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Revolutionising Teaching and Learning Through AI: A Case Study of South Africa

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Abstract

This paper explores how artificial intelligence (AI) is revolutionising education with respect to teaching, learning and educational outcomes in K-12 schools. We examine the adoption and integration of AI technologies and tools in education and examine the impact of AI on personalised learning, assessments, administration, and skill development. The paper is a literature review of recent articles and policy documents published from the beginning of the decade, which facilitate an assessment of the current state of AI in education. We systematically compartmentalise each area of AI in education, and the main areas of focus are AI and educational policy, AI and teaching, and AI and learning. In the first section, the subject of AI and educational policy is examined; the second section focuses on AI and teaching; and the third section is dedicated to AI and learning. A case study on how AI has thus far been implemented in basic (primary and high school) education in South Africa is outlined; as well as the role played in the initiative by the Sci-Bono Discovery Centre – a science centre in Gauteng Province.

Keywords: Artificial Intelligence; Education; K-12; Personalised Learning; Assessments; Skill Development

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1. Introduction

Artificial intelligence (AI) technologies have not only brought about a paradigm shift in education, but also effectively revolutionised the domain at all levels. By way of definition, Niemi (2021:1) maintains that: "We do not have a single common definition of artificial intelligence (AI), but we have a common understanding that AI is changing the world." On the other hand, Fitria (2021:134) asserts that AI "is the process of modelling human thinking and designing a machine so it can behave like humans." According to the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2021:5): AI systems are information-processing technologies that integrate models and algorithms that produce a capacity to learn and to perform cognitive tasks leading to outcomes such as prediction and decision-making in material and virtual environments" and "are designed to operate with varying degrees of autonomy by means of knowledge modelling and representation and by exploiting data and calculating correlations" and they have "the capacity to process data and information in a way that resembles intelligent behaviour, and

typically includes aspects of reasoning, learning, perception, prediction, planning or control." Whether one is able to define AI or not, it is a phenomenon that that is not only an element of the Fourth Industrial Revolution, but also global revolution, in and of itself.

Whereas not all people would be inclined to work in AI-technology specific jobs, a basic understanding of AI is essential for children and adults alike because AI tools span across social and career use. As a result, the term "AI literacy" has emerged in recent times to encompass the proficiencies necessary in AI teaching and learning. According to the Intel® AI For Youth: Global AI Readiness Program (2021) Learning Objectives, the full scope of AI education includes the following aspects:

- Accurate understanding of AI technology and its impact to the society;
- Understanding AI concepts and distinguishing between AI & non-AI technology;
- Ability to advocate how AI can be applied at home and school;
- Gain insights of AI societal implications - employment, ethics, privacy, inequality, inclusion, bias; Ability to use AI tools and methodologies responsibly to create purposeful solutions;
- Applying the AI project development process & choosing the appropriate AI tools;
- Building AI solutions in 3 domains: computer vision, natural language processing, and statistical data;
- Modifying original AI model provided in the course to suit youths' project needs. Using AI to make meaningful solutions to address various local and global challenges;
- Identifying current issues in the community & determining the addressability of the issues with AI;
- Building an AI solution for an identified issue in the community; and
- Evaluating positive & negative implications of AI solution, & recommendations to minimize the negative implications (IAIFY, 2021:20).

The AI for Youth project is aimed at not only literacy, but also at gaining proficiency. However, some of the mentioned learning objectives above demonstrate the societal implications of AI that impact upon both users and non-users. At a macro level, there is a real-world demand for AI knowledge and use in industry, business, governance, and community. This has increased the demand for AI-trained IT professionals. This macro context demand raises a number of questions, according to Goel and Joyner (2017:48): "How can we satisfy the rapidly growing desire for learning about AI? How can we scale learning of AI so that it is repeatable and testable? How can we ensure that the quality of learning AI at scale is comparable to that in small residential classes?" These questions all speak to the real-life implications of AI as well as the imperative to initiate learning as early as possible.

It is common knowledge that access to IT and AI in the past has been a privilege enjoyed by those with elite education or who originate from higher socio-economic demographics. Thus, the drive to scale up AI education access is aimed at addressing this digital divide. Moreover, Butler-Adam (2018:1) emphasises that "to succeed as a member of society, and as an employee, in the era of the Fourth Industrial Revolution, numeracy, literacy and an understanding of how the world operates are all essential." The world is increasingly becoming automated and without foundational knowledge of AI, many will be left behind.

The micro level of education feeds into the mentioned macro domain and determines the extent to which the future workforce will have both AI literacy and proficiency. In this regard, Ng et. al. (2022) undertook a twenty-year review (2000-2020) of AI teaching and learning (AITL) and found that in the higher education context, the focus was more on computer science education. What they also discovered is that in the same period AI education had not yet become popular in K-12 education due to the lack of age-appropriate teaching tools (Ng et. al., 2022). Additionally,

while online education, particularly from the Covid-19 pandemic era onwards has rapidly developed, the extent to which it has been integrated into primary school education is understudied.

Revolutionising education through AI presents the technological dimension and its related capabilities and utilities. On the other hand, is the impact AI has on classroom relations. Guilherme (2019:47) names the former phenomenon, the "technologization of education" and examines the latter using the "I-It and I-Thou" relations concept. AI in the education context serves the dual purpose of performing cognitive and non-cognitive tasks. These tools can facilitate agency, self-efficacy, engagement, and collaboration if they are used correctly. Effectively, the interaction of technology and human users produces the kind of dynamics that can change and thus revolutionise human relations. In some cases, which could be beneficial, but in others, there could be unforeseen and detrimental outcomes, such as student learning in silos and insufficient collaboration.

This paper explores multifaceted AI capabilities that include the personalisation of learning experiences, streamlining assessments, facilitation of skills development, and provision of administrative support. All these technologies and the accompanying tools help to cater to the diverse needs of students in the digital age. However, as it will become evident throughout the paper, the introduction and integration of AI in education has not been without teething problems. Yet, despite the challenges of implementation, scaling and monitoring, the literature demonstrates that the opportunities outweigh the downside.

Literature on AI in education provides insight into the evolution of personalised learning, adaptive assessments, and competency-based skill development. From many studies (see Seo et. al. 2021; Salido 2023; Kenchakkanavar 2023; Ou et. al. 2024) we understand that AI-powered tools are able to significantly improve student engagement, academic performance, and retention rates. Some researchers (see Popenici & Kerr 2017; Celik et. al. 2022; Kim & Kim 2022) have explored the potential of AI algorithms for analysing student data to provide tailored learning experiences and feedback.

This paper is a literature review of recent articles and policy documents since the beginning of the decade that offer innovative research on the current state of AI in education. Much of the content on AI education addresses the various topics of the AI revolution in an integrated manner. This paper, however, attempts to systematically compartmentalise each area of AI capabilities in education. In the first section, the subject of AI and education policy is examined; the second section