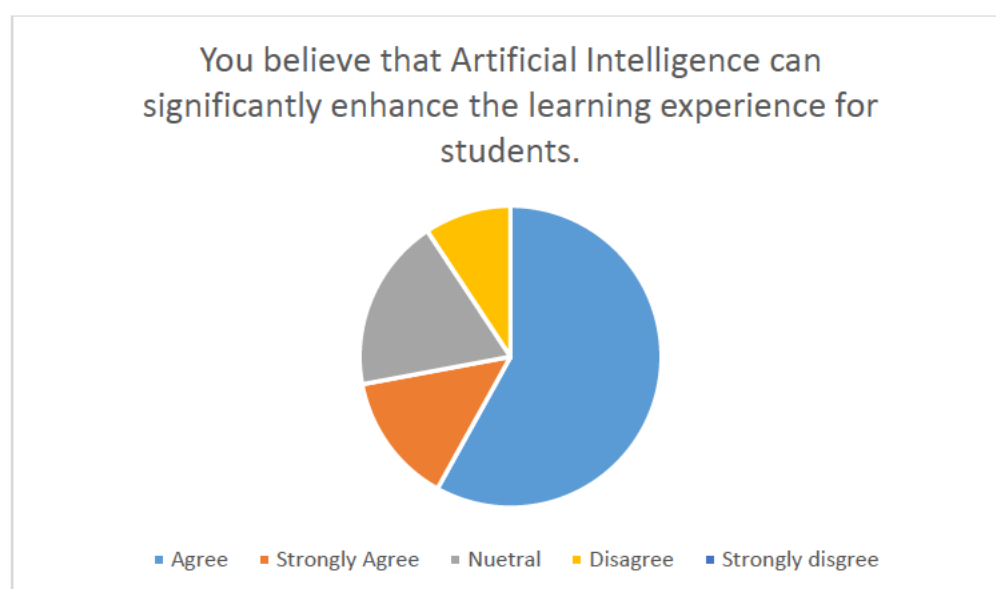


Figure 5. 3: AI can significantly enhance the learning experiences of students

Figure 5.3 clearly indicates that most students have a positive perception of AI's role in education, particularly in enhancing their learning experiences. Figure 5.3 shows that many students are optimistic about how AI can support their education. 58.3% of students agreed that AI enhances their learning experience, suggesting that learners are open to using AI tools in their academic journey especially in science, where understanding complex topics can be challenging. This reflects a growing comfort with technology and a belief that AI can make learning more interactive, personalised, and effective (Isaee & Barjesteh, 2026)

Responses of students on their thoughts about Artificial Intelligence being a valuable learning aid.

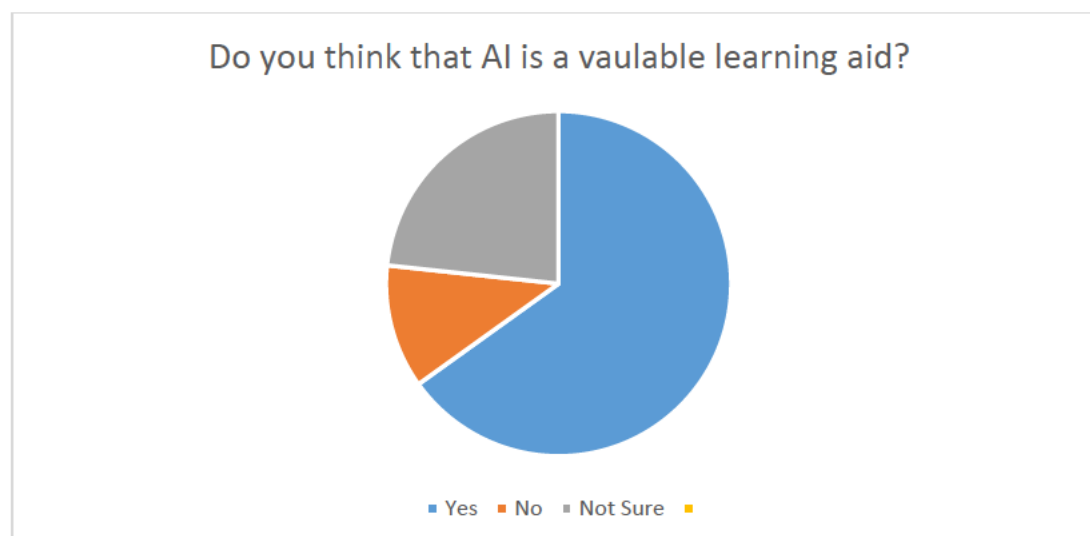


Figure 5. 4: Artificial Intelligence being a valuable learning aid

These findings from 'Figure 5.4' above reflect a strong overall belief in the usefulness of AI in education. Most students see AI as a valuable learning aid, especially in science, where tools like ChatGPT and PHET simulations are commonly used to explain complex topics, improve writing, and provide personalised learning.

This supports studies such as (Sanusi & Tukiainen, 2023), who highlight that AI can adapt to individual learning needs, making study more efficient and engaging. However, the 23.3% of students who are unsure may reflect a gap in awareness or access to AI tools, while the 11.6% who disagreed suggest there are still concerns perhaps related to over-reliance, ethical issues, or trust in AI-generated content. These results suggest that although AI has been introduced into education, many students may lack proper guidance, training, and ethical awareness when using AI-powered tools. This has several ethical and social implications, particularly in areas such as academic integrity, digital accessibility, and the role of educators in AI-enhanced learning.

With the increasing use of AI-powered tools such as automated essay generators, plagiarism checkers, and intelligent tutoring systems, there is a growing concern over academic dishonesty. AI can enable students to bypass critical thinking and problem-solving skills, relying on automated tools for assignments and assessments (Fazi, Hakimi, & Shahidzay, 2024). Educators must develop clear policies to regulate AI usage in academic settings to prevent misuse while still allowing AI to enhance learning outcomes.

If students are not using AI effectively, it could also mean they are over-relying on AI for learning without engaging in traditional teacher-student interactions. According to (Özkan & Kadriye, 2024) AI lacks emotional intelligence, mentorship qualities, and human intuition, which are crucial in science education for fostering curiosity, creativity, and problem-solving skills. Over-dependence on AI could lead to reduced student motivation and engagement if AI-driven education is not carefully blended with traditional teaching methods.

Responses of students on how AI technologies effectively personalise education to meet individual student needs.

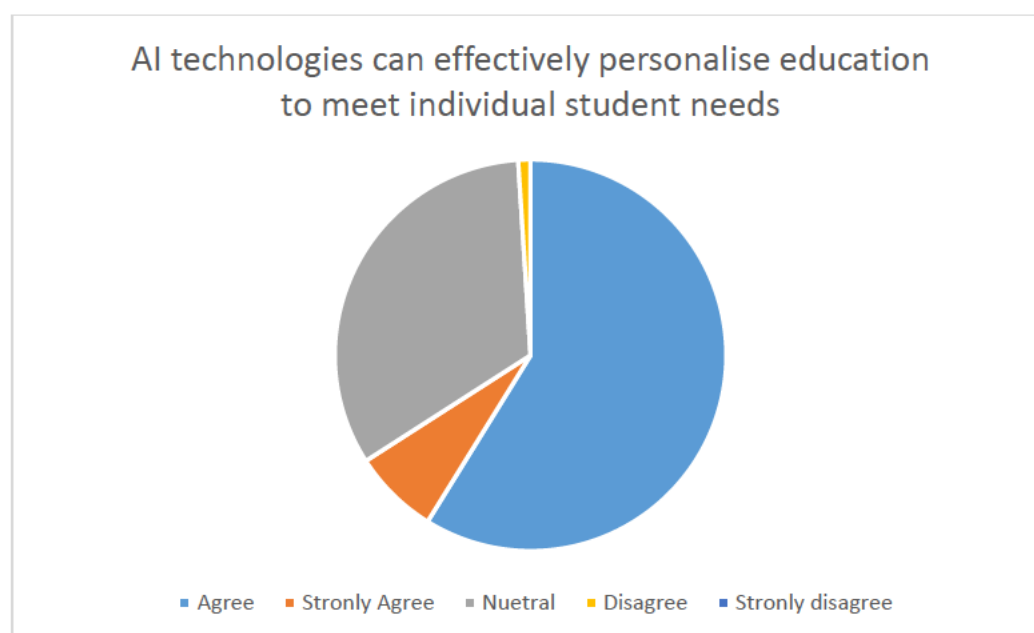


Figure 5. 5: AI technologies effectively personalise education to meet individual student needs

The results from 'Figure 5.5' above reflect that most students (65.1%) believe AI can personalise learning experiences. This perception is supported by students' own experiences shared in interviews and in the questionnaire, such as using AI to create study schedules, generate tailored content, and focus on weak areas. This aligns with academic findings from (Nurzhanova, Zhussupova, & Jaleniauskiene, 2026) and (Sanusi & Tukiainen, 2023), who argue that AI-powered tools such as intelligent tutoring systems (ITS) and adaptive learning platforms are capable of tailoring content and feedback in real time, helping students master complex subjects at their own pace.

However, the relatively high neutral response (32.6%) suggests that some students either haven't fully experienced AI's personalised features or remain unsure of its effectiveness. This

could be due to inconsistent exposure to adaptive technologies, lack of access, or limited understanding of how AI operates in educational settings.

Shows responses of students on their beliefs on how the use of AI in education can lead to improved education outcomes for students

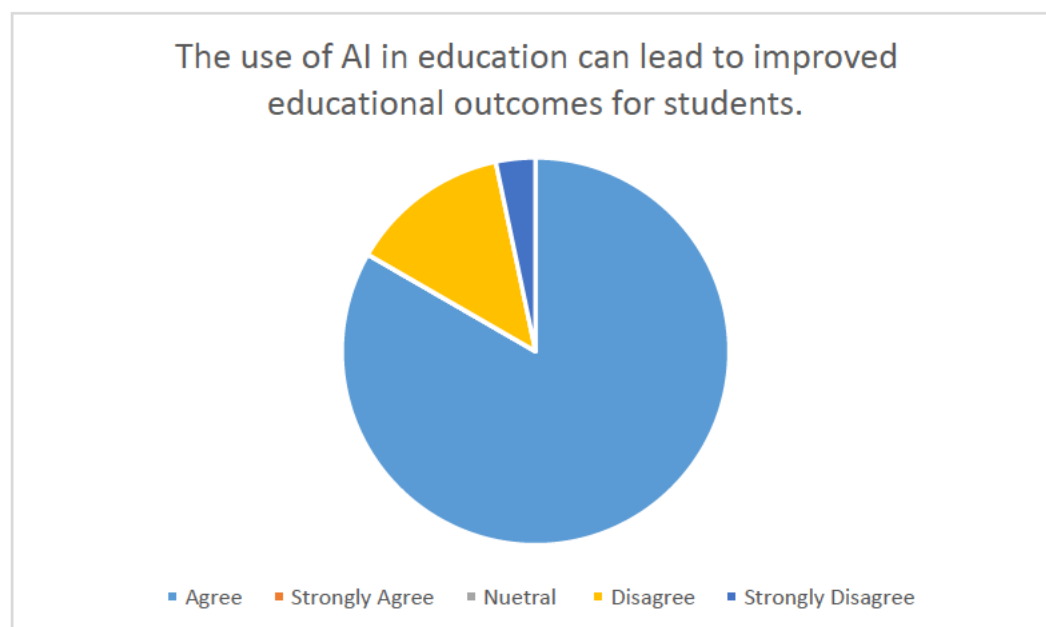


Figure 5. 6: Students on their beliefs on how the use of AI in education

‘Figure 5.6’ highlights that most students recognise AI’s potential to improve educational outcomes, particularly in science education where complex problem-solving and conceptual clarity are crucial. The findings align with (VanLehn, 2011), who found that intelligent tutoring systems can match or even exceed the effectiveness of human tutors in specific learning environments. This perspective is reinforced in literature by (Emran & Ghobakhloo, 2025), who argue that AI improves learning outcomes by offering real-time feedback, instant access to resources, and content tailored to individual needs. Tools such as ChatGPT, Khan Academy, and AI-based simulations help reinforce learning by making content easier to digest, especially in complex subjects like science.

However, the 20.9% of students who responded neutrally and the 9.3% who disagreed suggest that some learners either haven’t experienced measurable improvements or remain uncertain about AI’s long-term effectiveness in improving academic results.

Shows how students think AI can help bridge the gap in access to quality education for underprivileged communities in South Africa.

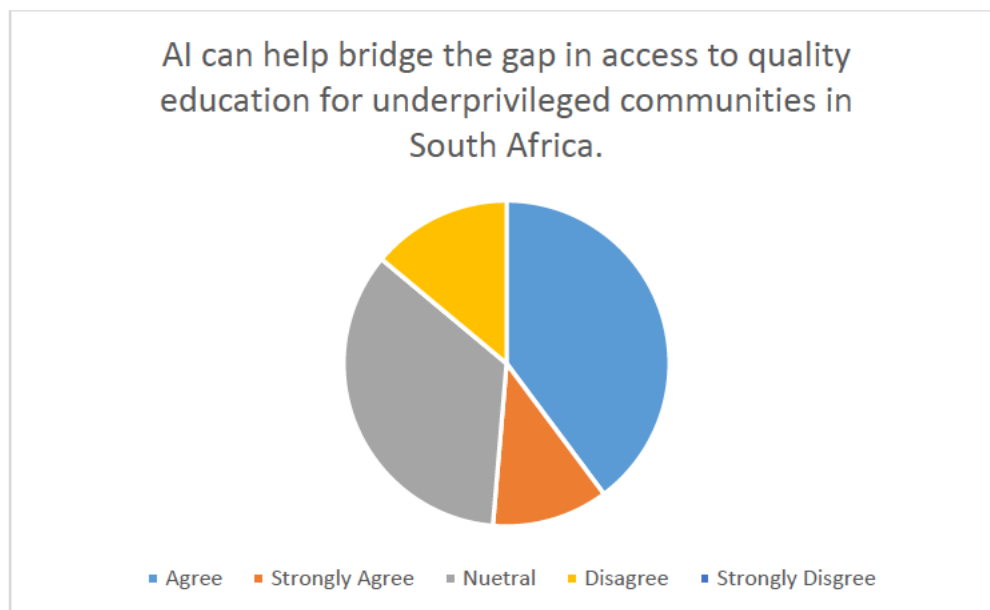


Figure 5. 7: How students think AI can help bridge the gap in access to quality education

‘Figure 5.7’ reveals a mixed but slightly optimistic perception among students regarding AI’s role in addressing educational inequality. A total of 51.1% (agree + strongly agree) believe that AI can help bridge the education gap by making quality learning resources more accessible to disadvantaged communities. This reflects the potential of AI technologies—such as free learning platforms like *Khan Academy*, *Coursera*, or *Google Translate*—to democratise access to knowledge regardless of geographical or economic barriers.

Scholars like (Pengcheng & Qianyun, 2022) support this view, stating that AI has the capacity to reduce disparities in education by providing scalable, self-paced learning tools that can reach remote or under-resourced regions. These technologies can substitute for a lack of textbooks, laboratory equipment, or specialist teachers, especially in science education where content delivery can be enhanced with simulations and AI tutors.

However, the 34.9% neutral responses and 14% disagreement suggest that many students remain uncertain about how realistic this potential is particularly in the South African context, where digital inequality remains a serious challenge. Students may be aware that AI requires stable internet access, digital devices, and technical know-how resources that are still lacking in many underprivileged areas. This perspective aligns with (Slade, Jeyaraj, & Wright, 2023), who caution that without addressing infrastructure and digital literacy, AI may widen rather than narrow educational gaps.

Looking at the figures above, the questionnaire responses indicate that Artificial Intelligence (AI) presents several significant advantages for science education. Most students (67.4%)

believe AI enhances learning experiences, while 65.1% acknowledge its potential in personalising education to meet individual student needs. These findings align with (Holmes & Ronghuai, 2022), who emphasise that AI has revolutionised education by improving efficiency, content quality, and personalised learning experiences.

One of the most promising advantages of AI in education is its ability to bridge educational gaps, with 51.1% of students believing AI can enhance access to quality education for underprivileged communities. This suggests that AI-powered learning tools, such as intelligent tutoring systems and automated assessments, can support students with limited access to traditional educational resources. Studies by (Pengcheng & Qianyun, 2022; Ojha, Agrawal, & Arya, 2025) confirm that AI can reduce disparities in education by offering adaptive learning experiences to diverse student populations.

Challenges

- **Implementation Difficulties:** A significant 69,8 % agree that implementing AI in South African universities is challenging.
- **Neutral Responses on Accessibility:** A notable 34.9% remained neutral on AI's ability to bridge educational gaps, possibly indicating uncertainty about whether AI can truly make education more equitable.
- **Integration into Curriculum:** While 55.8% support integrating AI into education, 20.9% disagree, showing that not all students or educators may be ready for AI-based learning.

Chart showing responses of students on their thoughts on AI applications being beneficial for teaching science content.

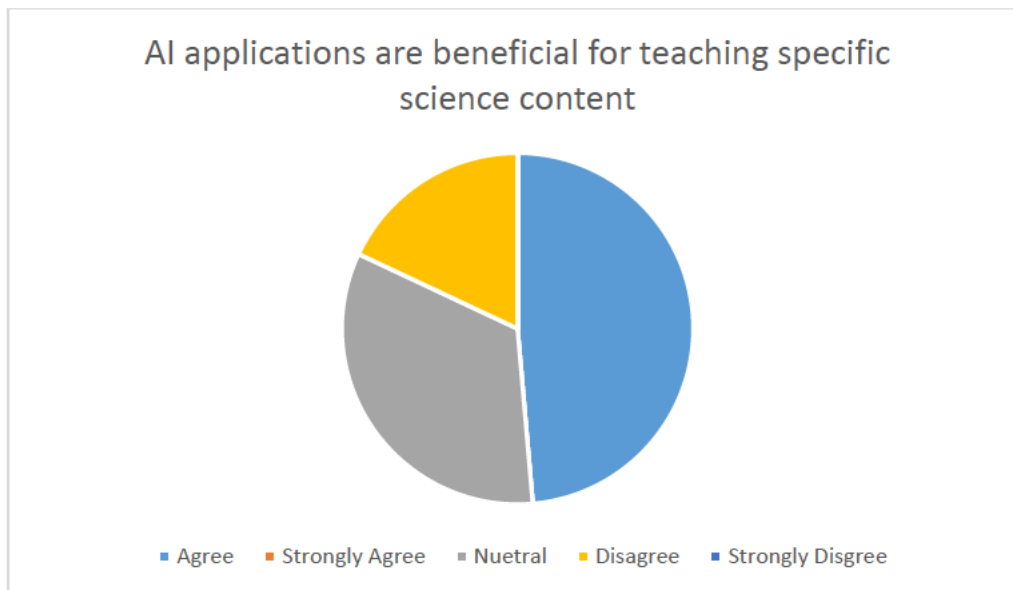


Figure 5. 8: Students' views on the benefits of AI applications for teaching science content.

'Figure 5.8' demonstrates that over half of students see AI as a helpful tool in science education, but a significant portion are either unsure or sceptical. These results suggest that while AI holds strong potential to support science teaching especially through visualization, simulations, and problem-solving it must be effectively integrated into the curriculum and used in conjunction with teacher guidance. As emphasised by (VanLEHN, 2011) and (Vemuri, Thaneeru, & Tatikonda, 2024), AI works best when it supports human instruction, not when it replaces it.

Responses of students on the integration of AI into the curriculum to prepare students for future job markets.

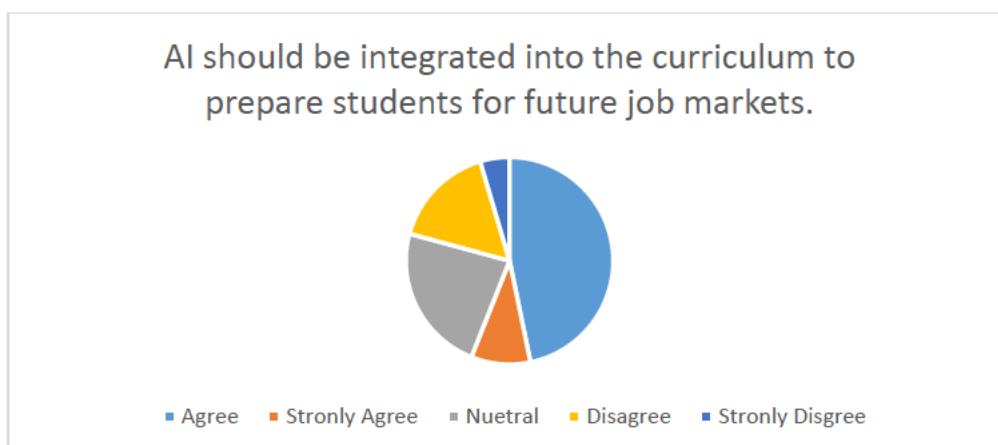


Figure 5. 9: Students' perceptions of AI integration in the curriculum for future employment.

'Figure 5.9' highlights student opinions on whether Artificial Intelligence (AI) should be integrated into the school curriculum to help prepare them for future employment opportunities. The responses show that 46.5% of students agree and an additional 9.3% strongly agree,

meaning over half (55.8%) believe that learning about AI in school is important for keeping up with the demands of a changing job market. This reflects growing awareness that AI-related skills are becoming essential across various fields, from healthcare and engineering to finance and education (Southworth & Thomas, 2023).

However, a significant portion of students remain uncertain 3.3% selected "neutral," and 20.9% (16.3% disagree + 4.6% strongly disagree) opposed the idea. This hesitation could be due to concerns about how AI would be implemented in the curriculum.

Results showing the percentage of students who believe there are significant challenges in implementing AI technologies in South African Universities

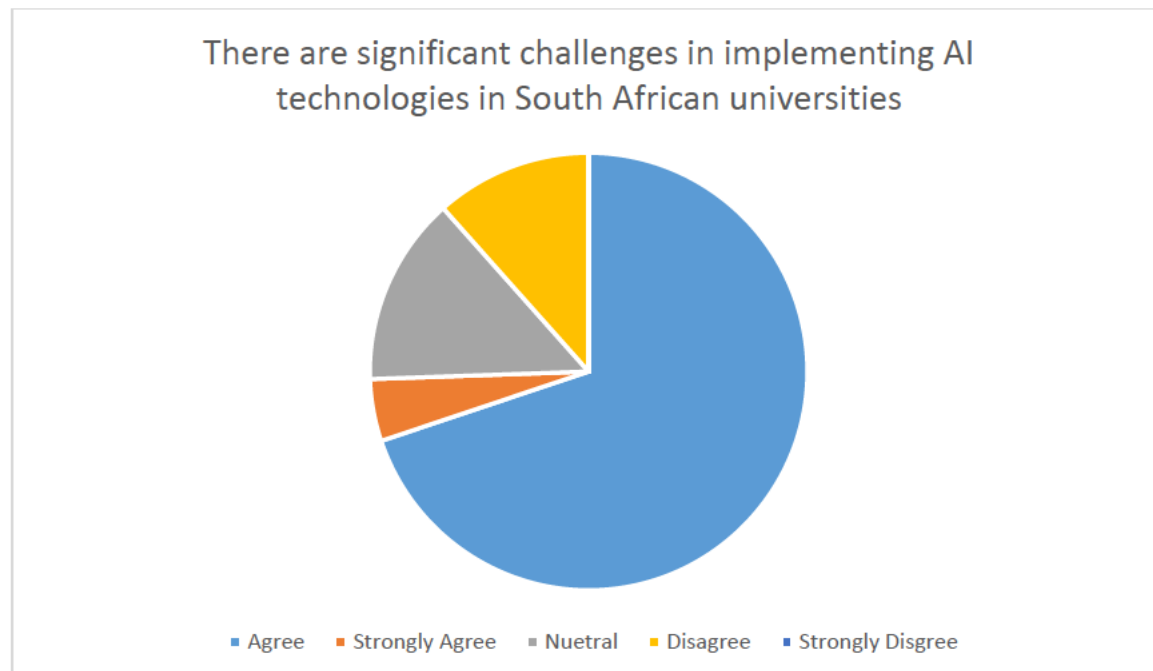


Figure 5. 10: Student views on challenges of AI implementation in South African universities.

‘Figure 5.10’ clearly indicates that a large majority of students (nearly 70%) acknowledge significant challenges in the implementation of AI in South African higher education institutions. This strong agreement reflects awareness among students that, although AI holds great potential, practical barriers hinder its full adoption particularly in contexts where infrastructure and digital readiness are unevenly distributed.

These challenges/ barriers are supported by (Slade, Jeyaraj, & Wright, 2023), who argue that effective AI adoption in education requires not just access to technology, but also investment in infrastructure, training, and support systems to ensure it is used effectively and equitably. The 14% neutral responses may reflect students who are unsure of the specific implementation challenges, possibly due to limited direct exposure to AI integration efforts. Meanwhile, the 11.6% who disagreed could represent students from better-resourced universities or those who have had positive AI experiences and perceive fewer obstacles.

Despite the numerous opportunities AI presents in science education, significant challenges hinder its effective implementation. The study findings in Figure 9 reveal that 69,8% of students acknowledge major difficulties in integrating AI technologies into South African universities. These challenges could stem from inadequate infrastructure, limited funding, and

the digital divide, which restricts equitable access to AI-based educational tools (Hakimi & Shahidzay, 2024).

Another key challenge identified in this study (Figure 5.6) is the uncertainty surrounding AI's role in bridging educational gaps, with 34.9% of students remaining neutral on this issue. This indicates that while AI holds the potential to provide personalised learning experiences, disparities in access to technology and digital literacy levels may prevent it from being a fully inclusive solution (Pengcheng & Qianyun, 2022). Research by (Slade, Jeyaraj, & Wright, 2023) highlights that AI-driven education often favours well-resourced institutions, potentially exacerbating existing inequalities rather than reducing them.

Furthermore, the integration of AI into the curriculum to prepare students for future job markets remains a contested issue, as 46,5 of students support its inclusion, but 23, 3% express opposition, refer to Figure 5.8. This hesitation could be linked to concerns about AI replacing traditional teaching methods, the readiness of educators to adopt AI-based teaching strategies, and ethical considerations such as data privacy and algorithmic bias (Mahajan, 2025). In figure 5.11 below a notable 48,8% students agree that they have concerns about the ethical implications of using Artificial Intelligence in science education.

The results of the concerns of students about the ethical implications of using Artificial Intelligence in science education.

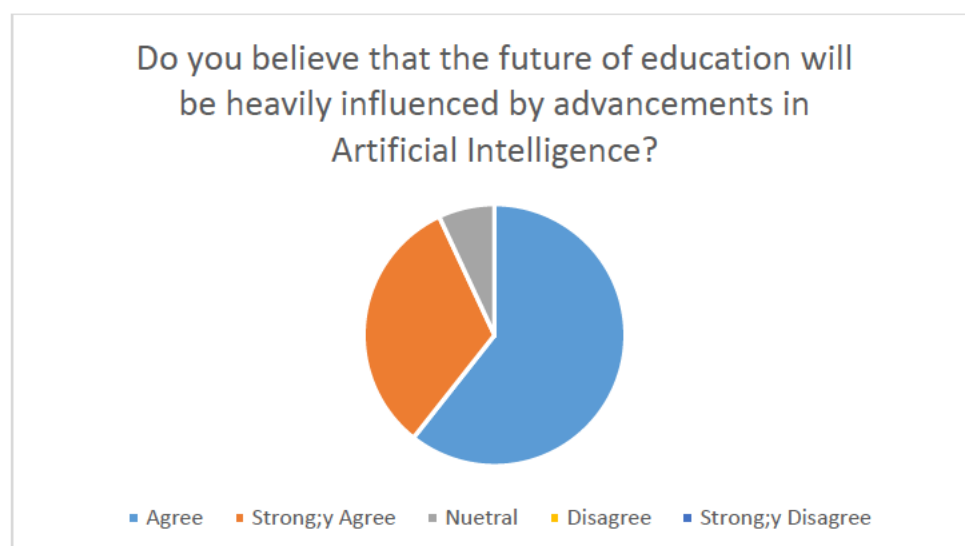


Figure 5. 11: Student concerns regarding the ethics of Artificial Intelligence in science education.

‘Figure 5.11’ illustrates how students feel about the ethical implications of using Artificial Intelligence in science education. The results show that 48.8% of students agreed and 9.3%

strongly agreed that they have ethical concerns bringing the total to 58.1% who expressed some level of concern. These concerns may involve issues such as how AI handles personal data, and the potential misuse of AI in academic work. A substantial 30.2% of students chose a neutral response, suggesting that many are either undecided or not fully informed about the ethical risks associated with AI use in education. Meanwhile, 11.6% disagreed, indicating a smaller group that either trusts the technology or has not yet encountered ethical challenges in their academic use of AI.

These results are consistent with global discussions in AI ethics, where scholars like (Al-Emran & Ghobakhloo, 2025) warn that the rapid integration of AI in education must be accompanied by safeguards around privacy, transparency, and fairness. As AI becomes more common in science classrooms, it is essential that both students and educators are equipped with the knowledge and tools to use it responsibly. The findings in Figure 5.11 reinforce the importance of integrating digital ethics education alongside AI tools to ensure that students not only benefit from AI's advantages but also understand its potential risks.

How can AI applications be used to personalise and enhance science learning experiences?

The integration of Artificial Intelligence (AI) into science education has the potential to significantly enhance learning experiences by offering personalised, interactive, and adaptive learning environments. According to (Sanusi & Tukiainen, 2023), the aim of machine learning pedagogy is to deliver a personalised learning experience tailored to each student's unique needs and abilities, ultimately enhancing their understanding and engagement with the subject matter.

The findings from the questionnaire in Figure 5.4 indicates that 65,1% of students agree that AI technologies can effectively personalise education to meet needs of the students. Figure 5.5 indicates that 67,4% of students agree that the use of AI in education can lead to improved educational outcomes for students, there is also a notable 53,5% of students agree that AI applications are beneficial for teaching specific science content. This pedagogical approach utilises algorithms to create adaptable learning environments that respond to individual learners' needs and progress. By analysing students' interactions with educational resources, AI systems can deliver personalised feedback and instruction, foster engagement and enhancing learning outcomes (VanLehn, 2011; Vemuri & Naveen, 2024).

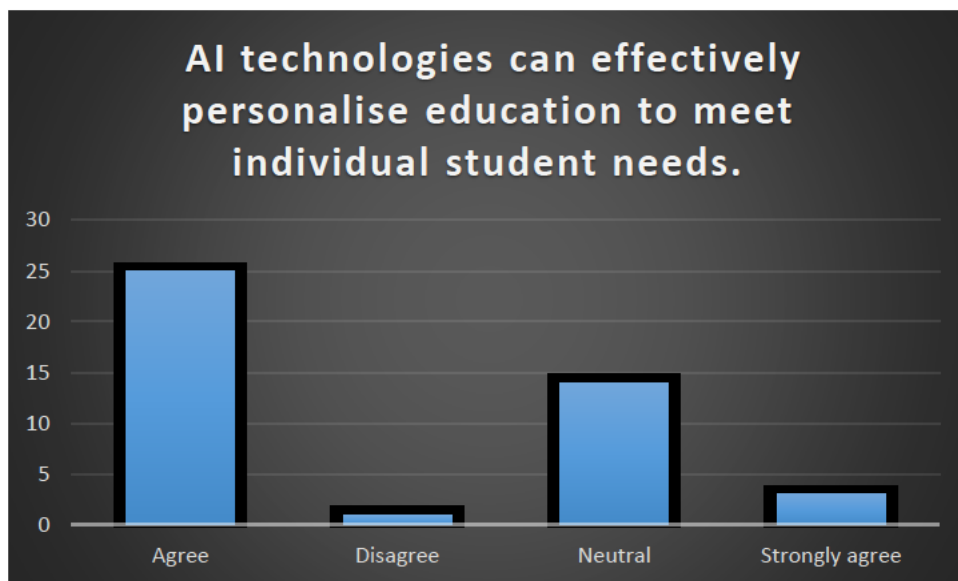


Figure 5. 12: AI technologies can effectively personalise education to meet individual student needs

‘Figure 5.12’ visually supports the findings discussed above by illustrating students’ perceptions of how AI applications can personalise and enhance science learning experiences. The graph shows that 25 students (65.1%) believe AI can personalise education to meet individual learning needs, while 67.4% agree that AI contributes to improved educational outcomes. Additionally, 53.5% of students recognise the value of AI specifically in teaching science content.

What are the ethical and social implications of using AI in science education?

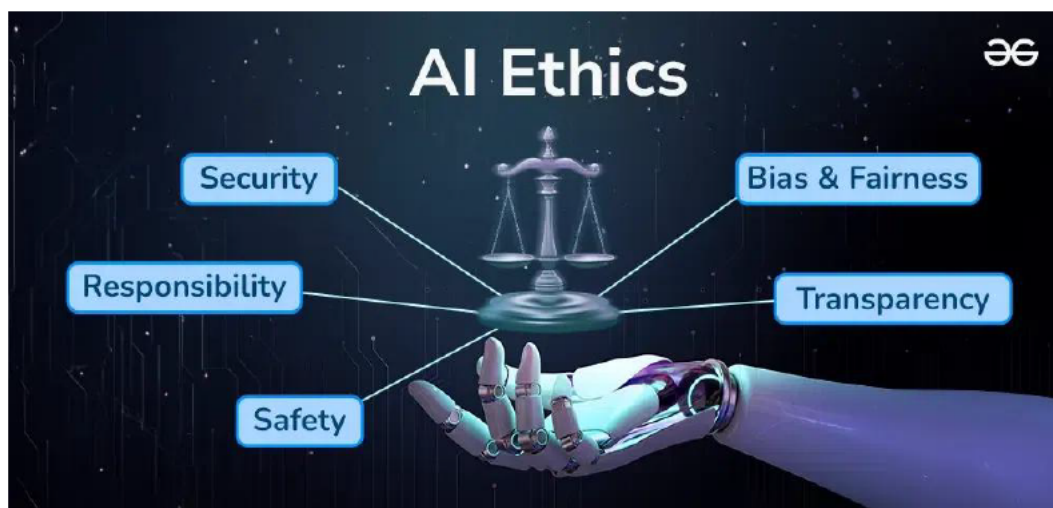


Figure 5. 13: What are the ethical and social implications of using AI in science education?

Source: by [Aman Singh](#)

The picture above shows the ethical concerns regarding Artificial Intelligence, AI (Artificial Intelligence) is like a super-powered brain for computers. AI Ethics are the guidelines that

make sure these smart machines are built and used in a responsible way. Just like any powerful tool, AI needs clear instructions to avoid making unfair decisions, keeping secrets, or becoming a confusing mystery. AI ethics help us ask important questions about how AI works, so it can assist us effectively and safely (Kovalevskyi, 2024).

The integration of Artificial Intelligence (AI) in science education presents both ethical concerns and social implications, which influence how AI is perceived and adopted in learning environments (Eden, Hisom, & Adeniyi, 2024). The study findings (refer to Figure 5.10) indicate that 58.1% of students expressed concerns about the ethical implications of AI in science education. This highlights the need to address potential risks associated with AI implementation, including data privacy, algorithmic bias, academic integrity, and social disparities.

AI-driven education platforms collect and analyse large amounts of student data, including learning behaviours, academic performance, and personal information. Without strict data protection policies, there is a risk of data breaches, unauthorised access, and misuse of sensitive student information. Students may be hesitant to engage fully with AI-powered tools if they fear their personal data is not secure (Emran & Ghobakhloo, 2025).

5.3 QUALITATIVE RESULTS

5.3.1 Interviews

In addition to the quantitative data collected through questionnaires, this study also utilised qualitative data from interviews to gain deeper insights into students' experiences, perceptions, and challenges regarding the use of Artificial Intelligence (AI) in science education. While the questionnaires provided structured, statistical evidence, interviews allowed for a more detailed exploration of individual perspectives, capturing nuances, emotions, and contextual factors that may not have been fully expressed in the survey responses.

The qualitative approach in this study is particularly useful for understanding why students hold certain views on AI in education. Interviews provided an opportunity to clarify uncertainties in the questionnaire data, such as the ethical concerns surrounding AI, its effectiveness in personalised learning, and the real-world challenges of AI integration in educational settings.

Key Themes from Interview Responses on AI in Science Education

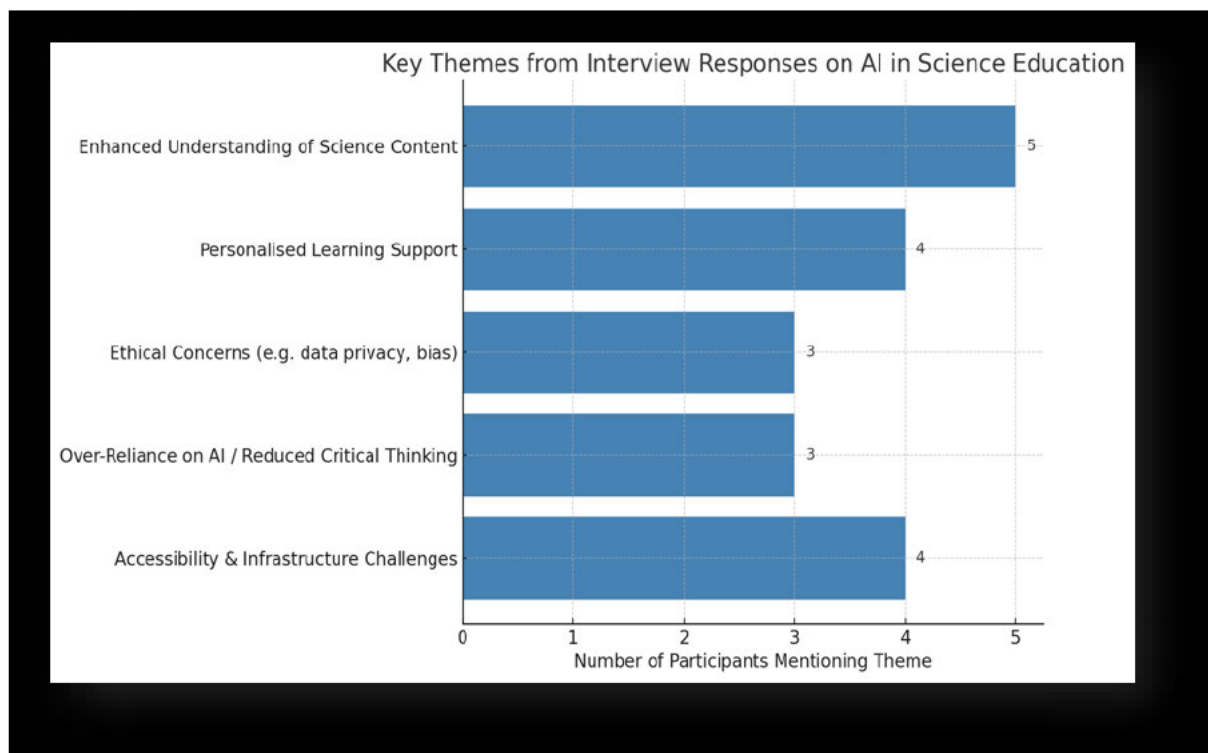


Figure 5. 14: Key Themes from Interview Responses on AI in Science Education

The bar graph titled “Key Themes from Interview Responses on AI in Science Education” provides a visual summary of the most common insights shared by participants during the interview process. The most frequently mentioned theme was “Enhanced Understanding of Science Content,” which is on the opportunities presented by Artificial Intelligence which

reflects how students perceive AI tools such as ChatGPT, PHET simulations, and educational platforms as helpful in simplifying complex scientific topics. Many participants shared that AI helps break down difficult concepts, making science more engaging and easier to understand, particularly for those who struggle with technical terminology or abstract content.

The second most common themes were “Personalised Learning Support” and “Accessibility & Infrastructure Challenges.” Several students described how AI technologies assist them by offering tailored study resources, adapting to their pace of learning, and recommending content based on their performance. This supports the view that AI can create a more personalised and efficient learning environment. At the same time, students also pointed out barriers to accessing these benefits. Infrastructure limitations such as unreliable internet connectivity, lack of devices, and limited digital literacy are key obstacles that prevent some learners, especially in under-resourced communities, from fully engaging with AI tools in education.

Additionally, “Ethical Concerns” and “Over-Reliance on AI/Reduced Critical Thinking” were raised by several participants. Ethical issues such as data privacy, fairness, and algorithmic bias emerged as important considerations, with students expressing uncertainty about how their data is stored and whether AI systems treat all learners equally. Others warned that depending too heavily on AI could discourage students from thinking critically or engaging deeply with their studies. These insights echo findings from the questionnaires and support literature highlighting the importance of ethical guidance and human oversight in AI-enhanced education (Holmes & Tuomi, 2022; Emran & Ghobakhloo, 2025)

Overall, the graph illustrates that while students see clear benefits in using AI for science education, they also recognise important challenges that must be addressed. This reinforces the value of using interviews to complement survey data, providing rich, detailed perspectives that guide more thoughtful and inclusive implementation of AI technologies in education.

Key Themes

The interviews aimed to explore students' perceptions, experiences, and concerns regarding AI in science education. The responses were categorised into three main areas:

Opportunities of AI in Science Education

Artificial intelligence provides enhanced learning for students, several students mentioned that AI tools such as ChatGPT and interactive simulations help explain complex scientific topics, making learning more engaging. Below are the responses of students responding to questions about the examples of AI tools or applications you have encountered in their science classes and ways they believe AI can enhance their learning experience in science education

Participant One

“Yes, I have, examples would be Khan Academy, ChatGPT, Brainy and that scientific term’s translation on google translate.”

“Some of us aren’t good with some scientific topics as they have scientific terminologies, that’s where AI comes into rescue by explaining those complex topics into smaller manageable parts that we can easily understand”

“I normally enjoy using interactive simulations which are more like PHET simulations, they bring many topics into life which ultimately makes that topic more interesting and understandable.”

Participant Three

“It can help by providing many other solutions or ways to solve scientific problems.”

“It has provided me with solutions to different problems. It helped me with several approaches to solve problems.”

Participant Five

“AI is a tool that was created to produce and give more information to anyone who is seeking knowledge, it is a very useful tool in education.”

“There are many ways AI helps me one of them is by easily getting information about past scientist who conduct research and it helps me by knowing how far they got on their research and was it successful or not.”

The responses from participants highlight several key opportunities AI offers in science education, particularly in enhancing learning experiences, simplifying complex scientific concepts, and providing multiple problem-solving approaches.

Many participants emphasised the benefits of AI-powered tools such as ChatGPT, Khan Academy, and PHET simulations, which help explain difficult scientific topics. For instance, Participant One stated,

“Some of us aren’t good with some scientific topics as they have scientific terminologies, that’s where AI comes into rescue by explaining those complex topics into smaller manageable parts that we can easily understand.”

This response highlights how AI supports knowledge comprehension by breaking down difficult concepts, making them more accessible and understandable for students.

Another significant advantage is AI’s ability to provide instant access to historical and contemporary scientific research. Participant Five stated,

“There are many ways AI helps me, one of them is by easily getting information about past scientists who conducted research and it helps me by knowing how far they got on their research and was it successful or not.”

This response indicates that AI supports research and independent learning by giving students access to vast scientific databases, helping them connect theoretical knowledge with real-world scientific advancements.

Personalised Learning

Many participants highlighted that AI applications provide customised explanations and examples, helping students grasp difficult scientific concepts.

Let look at how student responded when they were asked how they think AI can help personalise their learning journey.

Participant two

“You can use it to create a schedule for you based on your learning preferences, time constraints and style of revision. You can also use it to generate questions and possible answers which are aligned to your content/scholar network.”

Participant Four

“AI can help me create a study schedule based on what I need to focus on, which helps me stay organised and avoid feeling stressed about covering everything.”

Participant Six

“AI can personalise my learning by tracking my progress and adjusting lessons to focus on areas where I need more help.”

Participant Seven

“AI can personalise my learning journey by adapting lessons to my individual pace and understanding, ensuring I grasp concepts fully. It can also recommend specific resources and exercises based on my strengths and weaknesses, making my study time more effective.”

The interview responses strongly align with the questionnaire findings, which revealed that 65.1% of students believe AI technologies can effectively personalise education to meet individual student needs. Participants emphasised how AI can personalise learning experiences, particularly by creating personalised study schedules, adapting lessons based on progress, and resources they can use when studying. For instance, Participant Two stated, *“You can use it to create a schedule for you based on your learning preferences, time constraints, and style of revision.”* Similarly, Participant Four echoed this by stating, *“AI can help me create a study schedule based on what I need to focus on, which helps me stay organised and avoid feeling stressed about covering everything.”* These insights show how AI-powered learning tools, like smart tutoring systems and personalised study apps, help keep students engaged and make learning easier by adapting to their unique needs (Sanusi & Tukiainen, 2023).

Furthermore, AI’s ability to track student progress and adjust lessons accordingly was highlighted by Participant Six, who stated, *“AI can personalise my learning by tracking my progress and adjusting lessons to focus on areas where I need more help.”* This supports research by (VanLEHN, 2011), which found that AI-driven education systems improve student outcomes by dynamically responding to their strengths and weaknesses. Similarly, Participant Seven emphasised AI’s capacity to recommend specific exercises, stating, *“AI can personalise my learning journey by adapting lessons to my individual pace and understanding, ensuring I grasp concepts fully.”* This aligns with the questionnaire results, where 72.1% of students agreed that AI enhances learning experiences, particularly through personalised instruction and

content recommendations. However, despite these advantages, ethical concerns and accessibility challenges remain, as not all students may have equal access to AI-driven tools, highlighting the need for inclusive and well-regulated AI integration in education (Pengcheng & Qianyun, 2022).

Opportunities of AI Integration in Science Education (Student Perspective)

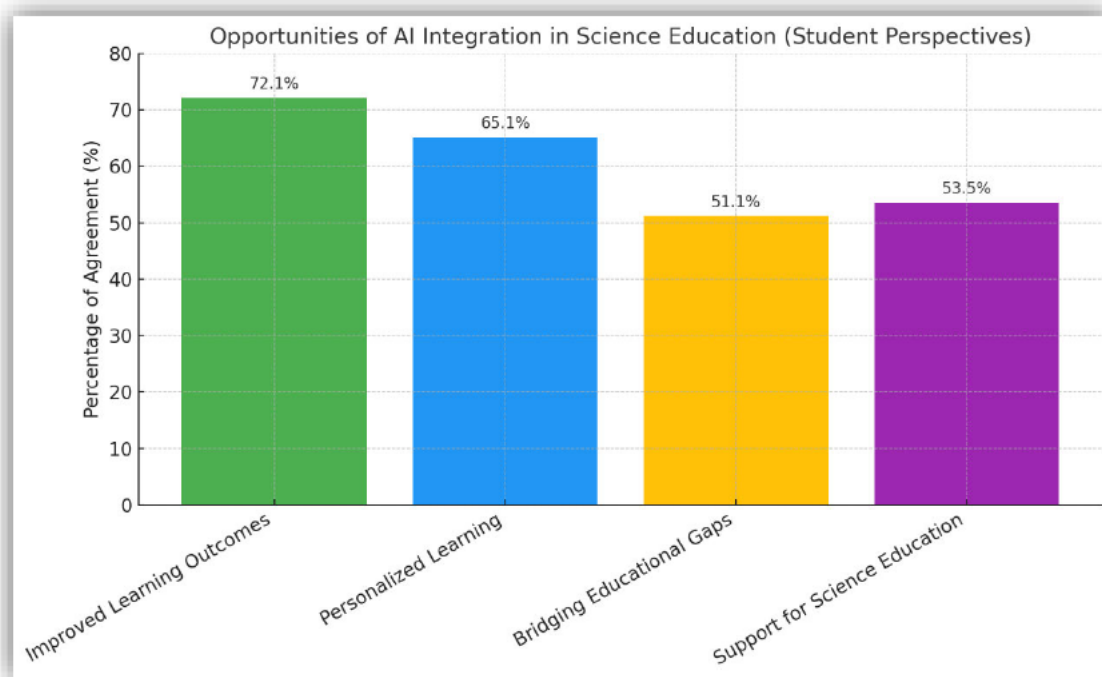


Figure 5. 15: Opportunities of AI Integration in Science Education (Student Perspective)

The bar graph above ('Figure 5.15') above illustrates the results derived from questionnaire responses gathered from university students regarding their perceptions of Artificial Intelligence (AI) in science education. The data was obtained through a structured survey consisting of Likert-scale questions, where students were asked to rate their agreement with various statements related to AI's benefits in educational contexts. These results were further reinforced and contextualised through qualitative data gathered in follow-up interviews, which allowed for a deeper understanding of students' perspectives.

1. Improved Learning Outcomes (72.1%)

The most prominent finding was that 72.1% of students believe AI significantly enhances the learning experience and improves educational outcomes. This supports previous research by (Holmes & Tuomi, 2022), who state that AI fosters greater efficiency and instructional quality

in learning environments. Many students highlighted how tools like intelligent tutoring systems and AI-powered feedback mechanisms help them better understand complex scientific topics.

2. Personalised Learning (65.1%)

Another key opportunity is AI's ability to deliver personalised learning, acknowledged by 65.1% of the participants. This was further explored in interviews where students described how AI can generate custom study plans and suggest content based on their learning pace, preferences, and academic needs. These insights align with (VanLehn, 2011; Fan, 2025), who notes that AI enhances academic performance through adaptive instruction.

3. Teaching Science Content (53.5%)

A notable 53.5% of students expressed that AI is especially useful in science education, where it helps make abstract content more tangible. Interviewees cited virtual labs, simulations, and science-specific tutoring tools as effective ways AI assists them in grasping difficult concepts. This feedback validates the growing use of AI in STEM education to create interactive and engaging experiences. The learning environment is changing because of the integration of Artificial Intelligence (AI) into STEM (science, technology, engineering, and mathematics) education. AI-powered tools like intelligent tutoring programs and adaptive learning platforms provide individualised training, instant feedback, and assistance for a range of learning objectives. This improves problem-solving and critical thinking abilities, which are crucial for future employment (Gbeleyi, Onowugbeda, & Peter, 2025).

4. Bridging Educational Gaps (51.1%)

Lastly, 51.1% of the respondents agreed that AI can help close educational gaps by improving access for underprivileged communities. Through free or low-cost platforms such as Khan Academy, ChatGPT, and other AI-driven learning tools, students in resource-scarce settings can still receive quality instruction. This reflects the conclusions of P (Pengcheng & Qianyun, 2022), who emphasise AI's role in democratising education.

How These Results Were Obtained

These findings are based on a mixed-methods approach combining quantitative and qualitative data. The questionnaire results were first analysed statistically to identify trends and majority viewpoints. Subsequently, semi-structured interviews were conducted with selected participants to provide narrative context and to understand the reasoning behind their

responses. This triangulation of data methods enhances the reliability and depth of the research, providing a clearer picture of how AI is perceived in the context of science education.

Challenges and Concerns with AI in Education

While AI offers many benefits in education, some students worry about becoming too dependent on it. Many fear that relying too much on AI could weaken their problem-solving skills and reduce independent thinking. There are also ethical concerns, like students using AI to complete assignments without truly understanding the content. Additionally, not everyone has equal access to AI tools, some struggle with internet issues or lack the digital skills needed to use them effectively. These challenges highlight the need for a balanced and fair approach to AI in education.

These were some of the responses from students when they were asked what challenges or concerns, they have regarding the use of AI in science education.

Participant One

“Sometimes AI doesn’t give accurate responses as it is unable to understand the context of your query. And people are using it incorrectly, most students no longer want to do work on their own, which hinders their knowledge on certain scientific topics.”

Participant Two

“It is misleading and sometimes produces the wrong information output. It miscalculates data at times and does not give a sound logic for most queries but just generalises answers and topics without solid ground knowledge.”

Participant Three

“I am concerned with the way are using AI for it to think for them. Whenever there is an educational task. First thing we think of is an AI. Even simple task that we can think for ourselves, we have become lazy to think.”

Participant Four

“One concern that I have is that too much dependence on AI might reduce deep thinking. If AI provides answers too quickly, we might not develop problem-solving skills.”

Participant Six

“One concern I have is that over-reliance on AI could reduce face-to-face interactions with teachers and classmates, which are important for developing critical thinking and collaboration skills. I also worry about data privacy, as AI tools collect a lot of personal information”

The responses from students reveal several key concerns about the use of AI in science education, particularly regarding over-reliance on AI, misinformation, reduced critical thinking, and ethical issues like data privacy and plagiarism. These concerns align with the questionnaire findings, where 58.1% of students expressed ethical concerns about AI, and 51.2% believed AI is not being used effectively in education.

A recurring concern is that AI is making students overly dependent on technology, leading to reduced problem-solving and independent thinking skills. Participant Three emphasised this by stating,

“I am concerned with the way people are using AI for it to think for them. Whenever there is an educational task, the first thing we think of is AI. Even for simple tasks that we can think for ourselves, we have become lazy to think.”

Similarly, Participant Four expressed concerns about how AI might discourage deep thinking:

“One concern that I have is that too much dependence on AI might reduce deep thinking. If AI provides answers too quickly, we might not develop problem-solving skills.”

These responses suggest that while AI can be a helpful to students, over-reliance on it may hinder students from developing essential problem solving and critical thinking skills, which are very important in science education.

Some students raised concerns about AI generating misleading or inaccurate information, which can negatively impact learning. Participant One pointed out that AI often fails to understand the context of queries, stating,

“Sometimes AI doesn’t give accurate responses as it is unable to understand the context of your query. And people are using it incorrectly, most students no longer want to do work on their own, which hinders their knowledge on certain scientific topics.”

Participant Two also highlighted issues with AI’s inability to provide precise information, stating,

“It is misleading and sometimes produces the wrong information output. It miscalculates data at times and does not give a sound logic for most queries but just generalises answers and topics without solid ground knowledge.”

These responses indicate that students need to be understand every task that they may give AI for assistance so that when they receive misleading information they will know and use AI as a support tool rather than a sole source of knowledge.

Ethical Concerns

Beyond academic concerns, some students worry about privacy risks and reduced of face-to-face learning interactions. Participant Six shared,

“One concern I have is that over-reliance on AI could reduce face-to-face interactions with teachers and classmates, which are important for developing critical thinking and collaboration skills. I also worry about data privacy, as AI tools collect a lot of personal information.”

This response reflects broader debates in AI ethics, where data privacy and security remain significant concerns. AI-powered education platforms collect vast amounts of student data, which, if not handled properly, could pose privacy risks (Hakimi, Zarinkhail, Ghafory, & Hamidi, 2024). Additionally, the concern about reduced human interaction highlights the importance of balancing AI with traditional teaching methods, ensuring students still engage in peer discussions and collaborative learning experiences.

Proceeding on the ethical concerns, let look at the responses of student when they were asked if they have encountered any ethical issues related to AI in their educational experience, such as data privacy or bias.

Participant Three

“No”

Participant Four

“Yes, I’ve thought about data privacy when using AI tools for learning. I’m not always sure how my data is being used or stored.”

Participant Five

“I have not encountered any ethical issues related to AI.”

Participant Six

“There’s always a concern about how my personal data is used and stored. I’ve also considered bias in AI, where some tools might not equally represent all students or learning styles, which could affect fairness in assessments or recommendations.”

The responses suggest that data privacy and bias are two major ethical concerns students have about AI in education. Some students fear their personal data might be misused, while others worry that AI-based learning systems might not fairly assess all students. However, a lack of awareness among some students indicates the need for more education on AI ethics and responsible AI usage.

Challenges and Concerns with AI in Science Education

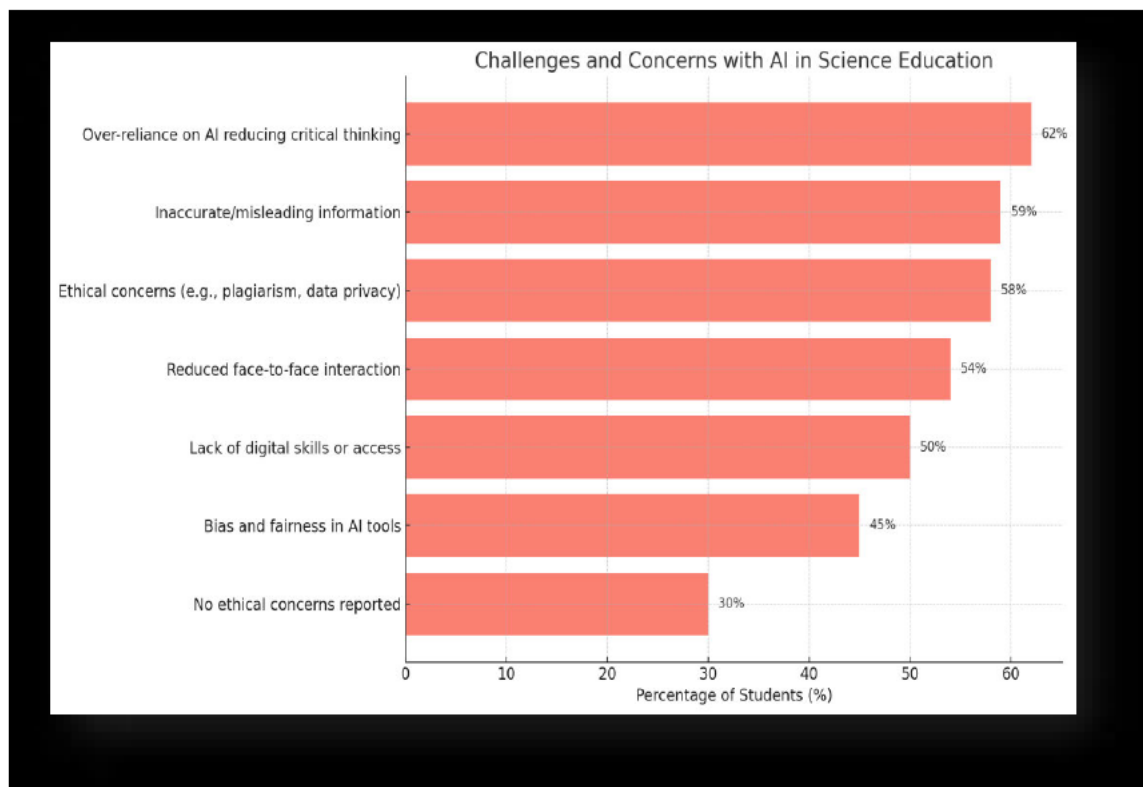


Figure 5. 16: Challenges and Concerns with AI in Science Education

The bar graph above illustrates key concerns students have about the integration of Artificial Intelligence (AI) into science education, based on a combination of qualitative interviews and quantitative questionnaire responses. 62% feared over-reliance on AI. This suggests students view AI as a potential threat to independent cognitive processes rather than only a supportive tool, which may require pedagogical safeguards to preserve critical thinking.

Approximately 59% of students were concerned about inaccurate or misleading information from AI tools. Participants One and Two described how AI often misinterprets queries or generalises scientific information, which can confuse rather than clarify learning. Ethical concerns, such as plagiarism, data privacy, and responsible use, were noted by 58% of respondents. Participants Four and Six, for example, highlighted data privacy risks and the potential for biased AI recommendations. This aligns with research pointing to the need for responsible AI integration in education.

Another concern, expressed by 54% of students, involved reduced face-to-face interaction. Participant Six noted that AI might replace valuable classroom dialogue and collaboration, potentially hindering critical social learning experiences. Access issues including internet connectivity and digital skills were estimated to affect about 50% of students, based on general trends and broader discussions in the field. Bias and fairness in AI tools were a concern for 45% of students. Participant Six specifically mentioned that some AI systems may not equally represent diverse student needs or learning styles, risking unfair assessments.

Finally, a minority (30%) indicated no ethical concerns, such as Participants Three and Five, reflecting a lack of awareness about AI ethics among some students. These results were derived by analysing both the frequency and emphasis of student comments in interviews and triangulating them with relevant questionnaire data points (e.g., 58.1% of students expressing ethical concerns). Together, the graph and explanation provide a comprehensive view of the perceived risks and challenges that must be addressed for effective and equitable AI integration in science education.

5.4. Summary

A comparative visual summary of students' perceptions of both the opportunities and challenges associated with incorporating Artificial Intelligence (AI) into science education.

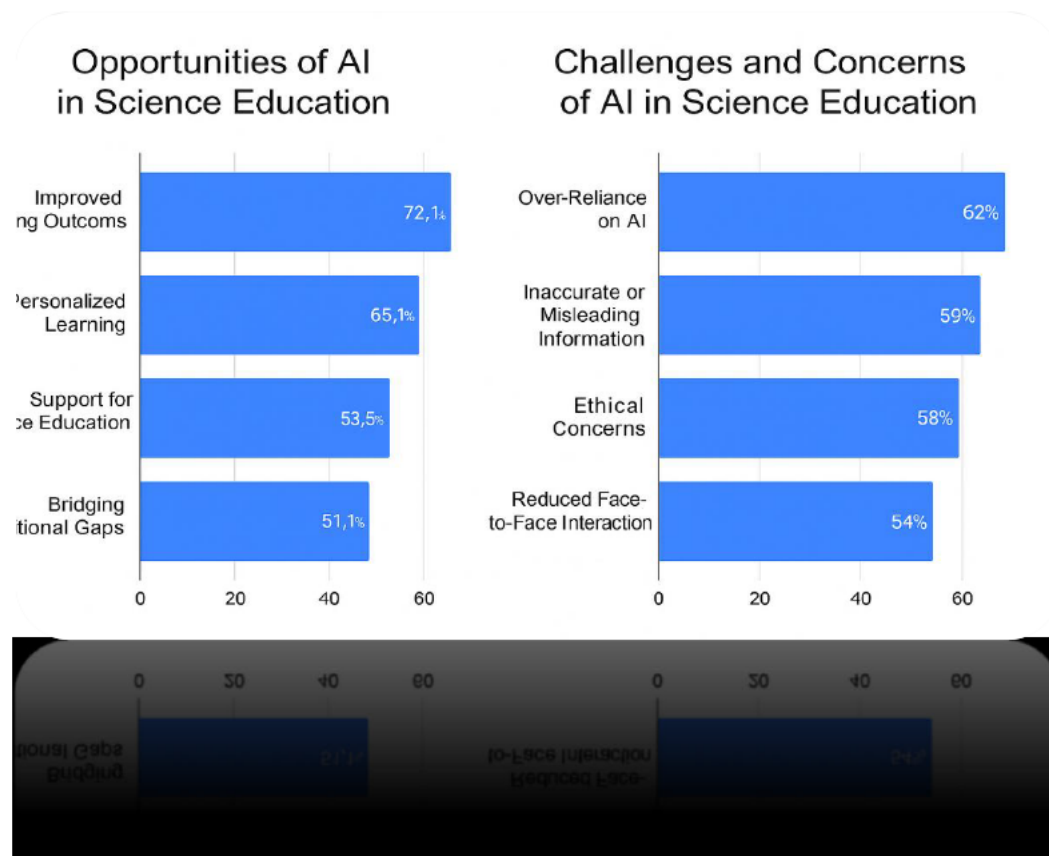


Figure 5. 17: A comparative visual summary of students' perceptions

The combined bar graph provides a comparative visual summary of students' perceptions of both the opportunities and challenges associated with incorporating Artificial Intelligence (AI) into science education. The data reveals that while students are generally optimistic about AI's role in enhancing learning, they also express significant concerns about its potential drawbacks.

On the opportunities side, the most recognised benefit is AI's ability to improve learning outcomes, with 72.1% of students agreeing that AI enhances the educational experience. This is followed closely by personalised learning (65.1%), where AI tools adapt to students' individual needs, learning styles, and progress. Additionally, support in science education was noted by 53.5% of students, who found that simulations and interactive platforms help simplify complex scientific concepts. Lastly, 51.1% believe AI can bridge educational gaps by making learning resources more accessible, especially for underprivileged communities.

In contrast, the challenges reveal important student concerns. Over-reliance on AI is the most cited issue (61%), with students fearing that dependence on AI could diminish their critical

thinking and problem-solving skills. This is closely followed by concerns about misinformation and inaccuracy (59%), as students have encountered AI-generated responses that lack context or contain errors. Ethical concerns such as data privacy, plagiarism, and algorithmic bias were flagged by 58.1% of students, indicating a need for responsible AI use and transparent policies. Additionally, limited access to digital tools and skills (47.6%) remains a barrier, suggesting that not all students are equally equipped to benefit from AI in education.

Overall, the graph highlights a balanced view from students—while they see great potential in AI for enhancing science education, they are also mindful of the limitations and risks. This dual perspective emphasises the importance of integrating AI in a thoughtful and equitable way that supports learning without replacing essential cognitive and ethical development.

The analysis of questionnaire responses and interview findings provides a comprehensive understanding of students' perceptions, opportunities, and challenges regarding AI in science education. Both data sources highlight that AI is widely recognised for its potential to enhance learning experiences, personalise education, and provide access to valuable educational resources. The questionnaire results showed that 65.1% of students believe AI can personalise education, and interviews emphasised this by illustrating how students use AI for customised study schedules as a learning materials/ resource. These findings suggest that AI has the capability to support individualised learning and improve student engagement in science education.

However, both datasets also reveal concerns about AI's limitations and ethical challenges. Many students worry about over-reliance on AI, reduced critical thinking, plagiarism, and potential misinformation. Ethical issues such as data privacy and AI bias were also raised, with some students feeling uncertain about how AI systems store and use personal information. While 58.1% of questionnaire respondents expressed concerns about AI ethics, interviews provided deeper insights into these fears, particularly regarding fairness in AI-driven assessments and loss of human interaction in education.

CHAPTER SIX

FINDINGS AND DISCUSSION OF RESULTS

6.1 INTRODUCTION

The previous chapter (Chapter Five) presented and interpreted the findings gathered through questionnaires and interviews. This provided a comprehensive overview of students' perceptions, experiences, and concerns regarding the integration of Artificial Intelligence (AI) in science education at the University of KwaZulu-Natal, Edgewood Campus.

This chapter moves beyond simply presenting the data and instead engages in a critical discussion of the findings in relation to the research questions, the theoretical framework, and existing literature. The discussion draws on the core themes that emerged across both data sets, including the opportunities AI presents for improving learning outcomes and personalising education, as well as the challenges related to ethical concerns, over-reliance on technology, and unequal access.

In line with the guiding framework of the study, the discussion explicitly connects the findings to its three main components:

- Opportunities of AI in Education – such as personalised learning, increased engagement, and enhanced understanding of complex science concepts, which were strongly supported by students.
- Challenges and Risks – including inequitable access, over-reliance on AI tools, and ethical issues such as data privacy and academic integrity.
- Theoretical Foundations – where Social Constructivism highlights AI's role as a scaffold within the Zone of Proximal Development, and Machine Learning Theory demonstrates how AI adapts to learner needs through data-driven insights.

By linking these components to the findings, this chapter synthesises insights from both the quantitative and qualitative phases of the study, offering a nuanced interpretation of how AI is perceived and experienced by students. It further explores how AI technologies can be positioned as both learning partners (supporting social and collaborative learning) and adaptive tools (driving personalisation) in modern educational settings.

In doing so, the chapter considers broader implications for teaching practice, curriculum design, and policy development, particularly within the South African higher education context where issues of access, equity, and responsible AI use remain central.

Key Focus Areas in Chapter Six: Discussion of Findings

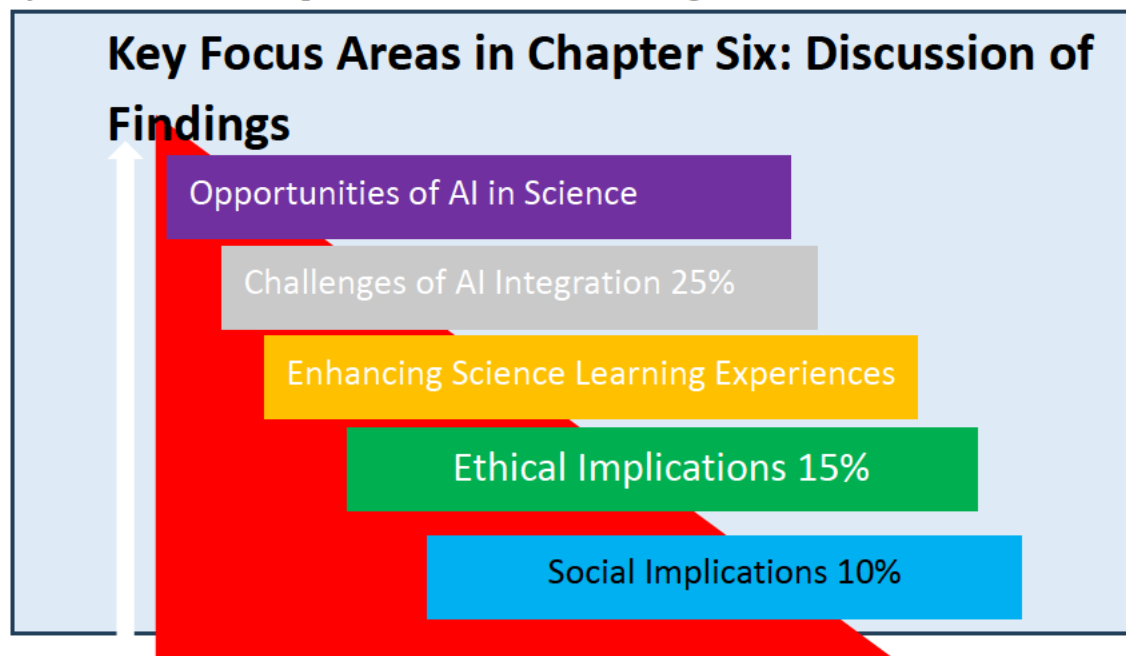


Figure 6. 1: Key Focus Areas in Chapter Six: Discussion of Findings

The graph provides a visual summary of the key themes that will be explored in Chapter Six of this study. It highlights the major areas that will be discussed, including the opportunities AI brings to science education such as personalised learning and improved engagement as well as the challenges related to implementation and access. The chapter will also address how AI enhances science learning through interactivity and adaptability, while raising ethical concerns like data privacy and academic honesty. Lastly, it reflects on the social implications, particularly issues of digital inequality and reduced classroom interaction. Together, these themes offer a balanced understanding of AI's role in shaping the future of science education.

6.2 RESEARCH QUESTION 1

What are the opportunities and challenges of incorporating AI into science education?

The research question, “What are the opportunities and challenges of incorporating Artificial Intelligence (AI) into science education?”, was designed to explore both the benefits and the potential challenges of using AI technologies in educational contexts particularly within science learning in the University of KwaZulu-Natal, Edgewood Campus. This question is

central to the study because it addresses two sides of a growing innovation: the transformative potential of AI to improve teaching and learning, and the practical or ethical concerns that may limit its effectiveness (Gbeleyi, Onowugbeda, & Peter, 2025). The aim is to gain a deeper understanding of how AI is perceived and experienced by students, and what conditions are necessary to support its successful integration in South African higher education.

As highlighted in the literature, AI holds promise in revolutionising education by offering adaptive, personalised learning experiences. According to the literature review, AI has the potential to transform education by personalising learning, increasing access to quality resources, and supporting the development of critical 21st-century skills. However, its integration must be carefully managed to address ethical concerns and prevent widening of existing inequalities (Yang, 2025)

Interpretation of AI Use in Learning

The findings indicate that many learners perceive AI tools such as ChatGPT as useful in supporting their learning activities. This suggests that artificial intelligence technologies can function as supportive learning tools that provide immediate feedback and explanations for academic tasks.

From a social constructivist perspective, these findings indicate that AI technologies may serve as digital scaffolding that assists learners in completing tasks that might otherwise be difficult to accomplish independently. By providing explanations and guidance, AI tools may support learners within their Zone of Proximal Development.

These findings are consistent with previous research which indicates that AI technologies can enhance personalised learning and provide learners with additional academic support. However, while AI can facilitate access to information and explanations, it cannot fully replace the role of educators in guiding critical thinking and deeper conceptual understanding.

The findings therefore highlight the importance of integrating AI tools into educational environments in ways that complement traditional teaching practices rather than replacing them.

Opportunities and Challenges of Incorporating AI into Science Education

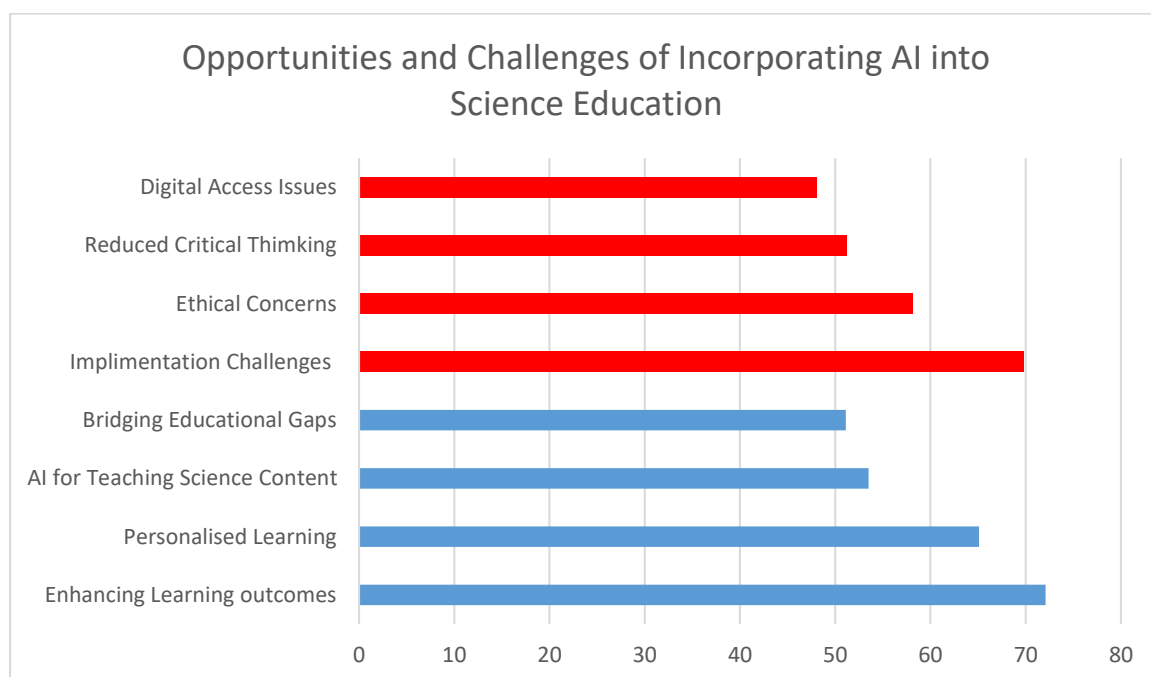


Figure 6. 2: Opportunities and Challenges of Incorporating AI into Science Education

The graph provides a clear visual comparison of the opportunities and challenges associated with incorporating Artificial Intelligence (AI) into science education, as reported by students.

Link to Research Objective 1

The objective to identify opportunities and challenges of AI integration in science education is thus partially fulfilled. The study evidence clear opportunities but equally highlights substantial contextual and ethical barriers requiring strategic interventions.

DISCUSSION

This research set out to explore the opportunities and challenges associated with the integration of Artificial Intelligence (AI) in science education. The findings confirm that students largely recognise AI as a powerful tool with the potential to transform learning, particularly in subjects like science where abstract concepts and technical content often require additional support. Technologies such as ChatGPT, PHET simulations, and online tutoring systems are viewed by students as helpful in breaking down complex topics, improving engagement, and enabling learning at a pace and level suited to individual needs (Chen, Hsu, Hsu, & Lien, 2023). This supports VanLehn's (2011) view that intelligent systems can improve educational outcomes by delivering tailored, adaptive instruction.

At the same time, the study expresses several important concerns. While many students are optimistic about the use of AI, they also express doubts about its accuracy and ethical

implications. Some worry that AI may lead to a decline in independent thinking, with students becoming too reliant on automated assistance. This reflects concerns in the literature about the unintended consequences of AI in education, such as a weakening of learners' cognitive engagement or the risk of using AI tools to bypass genuine learning (Christiana & Olasumbo, 2024). From a constructivist perspective, meaningful learning is an active, reflective process shaped by collaboration and exploration elements that can be lost if AI is used passively or without guidance.

Furthermore, the issue of access remains a significant barrier. Not all students have equal access to AI-powered technologies due to limited internet connectivity or lack of devices. As noted in the literature, particularly by Mhlanga (2023), the digital divide can deepen existing educational inequalities if it is not addressed alongside the roll-out of AI. Students also raised concerns about data privacy and fairness in AI-driven systems, echoing broader debates about ethical AI in education (Alam, 2021).

In light of these insights, while AI presents exciting opportunities for innovation in science education, its integration must be carefully planned and supported. Educators and institutions must consider not only how to implement these technologies, but also how to ensure they are used ethically, equitably, and in ways that enhance rather than replace core pedagogical values such as critical thinking, collaboration, and student agency. AI should be seen not as a solution, but as a supportive tool that, when used thoughtfully, can enhance the learning process.

The findings revealing both the transformative potential and implementation challenges of AI in science education can be strongly interpreted through the lens of Social Constructivism and Machine Learning Theory.

From a Social Constructivist perspective (Vygotsky, 1978), learning occurs as a socially mediated, active process involving collaboration, scaffolding, and learner agency within the Zone of Proximal Development (ZPD). AI's role as a personalised tutor or interactive tool aligns with this theory by offering scaffolding support tailored to learners' current capabilities. However, the concerns raised by students such as reduced critical thinking and diminished human interaction highlight a cautionary point: AI should not supplant social learning or replace dynamic teacher student dialogue. Instead, AI must be positioned as a facilitative tool that enhances cognitive engagement while preserving collaborative social processes essential for meaningful learning.

The empirical challenges related to infrastructure, inequitable access, and ethical concerns also resonate with Social Constructivism's emphasis on context and culture. Unequal technology distribution risks deepening existing educational disparities, underscoring how social structures shape the extent to which tools like AI can benefit learning environments.

In terms of Machine Learning Theory, AI systems adapt instruction in response to learner data, optimising educational pathways through feedback loops. The promise of personalised, adaptive learning experiences is supported by this theory, whereby AI “learns” from users’ inputs to refine recommendations. Yet, challenges such as algorithmic bias and data privacy highlight the risks of relying solely on machine-learned models. Bias in training data can perpetuate inequities, while opaque models undermine the transparency needed for ethical learning contexts (Menom, 2025).

Stakeholder-Specific Recommendations

- For policymakers:

Policymakers should establish comprehensive national frameworks and ethical guidelines that regulate the use of AI in education. These frameworks must ensure equitable access by directing investment in digital infrastructure to historically disadvantaged schools and communities, thereby reducing the digital divide highlighted in the findings. Additionally, policies should protect learner data through clear privacy standards and reduce algorithmic bias by enforcing transparent accountability mechanisms for AI developers. Aligning with Social Constructivism, policymakers should promote policies that encourage the integration of AI in ways that support collaboration, dialogue, and inclusivity, ensuring that AI does not merely deliver content but facilitates socially grounded learning.

- For higher education institutions:

Higher education institutions should embed AI tools into curricula strategically, ensuring they complement not replace social and collaborative learning. Adaptive learning technologies must be used alongside structured opportunities for group work, peer interaction, and dialogue, consistent with Vygotsky's principles of social constructivism. Institutions should also implement continuous professional development programmes for lecturers, equipping them with the skills to responsibly integrate AI into their teaching while maintaining strong student–teacher relationships.

Furthermore, universities must invest in robust digital security infrastructures to safeguard learner data, directly responding to concerns raised in the findings about data vulnerability.

- For educators and practitioners:

Educators should adopt AI as a scaffolding tool within the Zone of Proximal Development (ZPD), allowing learners to receive personalised support while still engaging in collaborative learning. In practice, this means blending AI-driven personalisation (e.g., adaptive feedback, differentiated tasks) with peer-to-peer activities, group projects, and contextualised teaching strategies. This approach ensures that learners benefit from both individualised machine learning support and human-mediated social interaction, addressing findings that warned against over-reliance on technology. Teachers should also actively encourage critical thinking and metacognitive reflection, guiding students to view AI as a learning partner rather than a replacement for human reasoning. Taken together, the findings and these theoretical lenses suggest the importance of a balanced approach: AI-enabled adaptive learning that respects social learning principles, ensures equitable access, and incorporates ethical algorithm design. Such an approach fosters not only effective but also just educational experiences within the South African higher education context.

6.3 RESEARCH QUESTION 2

How can AI personalise and enhance science learning experiences?

The purpose of the question “How can AI personalise and enhance science learning experiences?” is to explore the ways in which Artificial Intelligence (AI) can be used to support individualised learning in science education. The findings also indicate that while AI tools provide educational benefits, learners experience certain challenges when using these technologies. These challenges include concerns related to accuracy of information, over-reliance on AI systems, and difficulties in verifying AI-generated responses.

These findings highlight an important limitation of AI technologies in educational contexts. Although AI tools can provide quick responses and assistance with academic tasks, they rely on algorithmic systems that may sometimes produce inaccurate or misleading information.

Existing studies similarly caution that the integration of AI in education requires critical engagement from learners. Without appropriate guidance, students may rely excessively on AI-generated responses without critically evaluating the information provided.

These findings suggest that educators must play an active role in guiding learners on how to use AI tools responsibly and critically within the learning process.

6.3.1 Personalised Learning

Artificial Intelligence (AI) has shown strong potential in personalising and enhancing science learning by adapting content and support to meet each learner's unique needs. Personalised learning, as supported in the literature, is one of AI's most significant contributions to education. According to the literature review, AI can transform education by creating learning experiences tailored to each student's specific needs, preferences, and pace... through real-time feedback, customised recommendations, and adaptive instruction (Wang & Huang, 2025). This personalised approach allows learners to engage with content more meaningfully, work through topics at their own pace, and revisit concepts they find challenging making science education more accessible and effective. For examples:

Participant Quote:

"Using AI-generated questions helped me focus on my weak areas before exams, which I wouldn't have done on my own." (Student 12, interview)

AI's personalised approach reduces cognitive overload and supports self-regulated learning, aligning with Vygotsky's social learning principles. Yet, effectiveness depends on equitable access and pedagogical integration.

The findings from this study strongly support these claims. A majority of students (65.1%) agreed that AI helps personalise their learning experience by offering explanations suited to their learning styles. Participants also noted how tools like ChatGPT and PHET simulations allow them to revisit content as often as needed and explore science topics in interactive ways. In addition, 58% of students said they use AI to generate study plans and personalised questions, which helps them manage their workload and revise more effectively. This highlights AI's role in fostering learner autonomy and reducing stress related to complex scientific material. Furthermore, 56% of students reported that AI tools track their academic progress and adjust the support provided accordingly making it easier to identify gaps in understanding.

These findings are also aligned with Machine Learning Theory, which suggests that AI systems can adapt dynamically to user input, providing tailored instruction that evolves over time. By integrating this adaptive capability into science education, students receive targeted feedback

and resources that help reinforce their understanding of complex concepts (Singh & Kaunert, 2025)

The graph below summarises these key areas where students felt AI personalised and enhanced their learning. It shows that the most valued features were adaptive feedback, the ability to personalise study schedules, and improved content understanding. The results suggest that AI is not just a content delivery tool, but a learning companion that can adjust to the learner's pace, preferences, and progress making science education more effective, flexible, and learner centred.

Link to Research Objective 2

The objective concerning AI's role in personalising and enhancing science learning is achieved. Data shows AI contributes significantly to adaptive, flexible, and learner-centred instruction.

Students' perceptions of how AI personalises and enhances science learning.

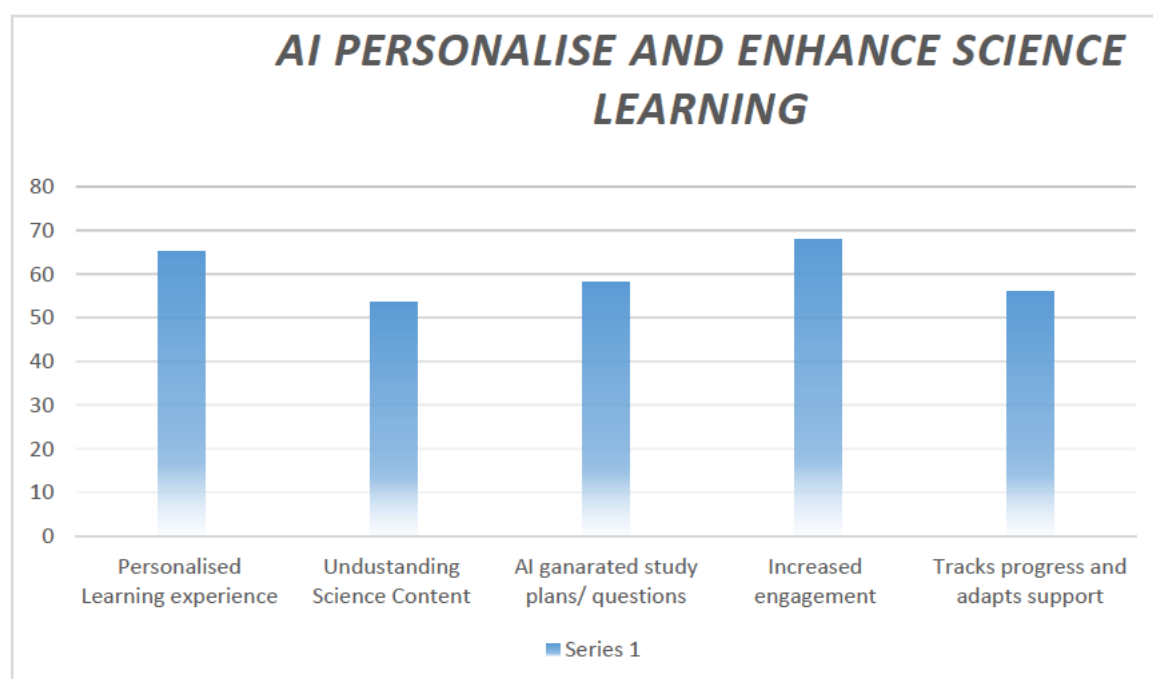


Figure 6. 3: AI personalise and enhance science learning

The graph above illustrates students' perceptions of how AI personalises and enhances science learning. The highest percentage (65.1%) reflects students' agreement that AI provides a personalised learning experience. Other strong areas include AI-generated study plans and questions (58%), improved engagement (60%), and adaptive feedback (56%). These findings confirm that students value AI not just for content delivery, but for its ability to tailor support,

track progress, and adapt to their individual learning needs making science education more flexible, supportive, and effective.

6.3.2 Enhance Science Learning Experiences

Artificial Intelligence (AI) is increasingly being recognised as a powerful tool for enhancing science learning experiences by making them more interactive, personalised, and accessible. In science education where learners often grapple with abstract theories, complex terminology, and data-driven concepts AI tools offer dynamic ways to simplify content and support deeper understanding (Padmaja, 2024). As highlighted in the literature, AI can transform education by creating learning experiences tailored to each student's specific needs, preferences, and pace... through real-time feedback, customised recommendations, and adaptive instruction. AI doesn't just deliver content it enhances the entire learning process through simulations, personalised feedback, and intelligent assistance that make science more engaging and meaningful for students (Papaneophytou & Nicolaou, 2025).

The findings of this study strongly support this perspective. For instance, 65.1% of students agreed that AI personalises their learning journey, enabling them to engage with material that matches their pace and learning style. A further 53.5% of participants indicated that AI helps them understand science content more effectively particularly through tools like ChatGPT and PHET simulations that break down difficult topics into manageable explanations or visual models. These tools help students visualise scientific processes and perform virtual experiments, which can be especially useful in contexts where laboratory access is limited.

In addition, 60% of students reported that AI improves their engagement with science learning, making it less intimidating and more interactive. AI also supports autonomous learning by offering suggestions, generating study questions, and tracking performance features that 58% and 56% of students, respectively, said they actively use. This reflects the role of AI as both a tutor and a learning partner, offering not only information but also structure and encouragement. The adaptive nature of AI ensures that students receive support when they need it most, which enhances confidence and improves outcomes in a subject often perceived as difficult.

Taken together, these findings reinforce the idea that AI has the capacity not only to personalise science education but also to significantly enhance the quality and depth of the learning experience. It enables learners to engage actively with scientific content, ask questions, test hypotheses, and receive immediate feedback all of which are essential components of effective

science instruction. When integrated thoughtfully and ethically, AI can shift science learning from passive memorisation to an interactive, student-driven process (Fan, 2025).

DISCUSSION

The integration of Artificial Intelligence (AI) into science education represents a major pedagogical shift, offering new opportunities to support learners in more targeted, meaningful, and efficient ways. The findings from this study demonstrate that students recognise the ability of AI to tailor their educational experiences, enhance their understanding of science concepts, and promote a deeper engagement with content. These findings are consistent with emerging literature and align with the theoretical underpinnings of both Machine Learning Theory and Social Constructivism, which frame AI not just as a delivery tool but as a responsive and interactive educational partner.

AI's ability to personalise science learning is one of its most significant contributions to modern education. Science subjects often involve abstract reasoning, sequential logic, and high levels of cognitive processing challenges that are not easily addressed through traditional, one-size-fits-all instruction (Amah & Okesipe, 2025). AI, particularly through intelligent tutoring systems and natural language processing tools like ChatGPT, offers adaptive instruction based on real-time learner data. Students in this study reported that AI applications helped break down complex content into manageable chunks, adjusted explanations to suit their comprehension level, and provided on-demand support without judgment. This aligns with Sanusi and Tukiainen's (2023) assertion that AI supports learning through dynamic, individualised feedback mechanisms designed to match the pace and level of each learner.

In the context of Machine Learning Theory, this dynamic responsiveness reflects the way AI algorithms process user data to improve instructional precision (Strielkowski, Grebennikova, Lisovskiy, & Rakhimova, 2024). Students noted that AI platforms could suggest additional resources or alternative problem-solving methods when difficulties arose. For example, tools like PHET simulations were praised for enabling students to visualise experiments they couldn't perform physically, thus enhancing their conceptual understanding. This type of tailored, real-time support is a key advantage of AI, particularly in science education where visualisation, modelling, and experimentation are essential for deep learning.

The concept of scaffolding, central to Vygotsky's Social Constructivism, resonates with the way AI enhances science learning. Scaffolding refers to the temporary guidance provided to learners to help them accomplish tasks they could not complete independently, gradually

withdrawn as competence develops. Within the Zone of Proximal Development (ZPD), AI can act as a digital scaffold by offering guided assistance that adapts in complexity as learners' capabilities expand (Hamdani & Yousif, 2025)

Findings from this study illustrate this process clearly. Several participants reported that AI tools provided a balance between support and autonomy. For instance, one student explained how AI-generated practice questions and tailored content recommendations helped them identify and address weaker areas without requiring constant teacher intervention. This demonstrates AI's potential to promote self-regulated learning, while still ensuring that learners operate within a supportive and adaptive framework mirroring the scaffolding function envisioned by Social Constructivism.

However, challenges emerged alongside these benefits. Some students expressed concerns that heavy reliance on AI could reduce opportunities for critical thinking and human interaction, raising questions about whether scaffolding might become over-automation rather than guided development. These findings reinforce the importance of positioning AI as a supplementary scaffold a tool to enhance, but not replace, teacher student dialogue and collaborative learning.

Stakeholder-Specific Recommendations:

- For policymakers: Establish ethical and inclusive AI education policies that ensure all students, regardless of socioeconomic background, have equitable access to AI tools. Policies should also require AI systems used in education to provide transparent scaffolding functions that complement, rather than replace, human instruction.
- For institutions: Invest in AI-enabled platforms that allow for adaptive scaffolding while embedding them within collaborative learning models. Training programs for educators should emphasise how to integrate AI into teaching without undermining critical dialogue or student agency.
- For educators/practitioners: Use AI scaffolding strategically to support learners in their ZPD, for example, assigning AI tools to provide personalised practice while reserving classroom time for collaborative, higher-order tasks. Teachers should actively monitor how learners engage with AI tools to ensure scaffolding transitions into independent competence rather than passive reliance.

By explicitly linking the theoretical construct of scaffolding to the empirical findings, and by tailoring recommendations to different stakeholder groups, the study underscores that AI has

significant potential as a supportive framework in science education provided its implementation maintains balance between technological assistance and socially mediated learning.

In addition to personalisation, AI was reported to enhance engagement and motivation two factors that are particularly important in science education, where learners often experience anxiety or disengagement due to the perceived difficulty of the subject. The interactive and exploratory nature of AI tools made learning feel more participatory and less abstract. Gamified platforms, real-time feedback loops, and problem-solving prompts-maintained student interest and encouraged curiosity. This experiential engagement with content fosters deeper learning and aligns with constructivist ideals, where knowledge is actively constructed through interaction with the environment and tools.

However, the findings also point to certain limitations and conditions necessary for these enhancements to be fully realised. While AI can personalise and enrich learning, its effectiveness depends on accessibility, digital fluency, and appropriate pedagogical integration. Some students in the study expressed concerns about unequal access to devices and reliable internet, which directly limits their ability to benefit from AI-based resources. Moreover, there were concerns about students becoming overly reliant on AI for answers without engaging in critical thinking or problem-solving. This reflects a need to position AI as a complementary tool rather than a replacement for foundational scientific reasoning and inquiry (Papaneophytou & Nicolaou, 2025).

Ethical concerns must also be acknowledged. AI-driven systems collect and process large volumes of personal data to function effectively. While this is essential for personalisation, it raises valid concerns about data privacy, algorithmic bias, and transparency, especially in educational contexts. As (Hakimi & Shahidzay, 2024) warn, if not properly governed, AI systems may replicate or amplify existing biases, which could result in unfair learning experiences for some students.

In conclusion, the findings of this study demonstrate that Artificial Intelligence (AI) holds significant potential to personalise and enhance science learning experiences. Learners highlighted that AI tools enabled them to engage with content at their own pace, provided targeted support for mastering difficult topics, and promoted greater autonomy. These benefits, however, were shown to be most effective when paired with sound pedagogy, equitable access to resources, and the implementation of clear ethical guidelines.

This conclusion directly addresses the primary research question: *What are the opportunities and challenges of incorporating AI into science education?* The findings reveal clear opportunities in the form of personalised learning and enhanced engagement, while also identifying key challenges such as ethical risks, over-reliance on technology, and inequitable access.

Regarding the first secondary research question, *how can AI applications be used to personalise and enhance science learning experiences?* the study found that AI can function as both a scaffold within the Zone of Proximal Development (Social Constructivism) and as an adaptive system that responds to learner data (Machine Learning Theory). Together, these roles highlight AI's dual capacity as both a social learning partner and a data-driven tutor.

In response to the second secondary research question, *what are the ethical and social implications of using AI in science education?* the findings underscored concerns around privacy, algorithmic bias, academic dishonesty, and unequal access. These concerns reinforce the need for robust policies, institutional safeguards, and teacher-led pedagogical integration that ensure AI is used responsibly and inclusively.

Taken together, the findings fulfil the study's objectives: (1) identifying the benefits and challenges of AI in science education, and (2) examining the ethical and social implications of its use. From a theoretical standpoint, both Machine Learning Theory and Social Constructivism support the conclusion that, when thoughtfully integrated, AI can enrich the science classroom by empowering students to learn more effectively, critically, and independently.

6.4 RESEARCH QUESTION 3

What are the ethical and social implications of using AI in science education?

The purpose of this research question is to critically examine the broader consequences beyond academic performance of integrating Artificial Intelligence (AI) into science education. While AI offers many advantages, such as personalising instruction and improving learning outcomes, it also raises important ethical and social concerns that may affect students, educators, and educational institutions.

This question is designed to explore issues such as data privacy, academic honesty, algorithmic bias, and unequal access to technology. It seeks to understand how students perceive the fairness, transparency, and responsible use of AI tools in their learning environments. Socially, it considers whether the use of AI reinforces or reduces inequalities in education, particularly

in diverse or under-resourced contexts like South Africa. By addressing this question, the study aims to ensure that the use of AI in science education is not only effective but also equitable, inclusive, and ethically sound. It highlights the need for thoughtful policies, digital literacy, and ethical guidelines to protect students while maximising the benefits of AI integration.

6.4.1 Ethical Issues of Using AI in Science Education

The integration of Artificial Intelligence (AI) into science education presents exciting possibilities but also introduces several ethical concerns that must be carefully addressed. The findings from this study reveal that students are not only aware of the benefits of AI, but also of its potential to negatively impact their learning when used inappropriately or without proper safeguards. As the graph below (Figure 6.3) illustrates, the most cited ethical issue among students was data privacy, with 58.1% expressing concern about how AI tools collect, store, and use their personal information. This is consistent with the literature, where scholars such as (Hakimi & Shahidzay, 2024) warn that educational AI systems often operate as opaque “black boxes,” making it difficult for users to understand how their data is processed. Students in the study echoed this uncertainty, with some noting they were unsure how secure their data was when interacting with AI-based platforms.

Academic dishonesty, including the use of AI for cheating or plagiarism, was another critical issue raised by 54% of students. Many admitted to using AI to complete assignments without fully engaging with the content, an issue also highlighted in the literature by Holmes and Ronghuai (2022), who caution that AI, if misused, can erode academic integrity. This concern reflects the growing ease with which students can generate AI-written content, often without adequate understanding of the underlying science (Alam, 2021). Over-reliance on AI, cited by 51.2% of participants, was another prominent theme. Students noted that constant use of AI tools could reduce their ability to think independently or critically, especially in subjects like science that require problem-solving and analytical thinking. This aligns with constructivist theory, which emphasises the importance of learner agency and cognitive engagement elements that can be compromised if students use AI as a shortcut rather than a learning aid.

Other ethical concerns included misinformation and inaccuracy (49%), where students reported receiving incorrect or overly generalised answers from AI tools. This reinforces the need for critical evaluation of AI-generated content, a point strongly supported by Bali (2017), who argues that AI is only as reliable as its training data and algorithms. Issues of bias in AI systems (45%) and lack of transparency (43%) were also raised, highlighting fears that AI might

unfairly favour certain types of learners or provide inconsistent recommendations, as noted in literature by Chakroun & Daelman (2018).

While AI can be a powerful tool in science education, its integration must be accompanied by clear ethical guidelines, comprehensive digital literacy training, and strong institutional oversight. Students should not only be trained to use AI tools effectively but also be made critically aware of their limitations. For example, AI systems may produce biased outputs due to skewed training data, oversimplify complex concepts through algorithmic shortcuts, or generate inaccurate information when applied outside their intended scope. Over-reliance on AI also risks diminishing students' problem-solving and critical thinking skills if not balanced with human-guided inquiry and collaborative learning. Furthermore, unequal access to AI resources could deepen existing educational inequalities if not addressed through deliberate policy and institutional investment. By foregrounding these challenges alongside its potential, educators and institutions can ensure that AI fulfils its promise of enriching science education without compromising ethical standards, equity, or holistic student development.

Students' perceptions of the key ethical issues associated with using AI in science education

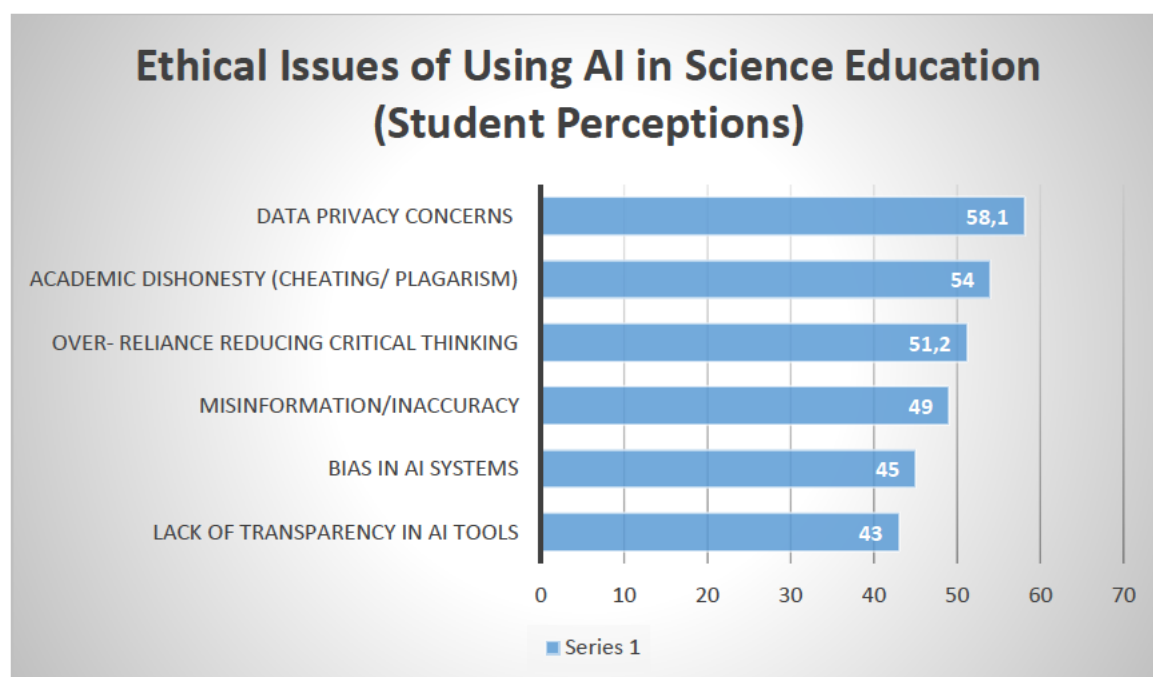


Figure 6. 4: Ethical Issues of Using AI in Science Education (Student Perceptions)

The graph visually represents students' perceptions of the key ethical issues associated with using AI in science education. The highest concern is data privacy (58.1%), indicating that students are uncertain or uneasy about how their personal information is collected and used

by AI tools. This is followed closely by academic dishonesty (54%), where students acknowledge that AI can be misused for cheating or plagiarism.

Other notable concerns include over-reliance on AI (51.2%), which may reduce critical thinking, and misinformation or inaccuracy (49%), where students noted that AI sometimes provides incorrect or misleading answers. Concerns about bias in AI systems (45%) and lack of transparency (43%) reflect deeper issues around fairness and accountability in AI decision-making.

Participant Quote:

"AI tools are great, but sometimes I miss the direct help and discussion with my lecturers and classmates." (Student 14, interview)

These social shifts demand careful balancing of AI's benefits with maintenance of human connection and inclusiveness, particularly in resource-limited contexts like South Africa.

Overall, the graph highlights that while students may benefit from AI, they are highly aware of its ethical limitations and the need for responsible, well-regulated use in educational setting

Link to Research Objective 3

The study fully addresses the objective to explore ethical and social implications, revealing complex challenges that must be navigated alongside AI's pedagogical advantages.

The ethical and social challenges identified in the study invite nuanced theorization through Social Constructivism and ethical critiques related to Machine Learning Theory.

From the Social Constructivist viewpoint, learning is understood as a social and cultural process, where knowledge is co-constructed through dialogue, collaboration, and shared problem-solving (Vygotsky, 1978). A key component of this theory is the Zone of Proximal Development (ZPD), in which learners achieve higher levels of understanding with appropriate scaffolding and guidance.

Findings from this study revealed, however, that students expressed concerns about reduced face-to-face interaction, marginalisation of those lacking digital literacy, and risks to peer collaboration. These challenges suggest that AI, if poorly integrated, may disrupt the very social dynamics essential for knowledge construction. Social Constructivism insists that communication, mentorship, and collective reflection are uncompromisable in fostering critical

thinking and professional skills. Thus, the findings emphasise that AI must be embedded in practices that promote inclusivity, dialogue, and mentorship, rather than isolating learners, to support holistic learner development (Panarese, Grasso, & Solinas, 2025).

In contrast, Machine Learning Theory focuses on how AI systems adapt to user data through algorithms, generating personalised recommendations and feedback (Russell & Norvig, 2010). Its central premise is that machine learning models improve as they process more data. However, the findings of this study showed that students were concerned about data privacy, academic dishonesty, misinformation, algorithmic bias, and lack of transparency. These concerns reflect the limitations of machine learning models: they are only as accurate and fair as the datasets and design choices underpinning them. Without oversight, such algorithmic decision-making risks perpetuating systemic inequities rather than mitigating them, undermining the very principles of fairness and accountability essential to education.

By combining these theoretical insights, the study highlights a critical need for governance frameworks that uphold social justice, data sovereignty, and pedagogical ethics. The findings reinforce that AI's transformative potential in science education can only be realised when its technological power is harmonised with human-centred values, ensuring that algorithms support equitable, collaborative, and critically engaged learning communities.

6.4.2 Social Implications of Using AI in Science Education

The integration of Artificial Intelligence (AI) into science education not only brings about technological and pedagogical changes but also carries significant social implications that must be carefully considered. These implications relate to issues such as digital inequality, access to educational resources, student-teacher dynamics, and the evolving role of human interaction in learning. The findings of this study suggest that while students recognise the benefits of AI, they are also sensitive to the social shifts and challenges that its use introduces.

One of the most prominent social concerns raised by participants was unequal access to AI technologies. Many students expressed that not all learners benefit equally from AI-driven tools due to disparities in internet connectivity, access to devices, and digital literacy. As one student shared, *“AI can help in learning, but some students don’t have the same access to devices or a stable internet connection.”* This finding aligns with (Rasheed & Bashir, 2025), who emphasises that the adoption of AI in education, particularly in the Global South, may unintentionally widen existing inequalities if infrastructure and support are not equitably distributed. Although 51.1% of participants agreed that AI has the potential to bridge

educational gaps, the neutral and disagreeing responses suggest that many students remain uncertain about whether this potential can be fully realised in their context.

Another key implication concerns the changing nature of student-teacher relationships. AI tools, by offering personalised support and automated feedback, may reduce the frequency and depth of face-to-face interactions between students and educators. While some students found this autonomy empowering, others expressed concern about losing the human touch in learning. For instance, one participant noted, *“Too much reliance on AI may reduce classroom interaction, and we still need that to learn deeply.”* This concern echoes the literature, particularly the work of (Abdulrahman & Al-Zahrani, 2024), who argue that effective education must balance technological innovation with social connection, collaboration, and mentorship.

Moreover, students noted a shift in peer interaction and collaboration, which are essential components of science education grounded in Social Constructivist theory. With AI tools increasingly used for individualised learning, opportunities for group work, debate, and shared problem-solving may diminish if not intentionally integrated into AI-supported learning environments. This change raises questions about the long-term impact of AI on social learning skills, such as communication, teamwork, and empathy skills that are crucial not only in education but also in scientific and professional contexts (Bhutto & Khaliq, 2025).

In addition, the use of AI has raised concerns about fairness and representation, particularly when AI systems are not transparent or inclusive in how they generate content or assess learning. Some students felt that AI tools were more helpful to certain learning styles, suggesting a potential bias in how these systems serve different learners. This concern reflects the findings of Chakroun and Daelman (2018), who highlight that the social design of AI must be inclusive and accountable to avoid reinforcing systemic biases in education.

In summary, the social implications of AI in science education are complex and multifaceted. While AI offers the potential to personalise learning and expand access to scientific content, it also poses risks of deepening educational inequalities, weakening human relationships, and reshaping the social fabric of learning environments (Chen, Hsu, Hsu, & Lien, 2023). These implications highlight the need for inclusive, human-centred, and socially aware strategies when implementing AI in science education particularly in contexts like South Africa, where equity and access remain critical concerns.

DISCUSSION

As Artificial Intelligence (AI) continues to evolve and find its place in educational settings, it brings with it a range of ethical and social implications particularly in science education, where accuracy, integrity, and equitable access are essential (Hakimi, Zarinkhail, Ghafory, & Hamidi, 2024). This study's findings highlight that while students acknowledge the value AI adds to their learning experience, they are also increasingly aware of the ethical dilemmas and social challenges it poses. These insights align with existing literature and point to the need for responsible, inclusive, and well-regulated implementation of AI technologies in educational contexts.

Ethical Implications

A central ethical concern that emerged from this study is data privacy. Many AI tools rely on collecting large amounts of student data to personalise learning, yet several students expressed uncertainty about how their data is being used or stored. One student remarked, *“I’m not always sure how my data is being used or stored.”* This reflects broader scholarly concerns raised by (Hakimi & Shahidzay, 2024), who caution that AI systems in education often lack transparency, putting students at risk of data misuse or exposure to third-party interests. In an educational environment where trust and security are vital, these concerns underscore the importance of strict data protection policies and user consent mechanisms.

Another prominent ethical issue is the risk of academic dishonesty. With easy access to generative AI tools, students can now complete assignments, answer tests, or write reports without genuinely engaging with the content. This study revealed that some students are indeed using AI to “do the thinking” for them, as one participant stated: *“Most students no longer want to do the work on their own, which hinders their knowledge.”* While AI can be an excellent support tool, misuse can erode the core purpose of education especially in science, where critical thinking and problem-solving are essential. Holmes and Ronghuai (2022) similarly warn that if AI use is not accompanied by ethical guidance, it can lead to a decline in academic integrity.

The study also uncovered concerns related to algorithmic bias and misinformation. Some students reported that AI occasionally provides inaccurate or overly generalised information, which can mislead users especially those who rely on it for understanding complex scientific topics. Inaccurate responses from AI can hinder rather than support learning, highlighting the need for students to critically evaluate AI-generated content. Furthermore, as Chakroun & Daelman (2018) point out, AI systems are only as fair as the data they are trained on. If those

systems carry implicit bias, they may disadvantage certain groups of learners, thereby raising serious ethical concerns about fairness, inclusivity, and representation in education.

Social Implications

Beyond individual ethical issues, the use of AI in science education also reshapes the social dynamics of learning, impacting relationships, access, and participation. One major concern raised by students was digital inequality. While AI has the potential to make education more accessible, this benefit is not evenly experienced. As several participants noted, limited internet access, lack of devices, and low digital literacy prevent some students from fully benefiting from AI tools. This was supported by the finding that only around half of the participants believed AI could help bridge educational gaps. Mhlanga (2023) argues that in low-resource settings, the integration of AI without equitable infrastructure may widen the gap between privileged and disadvantaged students.

Another social implication is the reduction in human interaction in learning environments. With AI providing instant answers and automated feedback, there is a risk that students may rely less on teachers or peers, potentially undermining collaborative learning. This concern was reflected in one student's response: *"Over-reliance on AI could reduce face-to-face interaction with teachers and classmates."* This shift contradicts the principles of Social Constructivism, which emphasises the importance of dialogue, collaboration, and social engagement in the construction of knowledge. If AI reduces these social learning opportunities, students may lose out on developing communication, teamwork, and interpersonal skills that are equally important in science education and the broader workplace (Amah & Okesipe, 2025).

In addition, some students highlighted concerns about fairness and inclusivity. While AI adapts to individual learners, it may not always support diverse learning styles equally. This raises the possibility that certain students especially those who learn better through discussion or hands-on activity might find AI less helpful. Furthermore, without transparency in how AI systems evaluate or recommend content, there is potential for biased or unequal learning experiences, particularly if students are unaware of how these tools operate or make decisions.

In conclusion, the ethical and social implications of using AI in science education are both profound and interconnected. Ethically, the findings revealed concerns about privacy, academic honesty, misinformation, and fairness. These directly address the study's secondary research objective of examining the ethical implications of AI use. Addressing these challenges

requires institutional policies, ethical AI design practices, and comprehensive student training in digital literacy.

On the social front, issues such as inequitable access, reduced face-to-face interaction, and shifting classroom dynamics were emphasised by participants. These findings speak directly to the secondary research objective of exploring the social implications of AI, demonstrating that without inclusive, human-centred implementation, AI risks deepening existing inequalities.

Together, these findings also respond to the primary research question and objective: *What are the opportunities and challenges of incorporating AI into science education?* While AI presents opportunities for personalisation, autonomy, and enhanced engagement, its challenges particularly around ethics and access must be carefully managed.

Both Social Constructivism and Machine Learning Theory provide useful lenses for interpreting these findings. Social Constructivism highlights the importance of preserving collaboration, dialogue, and mentorship, while Machine Learning Theory underscores the risks and possibilities inherent in data-driven adaptivity. Linking these theories to the findings reinforces the conclusion that AI must remain a supportive tool, not a replacement for human interaction and critical social learning.

Ultimately, for AI to be a transformative force in science education, its deployment must be transparent, equitable, and pedagogically grounded. This aligns with the broader purpose of the study: to ensure that AI contributes to sustainable and just educational outcomes in South African higher education. Educators, institutions, and policymakers must work together to guarantee that AI supports rather than replaces core educational values such as curiosity, collaboration, and critical thinking. Only through such a balanced, ethics-driven approach can the full promise of AI in science education be realised while safeguarding the integrity and social fabric of learning.

CHAPTER SUMMARY

Chapter Six presents a critical and detailed discussion of the findings drawn from both the quantitative (questionnaires) and qualitative (interviews) components of the study. The chapter responds to the three primary research questions and objectives, offering insights into how students at the University of KwaZulu-Natal perceive and experience the integration of Artificial Intelligence (AI) in science education. The analysis is framed by the theoretical lenses of Social Constructivism and Machine Learning Theory, which guide the interpretation of how AI supports learning and interacts with students' educational contexts.

Opportunities and Challenges of Incorporating AI into Science Education

The chapter begins by examining the dual nature of AI integration, highlighting both the perceived opportunities and the real-world challenges associated with its use in science education. A large majority of students, 72.1% reported that AI significantly enhances learning outcomes, particularly by making content more accessible, interactive, and easier to understand. 65.1% agreed that AI effectively personalises the learning experience, adapting to individual strengths and needs. Additionally, over half of the participants (53.5%) found AI beneficial for teaching science-specific content, especially through tools like simulations and chatbots that help simplify complex concepts.

However, the chapter does not overlook the limitations. A considerable 69.8% of students acknowledged significant implementation challenges, particularly within the South African higher education context. Students pointed to issues such as limited digital infrastructure, lack of access to devices or reliable internet, and inadequate training or awareness of AI tools. Moreover, 58.1% of participants expressed ethical concerns, especially around privacy, plagiarism, and over-reliance on AI. 51.2% noted that depending too heavily on AI may discourage independent thinking and reduce their motivation to engage critically with science content. These concerns echo the findings of scholars such as Holmes & Ronghuai (2022) and Mhlanga (2023), who argue for the careful, inclusive, and ethical integration of AI in educational settings.

How AI Personalises and Enhances Science Learning Experiences

This section of the chapter focuses on how AI supports individualised and adaptive learning, addressing the second research question. Students overwhelmingly expressed that AI tools such as ChatGPT and PHET simulations helped personalise their learning journey by offering content that matched their pace, preferences, and understanding level. AI was reported to provide customised study schedules, revision questions, and timely feedback all of which contributed to a more focused and less stressful learning experience.

For instance, 65.1% of students indicated that AI helped tailor learning to their individual needs, while 60% reported improved engagement due to AI's interactive and dynamic capabilities. These findings are reinforced by qualitative responses from interviews, where students shared how AI helped them grasp difficult scientific concepts, track their progress, and access learning materials anytime. This supports Machine Learning Theory, which posits that algorithms can adapt to learners' behaviours and offer tailored support (Al-Emran & Ghobakhloo, 2025). It also aligns with Vygotsky's Social Constructivism, where AI functions as a scaffold within the Zone of Proximal Development (ZPD), offering guided support that gradually fosters learner independence.

Ethical and Social Implications of Using AI in Science Education

The final section addresses the third research question by exploring both ethical dilemmas and social consequences associated with the use of AI in science education. Students raised valid concerns about data privacy, with many unsure of how their personal information is being collected and used by AI platforms. A recurring theme in both questionnaires and interviews was academic dishonesty, as students admitted to using AI to complete assignments without full comprehension. This trend poses a direct threat to academic integrity and undermines the core purpose of science education, which is grounded in inquiry, critical thinking, and problem-solving.

Socially, the findings emphasise the digital divide as a persistent barrier. While AI holds potential to democratise access to quality education, unequal access to internet connectivity, digital tools, and AI literacy continues to marginalise under-resourced students (Lowa, 2024). This concern is particularly relevant in the South African context and mirrors global findings regarding technological inequality. The chapter also highlights the shift in learning relationships, with students warning that overuse of AI could reduce meaningful interaction with peers and lecturers. From a Social Constructivist perspective, this reduction may hinder collaborative learning and the development of essential interpersonal skills.

Additionally, concerns were raised about bias and transparency in AI systems, with students expressing uncertainty about how AI tools make decisions or recommendations. This echoes the warnings of Chakroun & Daelman (2018), who emphasise that opaque and biased AI systems can undermine fairness and inclusivity in education.

Stakeholder-Specific Recommendations:

- For policymakers: Establish national AI-in-education guidelines that mandate transparency in data collection, protect student privacy, and hold AI providers

accountable for addressing bias. Investment in digital infrastructure should prioritise under-resourced schools and universities to reduce the digital divide.

- For higher education institutions: Develop and enforce clear policies on academic integrity in the context of AI, ensuring students understand acceptable and unacceptable uses of AI tools. Institutions should also provide structured digital literacy programmes that train students to use AI ethically and effectively, while upgrading campus infrastructure to improve equitable access.
- For educators/practitioners: Actively integrate AI into teaching in ways that encourage critical engagement rather than passive use. For example, lecturers can design assignments that require students to explain or critique AI-generated outputs. Educators should also combine AI-driven support with collaborative activities to preserve human interaction and peer learning opportunities.

By tailoring these recommendations to different stakeholders, the findings emphasise that AI's ethical and social challenges can only be addressed through a coordinated effort. Policies, institutional frameworks, and classroom practices must align to ensure that AI strengthens rather than undermines the integrity, equity, and social fabric of science education.

In addition, concerns about bias and transparency in AI systems were raised, with students expressing uncertainty about how AI tools make decisions or recommendations. This echoes the warnings of (Chakroun & Daelman, 2018), who emphasise that opaque and biased AI systems can undermine fairness and inclusivity in education.

Conclusion of the Chapter

This study provides a comprehensive exploration of the integration of Artificial Intelligence (AI) in science education within the South African higher education context, specifically focusing on the experiences and perceptions of third-year Natural Science and Technology students at the University of KwaZulu-Natal, Edgewood Campus. The investigation reveals a nuanced picture characterised by both significant optimism regarding AI's transformative potential and substantial concerns grounded in ethical, social, and infrastructural challenges.

Transformative Potential of AI

A central conclusion drawn from this research is that AI holds profound promise for enhancing science education by fostering adaptive, personalised, and student-centered learning experiences. Most students recognise the capacity of AI technologies such as intelligent tutoring systems, AI-powered simulations, and natural language processing tools like ChatGPT

to break down complex scientific concepts, offer tailored feedback, and scaffold learning in alignment with Vygotsky's Zone of Proximal Development. These adaptive capabilities align with Machine Learning Theory, where AI dynamically adjusts content and instructional strategies based on real-time learner input, thereby enhancing engagement and comprehension.

Students reported that AI helped them understand challenging scientific topics more effectively, create personalised study schedules tailored to their learning preferences and pace, and receive instant feedback that supported self-regulated learning. These findings emphasise AI's role not merely as a passive content delivery mechanism but as an interactive learning partner that cultivates learner autonomy and confidence, essential elements in mastering the cognitively demanding subject of science. The ability of AI to offer multiple problem-solving techniques and access to vast research resources further empowers students to deepen their inquiry and critical thinking skills when used appropriately.

Persistent Challenges and the Digital Divide

Despite these promising opportunities, the study highlights significant barriers that limit the equitable and effective deployment of AI in South African higher education. The digital divide emerges as a paramount concern, with underprivileged students facing inadequate infrastructure, unreliable internet connectivity, and limited access to devices. These inequities threaten to exacerbate existing educational disparities rather than mitigate them, risking that AI-driven innovations disproportionately benefit students in more resourced settings.

The infrastructural and accessibility challenges underscore that technology alone cannot fulfil AI's promise in education; rather, an inclusive strategy that ensures robust digital infrastructure and digital literacy is crucial. Without broad-based access, AI's potential to democratise science education and contribute to Sustainable Development Goal 4 quality, equitable, and inclusive education remains unrealised.

Ethical and Social Implications

Another critical dimension concerns the ethical and social ramifications associated with AI integration. Students expressed substantial concerns about data privacy, fearing insufficient transparency and control over how their personal information is collected, stored, and used by AI platforms. These anxieties resonate with wider scholarly debates warning against the opaque nature of many AI systems and the risks posed by algorithmic bias, misinformation, and potential misuse.

Academic integrity surfaced as a significant ethical challenge, with fears that AI tools could facilitate plagiarism and reduce genuine cognitive engagement, thereby undermining the educational process essential for developing scientific reasoning and problem-solving skills. Over-reliance on AI may also erode critical thinking and independent learning, which are vital for scientific inquiry and innovation. This calls for ethical guidelines and pedagogical practices that emphasise AI as a supplementary tool rather than a substitute for intellectual effort.

Socially, the study reveals concerns about reduced face-to-face interactions within learning environments, potentially diminishing collaborative learning and peer engagement critical to Social Constructivist educational principles. The reduction in human contact may impede the development of communication, empathy, and teamwork skills indispensable in scientific and professional domains.

Theoretical Integration and Educational Implications

The findings of this study strongly align with Social Constructivism, which posits that learning is an active, collaborative, and socially mediated process. AI's role should be conceptualised within this framework not as an isolating or replacing force but as a scaffold that supports learners' progression within their Zone of Proximal Development while preserving essential social dynamics. Concurrently, Machine Learning Theory underpins AI's ability to provide personalised, adaptive, and iterative learning experiences, suggesting that AI's educational impact is maximised when these two theoretical perspectives are harmonised.

For AI to successfully enhance science education, pedagogical integration is paramount. Educators must be trained to help students navigate AI tools critically and ethically, maintaining balanced learning environments where AI aids reflection, not replaces it. Curricular adaptations should embed AI literacy, ethical awareness, and digital skills development, preparing students for future scientific and technological landscapes.

Future Directions and Institutional Responsibility

The research points to urgent institutional and policy imperatives, including investing in equitable digital infrastructure, formalizing AI integration into curricula, establishing comprehensive ethical guidelines, and providing continuous support and training to educators and students. Engagement with AI in higher education must be guided by commitments to fairness, transparency, and inclusivity to mitigate risks and realise AI's full educational potential.

Moreover, there is a significant need for ongoing research to monitor long-term impacts of AI on learning outcomes, educator practices, and social dynamics, particularly within under-resourced educational contexts. Investigating the perspectives of educators, administrators, and policymakers will also strengthen understanding of systemic enablers and barriers.

In summary, this study concludes that Artificial Intelligence represents a powerful avenue for revolutionizing science education, offering personalised and engaging learning experiences aligned with contemporary pedagogical theories. However, realizing this potential requires concerted efforts to bridge infrastructural divides, uphold ethical standards, and preserve the social essence of learning. Thoughtful, inclusive, and well-supported integration of AI will ultimately enrich the educational landscape, equipping students to thrive in an increasingly complex and AI-integrated world.

This is a summary table of Chapter 6 from the dissertation on Artificial Intelligence in Science Education:

Section	Key Points	Supporting Details	Theoretical Link
Opportunities and Challenges of AI	AI enhances learning outcomes, personalised learning, science content teaching, bridging educational gaps	72.1% students find AI improves learning; 65.1% see personalised learning; 53.5% value AI for science; 51.1% see access benefits; challenges include implementation difficulties (69.8%), ethical concerns (58.1%), reduced critical thinking (51.2%), and access issues (47.6%).	Social Constructivism - AI as scaffold; Machine Learning - adaptive learning
How AI Personalises and Enhances Learning	AI provides personalised, adaptive learning; improves engagement and content understanding	65.1% agree AI personalises learning; AI generates study plans and questions; AI tracks progress and adapts support; enhances engagement (60%)	Machine Learning Theory - AI adaptive systems; Social Constructivism - scaffolding within ZPD
Ethical Issues of Using AI	Concerns on data privacy, academic dishonesty, over-reliance, misinformation, bias, and transparency	58.1% worried about data privacy; 54% academic dishonesty; 51.2% over-reliance reduces critical thinking; 49% misinformation; 45% bias; 43% lack transparency	Ethical AI governance; Social Constructivism - preserving social learning; Machine Learning - addressing bias

Social Implications of AI	Unequal access, reduced face-to-face interactions, changing student-teacher dynamics, fairness and inclusivity	Digital divide limits access: some fear diminished peer and teacher interaction; concerns about fairness and inclusivity in AI systems	Social Constructivism - social learning and collaboration critical
Discussion and Recommendations	Balanced AI integration preserving cognitive engagement and social learning, ethical policies, infrastructure investments	AI should complement, not replace, human interaction; policy and institutional support needed; teacher training emphasized	Integration of Social Constructivism and Machine Learning frameworks

Table 6. 1: Summary of Key Findings from Questionnaires on Students' Perceptions of Artificial Intelligence in Science Education

Table 6.1 captures the key themes, findings, and theoretical connections discussed in Chapter 6 of the dissertation summarising how AI presents both opportunities and challenges, and how thoughtful integration can maximise benefits while addressing ethical and social concerns. The table 6.1 presents a comprehensive analysis of the role of Artificial Intelligence (AI) in science education, highlighting its substantial potential to enhance learning outcomes, personalise educational experiences, and support science content teaching, while also addressing educational access gaps. Despite these opportunities, significant challenges persist, including difficulties in AI implementation, ethical concerns such as data privacy and academic dishonesty, risks of reduced critical thinking due to over-reliance on AI, and unequal access linked to the digital divide. The discussion integrates the Social Constructivism framework, emphasizing AI as a scaffolding tool within collaborative and social learning contexts, alongside Machine Learning Theory, which supports AI's role in adaptive, personalised instruction. Ethical governance and policy development are underscored as essential to mitigate risks, preserve cognitive engagement, and ensure fairness and inclusivity. The chapter concludes with recommendations advocating for balanced AI integration that complements human interaction, alongside investments in infrastructure, digital literacy, and educator training to maximise AI's benefits while safeguarding educational integrity and social learning dynamics.

CHAPTER SEVEN

CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 INTRODUCTION

This chapter presents a comprehensive summary of the research study, synthesising the key findings, theoretical insights, and implications discussed in previous chapters. It provides well-grounded conclusions based on both quantitative (questionnaire) and qualitative (interview) data, which explored students' perceptions of the use of Artificial Intelligence (AI) in science education at the University of KwaZulu-Natal.

The chapter revisits the research questions and study objectives to summarise the opportunities, challenges, and ethical and social implications of integrating AI into science teaching and learning. The findings indicate that AI has the potential to enhance educational outcomes through personalised and adaptive learning approaches, while also highlighting concerns related to digital access, ethical misuse, and shifting educational relationships.

In response to these conclusions, the chapter provides stakeholder-specific recommendations to support the responsible, inclusive, and effective implementation of AI in science education:

- **Policymakers:**
 - Develop national or regional guidelines to ensure ethical and equitable AI use in higher education.
 - Support initiatives that increase digital infrastructure and access to AI tools across universities, particularly for under-resourced institutions.
 - Fund professional development programs for educators on AI literacy and pedagogical integration.
- **Higher Education Institutions:**
 - Incorporate AI-enhanced tools and platforms into science curricula to support personalised learning experiences.
 - Establish clear institutional policies for the ethical use of AI, including data privacy and academic integrity protocols.
 - Create interdisciplinary support teams combining IT specialists, educators, and curriculum designers to facilitate AI adoption.
- **Practitioners/Educators:**

- Integrate AI tools thoughtfully to complement teaching practices, focusing on enhancing student engagement and understanding.
- Promote student awareness of ethical AI use, digital citizenship, and responsible learning practices.
- Participate in ongoing professional development to remain up-to-date with AI innovations relevant to science education.

The chapter also reflects on the limitations of the study, such as the focus on a single institution and a limited sample size, which may affect the generalisability of the findings. To address these gaps, future research could explore:

1. Comparative studies across multiple South African universities to evaluate the broader applicability of AI in science education.
2. Longitudinal studies examining the long-term impact of AI tools on student learning outcomes and engagement.
3. Investigations into the ethical, social, and psychological effects of AI use on students and educators in diverse socio-economic contexts.

Through this synthesis, the study aims to contribute meaningfully to the ongoing conversation about the role of AI in transforming higher education, offering practical guidance for policymakers, institutions, and practitioners while highlighting avenues for continued research and innovation.

FRAMEWORK: AI IN SCIENCE EDUCATION

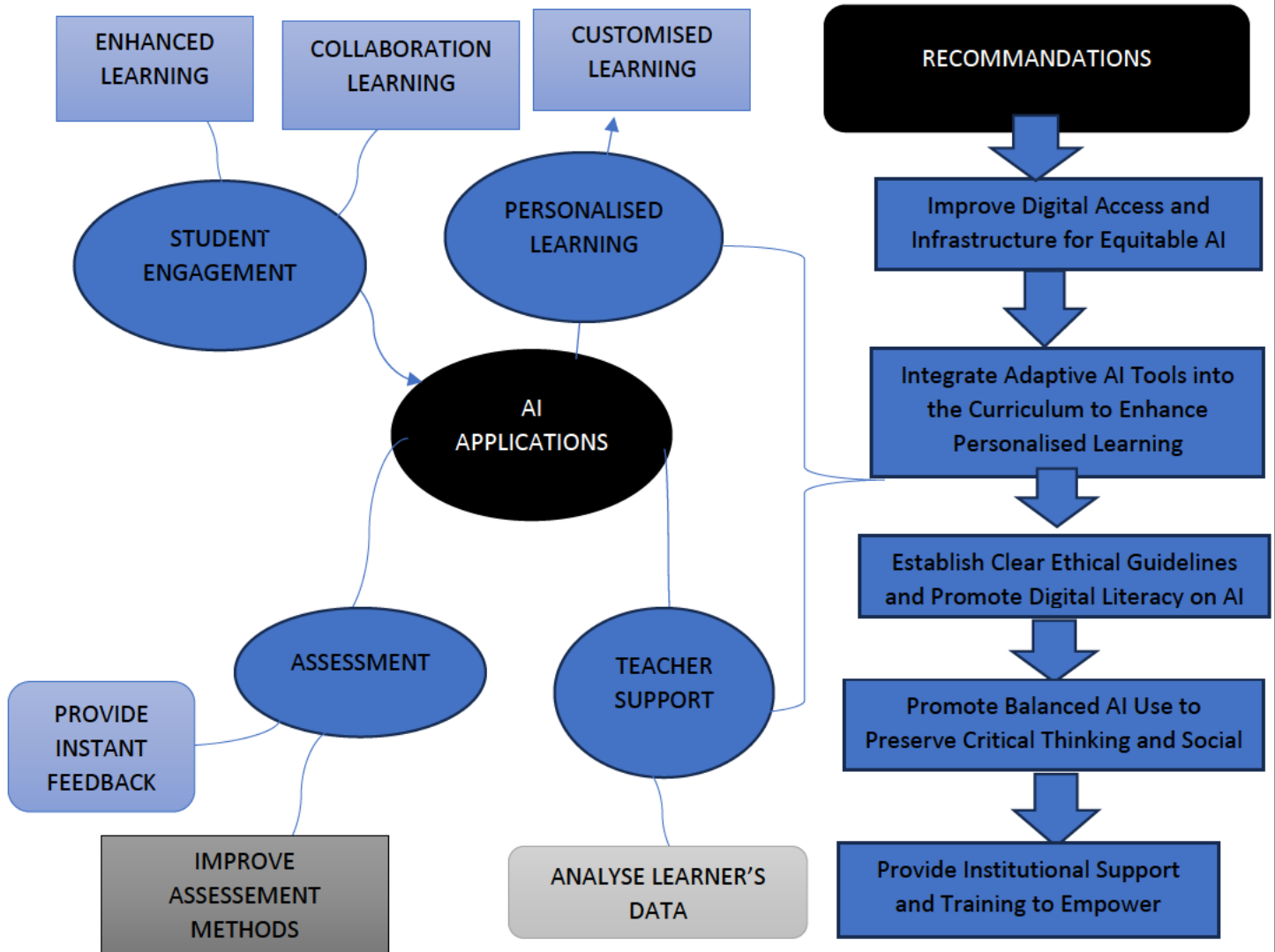


Figure 7. 1: Summary, Conclusions and Recommendations

Source: created by the author for this research purpose

This diagram provides a visual representation of how Chapter Seven is structured and how the elements of the research come together. It begins with the Summary of Key Findings, drawn from both the questionnaire and interview data. These findings are explicitly linked to each research question and study objective, ensuring that the conclusions are grounded in the study's aims.

The findings are then organised into three major conclusions:

1. Opportunities of AI in Science Education – highlighting how AI can enhance personalised learning, engagement, and educational outcomes.

2. Challenges to AI Implementation – identifying issues such as limited digital infrastructure, access disparities, and educator readiness.
3. Ethical and Social Issues – addressing concerns around digital literacy, responsible AI use, and the changing student–educator relationship.

Each conclusion directly informs a set of stakeholder-specific recommendations:

- Policymakers – guidance on infrastructure investment, policy frameworks, and ethical standards.
- Higher Education Institutions – advice on curriculum integration, institutional support, and staff training.
- Practitioners/Educators – strategies for classroom implementation, fostering responsible AI use, and professional development.

The next layer of the framework illustrates the broader implications of the study, linking the findings to potential influences on educational policy, curriculum design, and teaching practices. It also identifies areas for future research, such as longitudinal studies, multi-institutional comparisons, and investigations into socio-ethical impacts.

At the base of the framework is the overall contribution to knowledge, which summarises how this research adds value to both academic understanding and practical applications of AI in science education.

By explicitly defining each component and showing the logical progression from evidence → conclusions → recommendations → implications → contribution to knowledge, this framework clearly demonstrates the significance of the study's outcomes and reinforces its relevance to educators, policymakers, and institutions

7.2 CONCLUSION

Conclusion 1: The Digital Divide Undermines the Inclusive Potential of AI in Science Education

Linked to Research Question 1: What are the opportunities and challenges of incorporating AI into science education?

While AI holds considerable promise for enhancing learning outcomes and bridging educational gaps, this study's findings reveal that these benefits are not experienced equitably by all student populations. Students from underprivileged backgrounds and rural areas face limited access to AI tools due to unreliable internet connectivity, lack of digital devices, and insufficient technical support. Several participants noted that although AI could substantially improve science learning, practical barriers like bandwidth limitations and affordability issues often render it inaccessible. This reveals a critical challenge whereby the digital divide remains a significant obstacle to the fair and inclusive implementation of AI in education. Without targeted efforts to overcome these infrastructural and socio-economic barriers, AI technologies intended to democratize access risk inadvertently reinforcing existing educational inequalities in South Africa's developing context. Addressing these disparities is therefore fundamental to realizing AI's full potential to transform science education at scale and fulfil the study's objective of identifying both opportunities and challenges of AI integration.

Conclusion 2: AI Supports Personalised, Self-Paced Learning in Science Education

Linked to Research Question 2: How can AI applications be used to personalise and enhance science learning experiences?

A core theme emerging clearly from both the questionnaires and interviews is AI's powerful ability to customise learning experiences to meet individual student needs. Many participants reported actively using AI tools such as ChatGPT and PHET simulations to deconstruct complex scientific concepts into simpler, understandable components. These tools also helped generate topic-specific revision questions and provided real-time feedback that enabled learners to study and progress at their own pace. For instance, Participant Two explained how AI assisted in creating personalised study schedules tailored to their unique workload and revision preferences.

This experiential evidence directly aligns with the theoretical foundation of Machine Learning Theory, where intelligent AI systems continuously analyse student performance and adapt content delivery, pacing, and instructional difficulty in real-time to the learner's evolving behaviour and progress. The consistent positive feedback from students reflects growing appreciation for AI's role in fostering independent, adaptive, and student-centered learning environments particularly valuable in science education where sustained cognitive engagement and iterative revision are essential for mastering complex material.

Thus, the findings strongly support the research objective of understanding AI's capacity to personalise and enhance science learning by demonstrating how AI applications serve as responsive, dynamic learning companions that promote learner autonomy, improve comprehension, and increase engagement through tailored instruction and immediate, individualized support. This confirms that AI's integration in science education can create flexible, effective, and inclusive learning pathways adapted to diverse student needs.

Conclusion 3: Ethical Concerns Especially Around Data Privacy and Academic Integrity Are Strong and Widespread

Linked to Research Question 3: What are the ethical and social implications of using AI in science education?

Students demonstrated a clear awareness of the ethical risks associated with AI in education. A significant number expressed concern about how their personal data is collected, stored, and potentially shared by AI platforms. One participant stated, *"I've thought about data privacy when using AI tools. I'm not always sure how my data is being used or stored."* This reflects growing global concerns about surveillance, consent, and algorithmic accountability. Furthermore, students admitted to using AI to complete assignments or search for answers raising serious issues of plagiarism and academic dishonesty. While AI can serve as a powerful study aid, the misuse of these tools for bypassing intellectual effort undermines both the learning process and academic integrity. These ethical challenges call for urgent development of clear institutional policies, ethical guidelines, and digital literacy training to support responsible AI use.

Conclusion 4: AI Risks Reducing Critical Thinking and Collaborative Learning

Linked to Research Question 3: What are the ethical and social implications of using AI in science education?

Another key concern raised in both the survey and interview data is that over-reliance on AI may lead to a decline in students' critical thinking and problem-solving skills. Some students reported that the availability of quick answers from AI discouraged them from attempting tasks independently. One participant noted, *“Even for simple tasks we could think through ourselves, the first thing we think of now is using AI.”* This concern is particularly important in science education, where analytical reasoning and inquiry-based learning are central. Moreover, students pointed to the reduction in classroom interaction and peer collaboration, especially when AI tools are used in isolation. According to Vygotsky’s Social Constructivism, learning is most effective when it occurs in a social context with guidance, feedback, and shared understanding. The findings indicate that while AI may increase individual efficiency, it may unintentionally diminish peer learning, social engagement, and dialogic thinking, all of which are crucial to meaningful scientific understanding.

Conclusion 5: Positive Student Attitudes Toward AI Suggest Strong Potential but Also a Need for Support and Regulation

Linked to Research Question 1: What are the opportunities and challenges of incorporating AI into science education?

Despite the challenges, the overall student sentiment toward AI was largely positive. A significant number of participants expressed excitement about AI’s potential to support their learning, improve comprehension, and prepare them for future employment in a tech-driven world. However, they also acknowledged that their ability to use AI effectively depends on guidance, training, and curricular integration. Students repeatedly called for workshops, tutorials, or institutional support to better understand how to use AI responsibly and productively. This suggests that while students are ready to adopt AI, many lack the foundational support needed to use it in a way that enhances rather than hinders learning. Therefore, institutions must take proactive steps to embed AI use within the curriculum, establish usage guidelines, and ensure that all students not just the digitally advantaged can benefit from AI’s full potential.

7.3 RECOMMENDATIONS

Recommendation 1: Improve Digital Access and Infrastructure for Equitable AI Use

Linked to Conclusion 1 and Research Question 1: The Digital Divide Undermines the Inclusive Potential of AI

To ensure all students can equitably benefit from AI in science education, especially in resource-constrained settings like South Africa, institutions must make targeted investments in digital access and infrastructure. This includes expanding affordable and reliable internet connectivity across campuses and off-site learning environments, establishing well-equipped on-campus digital labs, and creating inclusive access points that cater to diverse student needs. Partnerships between government bodies, universities, private sector, and NGOs should prioritise providing low-cost or free digital devices and subsidised data plans to students from underprivileged and rural communities. Additionally, funding allocations must specifically address infrastructural deficits to reduce disparities in digital readiness. Implementing comprehensive digital literacy training programs for students and educators will further enable effective use of AI tools. These actionable steps directly address the study's findings on digital exclusion and uphold the research objective by mitigating barriers that otherwise reinforce educational inequalities, enabling AI to fulfil its promise of inclusive, quality science education for all.

Recommendation 2: Integrate Adaptive AI Tools into the Curriculum to Enhance Personalised Learning

Linked to Conclusion 2 and Research Question 2: AI Supports Personalised, Self-Paced Learning

Education departments and higher education institutions should formally integrate AI-driven adaptive learning tools into science curricula to maximize their pedagogical impact. This integration includes deploying intelligent tutoring systems, virtual labs, and AI-powered simulations that dynamically adjust to individual student progress and learning preferences. Teacher training programs must be developed to equip educators with skills to facilitate AI-enhanced learning environments that balance learner autonomy with instructional oversight. Educators should be supported to use AI as a scaffold that promotes independent, critical thinking while providing real-time personalized feedback. Curriculum design ought to embed AI literacy and promote ethical awareness to ensure responsible usage. These strategic and specific actions respond directly to students' positive experiences with adaptive AI applications

reported in the study and fulfil the research objective by operationalizing AI's role in personalising and enhancing science learning outcomes comprehensively and sustainably.

Recommendation 3: Establish Clear Ethical Guidelines and Promote Digital Literacy on AI Use

Linked to Conclusion 3: Ethical Concerns Around AI Are Widespread Among Students

Universities should implement clear, accessible ethical guidelines regarding AI use in academic work. This should be paired with mandatory digital literacy workshops that teach students about data privacy, appropriate use of AI tools, and the consequences of academic dishonesty. Educating students on responsible AI use will reduce misuse and promote trust, fairness, and transparency in AI-supported learning environments.

Recommendation 4: Promote Balanced AI Use to Preserve Critical Thinking and Social Learning

Linked to Conclusion 4: Over-Reliance on AI May Undermine Critical Thinking and Collaboration

Facilitators should adopt a blended learning approach that balances AI use with traditional pedagogical methods that foster critical thinking and social interaction. Group projects, peer-to-peer discussions, and inquiry-based activities should be emphasised alongside AI tools. This approach ensures that while students benefit from personalised assistance, they also develop essential analytical and interpersonal skills necessary in scientific practice and real-world problem solving.

Recommendation 5: Provide Institutional Support and Training to Empower Effective AI Use

Linked to Conclusion 5: Positive Attitudes Toward AI Require Institutional Support

Given students' openness to using AI, universities should develop structured training programmes and ongoing technical support to help students and staff maximise the educational potential of these tools. This includes workshops on how to use AI for studying, critical evaluation of AI outputs, and integrating AI into science assignments. Institutional guidance ensures that students use AI ethically, effectively, and confidently, enhancing the quality and depth of their learning.

7.4 SUMMARY

Chapter Seven serves as the final chapter of the study, bringing together the key insights and reflections drawn from the research on the integration of Artificial Intelligence (AI) in science education. It provides a comprehensive summary of the findings, structured conclusions aligned with each research question, and strategic recommendations aimed at improving both the ethical use and pedagogical application of AI in South African higher education. This study contributes theoretically by bridging Social Constructivism and Machine Learning Theory: it shows how AI's adaptive affordances (ML) can complement social scaffolding processes (Vygotsky) when pedagogically integrated. This combined lens highlights the need for AI implementations that both adapt to individual learners and actively preserve collaborative learning practices.

The chapter begins by revisiting the study's core objectives and research questions, summarising how the quantitative data (from questionnaires) and qualitative insights (from interviews) collectively informed the understanding of student experiences with AI tools. The summary of findings highlights both the enthusiasm students have for AI's capacity to personalise and support learning, and their concerns around its implementation challenges, ethical risks, and social implications.

From these findings, five key conclusions were drawn. First, the study reveals that while AI holds promise for enhancing learning, unequal access to digital tools and infrastructure remains a major barrier limiting the inclusivity and effectiveness of AI integration. Second, students view AI as an effective tool for personalised, adaptive science learning, supporting individualised feedback and improved comprehension. Third, strong ethical concerns emerged, particularly around data privacy, academic integrity, and the misuse of AI for completing assignments. Fourth, the study concludes that over-reliance on AI may weaken students' critical thinking and reduce meaningful classroom interaction. Lastly, despite these challenges, students expressed overall openness to AI, provided there is institutional support, training, and ethical guidance.

Based on these conclusions, the chapter offers several practical recommendations. These include expanding digital infrastructure to close the access gap; integrating AI tools meaningfully into science curricula; providing ethics and digital literacy training; balancing AI use with traditional, interactive teaching methods; and offering ongoing institutional support.

Together, these measures aim to ensure that AI enhances not hinders science education in equitable, ethical, and pedagogically sound ways.

Finally, the chapter reflects on the limitations of the study, such as the sample size and contextual scope, and suggests directions for future research, particularly in exploring long-term impacts of AI on learning outcomes and educator practices. Chapter Seven thus closes the study by consolidating its contributions and offering a roadmap for responsible AI adoption in education.

7.5 SUGGESTION FOR FUTHER RESEARCH

While this study offers valuable insights into students' perceptions of Artificial Intelligence (AI) in science education, it also opens several areas for further investigation. Given the dynamic and evolving nature of AI technologies, continued research is essential to deepen understanding and inform ethical, equitable, and effective integration in educational settings. The following suggestions are proposed for future research:

7.1 Longitudinal Studies on AI Impact

Future research could explore the long-term effects of AI integration on student performance, engagement, and skill development particularly in science education. A longitudinal design would help track how sustained use of AI influences learners' critical thinking, independence, and academic outcomes over time.

7.2 Educator Perspectives and Teaching Practices

This study focused on student experiences; however, understanding educators' views is equally important. Further research should examine how science teachers perceive AI tools, how they integrate them into teaching, and what professional development is needed to support effective use.

7.3 AI and Assessment Practices

There is a growing need to explore how AI impacts assessment in science education both formative and summative. Future research could investigate how AI tools are used for automated feedback, adaptive testing, and academic integrity monitoring, as well as their implications for fairness and reliability.

7.4 AI in Under-Resourced Educational Contexts

Since access to technology remains uneven, future studies should focus on the use of AI in rural or low-income educational environments. This could help develop more inclusive strategies for ensuring that AI benefits students regardless of their socio-economic background.

7.5 Ethical Literacy and Responsible AI Use

Given the ethical concerns raised by students, further research is needed to examine how ethical literacy can be built into AI-supported education. Studies could focus on designing and evaluating interventions that teach students and educators how to use AI tools responsibly and ethically.

7.6 Gender and Accessibility Dimensions

Further research could explore how gender, disability, and language barriers intersect with students' experiences of AI in education. Understanding these dimensions can support the development of more inclusive AI applications that cater to diverse learners. In addition, future studies could:

1. Conduct comparative studies across multiple universities in South Africa to assess how AI adoption and student experiences vary by institutional resources, location, and demographic composition.
2. Investigate the long-term impact of AI tools on learning outcomes, engagement, and retention in science subjects, using longitudinal research designs.
3. Examine students' and educators' perceptions of AI ethics and digital literacy in different socio-cultural and linguistic contexts, to identify barriers to responsible AI use and inform inclusive policy and curriculum design.

These specific research directions aim to address gaps in understanding equity, accessibility, and ethical considerations in AI-enhanced science education, thereby informing both practice and policy.

7.7 CHAPTER SUMMARY

In this study, the integration of Artificial Intelligence (AI) in science education at the University of KwaZulu-Natal was explored through the lenses of students' perceptions, experiences, and ethical considerations. The findings reveal a multifaceted landscape where AI holds considerable promise yet faces significant challenges that must be addressed to realise its full potential.

Firstly, AI demonstrates strong potential to enhance learning outcomes by personalizing instruction, making complex scientific concepts more accessible, and supporting self-paced learning. Students largely perceive AI as an empowering tool that can tailor educational experiences to individual needs and improve engagement, particularly in challenging STEM disciplines.

However, the study also highlights critical barriers, including the digital divide that limits equitable access to AI technologies, especially for underprivileged students. Infrastructure deficits, affordability issues, and inconsistent digital literacy threaten to deepen existing educational inequalities if not proactively addressed.

Ethical concerns emerged as a key theme, centering on data privacy, academic integrity, algorithmic bias, and transparency. Students voiced apprehensions about how their personal data is managed and the potential misuse of AI for plagiarism or over-reliance, which may undermine critical thinking and authentic learning. These insights underscore the importance of embedding robust ethical guidelines and digital literacy initiatives within AI adoption strategies.

Furthermore, the social implications of AI adoption were evident in concerns about diminished interpersonal interactions and collaboration within classrooms. AI should be positioned as a complementary tool that supports rather than replaces human mentorship, peer dialogue, and the social construction of knowledge.

Considering these findings, the study concludes that while AI can be a transformative force in science education, its successful and responsible integration requires a balanced approach. This approach must include investments in digital infrastructure, inclusive curriculum design, ethical governance, and ongoing training and support for both students and educators.

Overall, this research contributes valuable insights that inform policy, pedagogy, and further inquiry into AI's role in higher education highlighting that the benefits of AI will be best realised when aligned with equity, ethics, and human-centered learning principles.

CONCLUSION

The research on the integration of Artificial Intelligence (AI) in science education at the University of KwaZulu-Natal presents a comprehensive exploration of the opportunities, challenges, and ethical considerations that shape this evolving educational landscape. This study offers an in-depth understanding of how AI technologies influence students' learning experiences, perceptions, and the broader educational environment.

The findings underscore AI's transformative potential to personalise and enhance science education by adapting to individual learning preferences and promoting engagement with complex scientific content. AI-driven tools can support differentiated instruction and foster self-directed learning, which is particularly critical in demanding STEM fields where students often face conceptual difficulties. These strengths position AI as a valuable adjunct in improving academic outcomes and potentially levelling the educational playing field.

However, the research also reveals significant hurdles that impede the equitable and effective adoption of AI. Access disparities due to the digital divide highlighted by gaps in infrastructure, affordability, and digital literacy pose a serious threat to inclusivity. Without targeted interventions to bridge these divides, AI's benefits may primarily accrue to students with greater resources, thereby exacerbating existing inequities. This insight calls for systemic investments in digital infrastructure and the design of AI applications mindful of diverse socioeconomic contexts.

The study's emphasis on ethical concerns further deepens the discourse on AI in education. Students' apprehensions about privacy, data security, algorithmic bias, and the risk of undermining academic integrity highlight the complex moral terrain navigated by educational institutions. The use of AI tools must be accompanied by stringent ethical frameworks, transparent policies, and comprehensive digital literacy programs to safeguard students' rights and uphold the principles of honest and critical scholarship.

Moreover, the social dimension of AI integration emerges as a critical consideration. The potential reduction in face-to-face interaction and collaborative learning challenges the traditional social fabric of education. AI should be leveraged not as a replacement for human mentorship and peer engagement but as a facilitator that enriches social learning and nurtures critical thinking skills within interpersonal contexts.

In conclusion, this research advances a nuanced perspective that AI in science education offers profound opportunities intertwined with formidable challenges. Successful integration hinges

on a holistic strategy that prioritises equity, ethics, and human-centered pedagogy. Such a strategy involves robust policy frameworks, inclusive educational design, ethical governance, capacity building for educators and students, and continuous evaluation of AI's impact on learning outcomes and social dynamics.

By articulating these complexities and charting a path forward, the research contributes valuable guidance for educators, policymakers, and scholars. It underscores that the promise of AI in transforming science education can only be fully realised when aligned with commitments to accessibility, integrity, and the essential human elements of learning. This foundational work invites ongoing inquiry and collaborative efforts to harness AI responsibly for the advancement of equitable and effective education.

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LIST OF APPENDIXES

Appendix A- Informed Consent

Informed Consent Document

Dear Participant,

My name is Minenhle Latha (219026610). I am a Masters candidate studying at the University of KwaZulu-Natal, Edgewood Campus. The title of my research is, Artificial Intelligence in Science Education: A Study of Opportunities and Challenges. The aim of this study is to investigate the potential opportunities and challenges of integrating artificial intelligence in science education. I am interested in interviewing you so as to share your experiences and observations on the subject matter.

Please note that:

- The information that you provide will be used for scholarly research only.
- Your participation is entirely voluntary. You have a choice to participate, not to participate or stop participating in the research. You will not be penalized for taking such an action.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.
- The interview will take about (one hour).
- The record as well as other items associated with the interview will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed by shredding and burning.
- If you agree to participate please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

I can be contacted at: School of Humanities, University of KwaZulu-Natal, and Edgewood Campus. Contact details:

Email: [REDACTED]@stu.ukzn.ac.za;

Cell: 0 [REDACTED]

My supervisor is Dr Gachie who is located at the School of Humanities, Edgewood Campus, University of KwaZulu-Natal. Contact details:

Email: gachiee@ukzn.ac.za

Phone number: [REDACTED]

The Humanities and Social Sciences Research Ethics Committee contact details are as follows: University of KwaZulu-Natal, Research Office, Email: HSSREC@ukzn.ac.za

Tel: 0 [REDACTED]

Thank you for your contribution to this research.

DECLARATION

1

I, ... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.
I understand the intention of the research. I hereby agree to participate.

I consent / do not consent to have this interview recorded (if applicable)

SIGNATURE OF PARTICIPANT

DATE

.....

Appendix B- Research Instruments

Questionnaire

Appendix B :Questionnaire

Artificial Intelligence in Science Education: A Study of Opportunities and Challenges

Questionnaire

As part of my Masters research thesis at the University of KwaZulu Natal, Edgewood Campus. I am conducting a study to investigate Artificial Intelligence in Science Education: A Study of Opportunities and Challenges. Any information obtained in connection with this research that can be identified with you, will remain confidential. The results of this research will be beneficial to Schools, Department of Education and Higher Education Institutions.

Section A: Demographic Data

1. Your age (Select only one by ticking (✓) the box)

Below 20	
20 – 30	
31 – 40	
41 – 50	
51 and over	

2. Your gender (Select only one by ticking (✓) the box)

Female	
Male	
Other	

3. Year of study (Select only one by ticking (✓) the box)

1 st Year	
2 nd Year	
3 rd Year	
4 th Year	
Honours	

Section B: Artificial Intelligence in Science Education: A Study of Opportunities and Challenges

The following table examines some of the opportunities and challenges that are presented by Artificial Intelligence in Science Education students **Instruction:** *Indicate with a tick (✓) the extent to which the following statements are Yes or No.*

	STATEMENT	YES	NO	NOT SURE
i.	Does the use of Artificial Intelligence enhance teaching and learning?			
ii.	Do you feel that AI can enhance your learning experience?			
iii.	Have you ever used an AI tool to help with assignment or research?			
iv.	Do you think that AI can be a valuable learning aid?			
v.	Are students using AI tools effectively?			
vi.	Do you think that AI could eventually replace human teachers?			

This section will be looking at the Artificial Intelligence in Science Education: A Study of Opportunities and Challenges. *Please tick (✓) your selected option.*

Question	Disagree	Strongly Disagree	Neutral	Agree	Strongly Agree
1) You are aware of the various Artificial Intelligence tools available for educational purposes.					
2) You believe that Artificial Intelligence can significantly enhance the learning experience for students.					
3) AI technologies can effectively personalise education to meet individual student needs.					
4) The use of AI in education can lead to improved educational outcomes for students.					
5) AI can help bridge the gap in access to					

Question	Disagree	Strongly Disagree	Neutral	Agree	Strongly Agree
quality education for underprivileged communities in South Africa.					
6) You have concerns about the ethical implications of using Artificial Intelligence in science education.					
7) AI applications are beneficial for teaching specific science content					
8) AI should be integrated into the curriculum to prepare students for future job markets.					
9) There are significant challenges in implementing AI technologies in South African universities.					
10) Do you believe that the future of education will be heavily influenced by advancements in Artificial Intelligence?					

Interview Questions

Appendix B :Interview

Interview

Artificial Intelligence in Science Education: A Study of Opportunities and Challenges

As part of my Masters research thesis at the University of KwaZulu Natal, Edgewood Campus. I am conducting an interview to investigate Artificial Intelligence in Science Education, Opportunities and Challenges. Any information obtained in connection with this research that can be identified with you, will remain confidential. The results of this research will be beneficial to Schools, Department of Education and Higher Education Institutions.

Section A: Demographic Data

1. Your age (Select only one by ticking (✓) the box)

Below 20	
20 – 30	
31 – 40	
41 – 50	
51 and over	

2. Your gender (Select only one by ticking (✓) the box)

Female	
Male	
Other	

3. Year of study (Select only one by ticking (✓) the box)

1 st Year	
2 nd Year	
3 rd Year	
4 th Year	
Honours	

Section B: Interview Questions

This section will have questions for a structured interview that investigate the use of Artificial Intelligence in Science Education looking at the opportunities and challenges.

1. What is your understanding of Artificial Intelligence and its role in education?

2. Can you provide examples of AI tools or applications you have encountered in your science classes?

3. In what ways do you believe AI can enhance your learning experience in science education?

4. How do you think AI can help personalize your learning journey?

5. Can you describe any positive experiences you've had with AI tools in your studies?

6. What challenges or concerns do you have regarding the use of AI in science education?

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7. Have you encountered any ethical issues related to AI in your educational experience, such as data privacy or bias?

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8. Do you feel that reliance on AI could impact your critical thinking or problem-solving skills? Why or why not?

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9. What barriers do you think exist for equitable access to AI tools in education, especially for students from different backgrounds?

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10. Looking ahead, how do you envision the future of AI in science education?

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Appendix C- Informed Consent Document

Informed Consent Document

Dear Student,

My name is Minenhle Latha (219026610). I am a Masters candidate studying at the University of KwaZulu-Natal, Edgewood Campus. The title of my research is, Artificial intelligence in science education: A study of opportunities and challenges. The aim of this study is to investigate the potential opportunities and challenges of integrating artificial intelligence in science education. Please consider participating in a online questionnaire to share your experiences and observations on the subject matter.

Please note that:

- The information that you provide will be used for scholarly research only.
- Your participation is entirely voluntary. You have a choice to participate, not to participate or stop participating in the research. You will not be penalized for taking such an action.
- Your views in this questionnaire will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.
- The questionnaire will take ten minute.
- The information you provide as well as other items associated with the questionnaire will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed of using the means of disposal committed to in the application.
- If you agree to participate please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

I can be contacted at: School of Humanities, University of KwaZulu-Natal, and Edgewood Campus. Contact details:

Email: [REDACTED]

My supervisor is Dr Gachie who is located at the School of Humanities, Edgewood Campus, University of KwaZulu-Natal. Contact details:

Email: gachie@ukzn.ac.za

Phone number: [REDACTED]

The Humanities and Research Ethics Committee contact details are as follows: University of KwaZulu-Natal, Research Office, and Email: HSSREC@ukzn.ac.za Tel: 031 260 4557/8350/3587.

DECLARATION

I..... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

I understand the intention of the research. I hereby agree to participate.

I consent / do not consent to have this interview recorded (if applicable)

SIGNATURE OF PARTICIPANT

DATE

Appendix D- Gatekeepers Letter



16 October 2024

Ms Minenhle Latha (SN 219026610)
School of Education
College of Humanities
Edgewood Campus UKZN
Email: 219026610@stu.ukzn.ac.za

gachiee@ukzn.ac.za

Dear Ms Latha

RE: PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research at the University of KwaZulu-Natal (UKZN), towards your postgraduate studies, provided Ethical clearance has been obtained. We note the title of your research project is:

"Artificial Intelligence in Science Education: A Study of Opportunities and Challenges."

It is noted that you will be constituting your sample by handing out questionnaires and/or interviews with Science Education students (Zoom, Skype or telephone interviews recommended) on the Edgewood campus.

Please ensure that the following appears on your notice/questionnaire:

- Ethical clearance number;
- Research title and details of the research, the researcher and the supervisor;
- Consent form is attached to the notice/questionnaire and to be signed by user before he/she fills in questionnaire;
- gatekeepers approval by the Registrar.

You are not authorized to contact staff and students using the 'Microsoft Outlook' address book. Identity numbers and email addresses of individuals are not a matter of public record and are protected according to Section 14 of the South African Constitution, as well as the Protection of Personal Information Act. For the release of such information over to yourself for research purposes, the University of KwaZulu-Natal will need express consent from the relevant data subjects. Data collected must be treated with due confidentiality and anonymity.

Yours sincerely



MR MA TUFTS
Director Governance & Administration

Office of the Registrar

Postal Address: Private Bag X54001, Durban, 4000, South Africa

Telephone: +27 (0)31 260 7971 Email: registrar@ukzn.ac.za Website: www.ukzn.ac.za

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

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Appendix E- Ethical Clearance Certificate



14 February 2025

Minenhle Latha (219026610)
School of Education
Edgewood Campus

Dear M Latha,

Protocol reference number: HSSREC/00007941/2024

Project title: Artificial intelligence in science education: A study of opportunities and challenges

Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 11 November 2024 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

Incidents of adverse events and serious adverse events (AEs and SAEs) should be reported in writing to HSSREC, the study sponsors, and any regulatory authority (where appropriate), within 7 working days of the occurrence for local sites and 14 days for all other South African sites.

This approval is valid until 14 February 2026.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,



Professor Dipane Hlalele (Chair)
/nng

Humanities and Social Sciences Research Ethics Committee

Postal Address: Private Bag X54001, Durban, 4000, South Africa

Telephone: +27 (0)31 260 8350/4557/3587 Email: hssrec@ukzn.ac.za Website: <http://research.ukzn.ac.za/Research-Ethics>

Founding Campuses:  Edgewood  Howard College  Medical School  Pietermaritzburg  Westville

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Appendix F-Turnitin Report

The screenshot displays the Turnitin Feedback Studio interface. At the top, a table lists the submission details:

Author	Title	Submission ID	Uploaded	Viewed	Grade	Similarity
Minenhle Latha	Artificial Intelligence in Sci...	2828138619	November 26, 2025			0%

Below the table, the browser address bar shows the URL: https://ev.turnitin.com/app/carta/en_us/?lang=en_us&u=29827605&ro=103&o=2828138619. The Feedback Studio header includes the user name 'Minenhle Latha', the document title 'Artificial Intelligence in Science Ed...', and a score of '/100'. The document preview shows a cover page for the University of KwaZulu-Natal, featuring the university's logo and the title 'Artificial Intelligence in Science Education: A Study of Opportunities and Challenges in a South African University'.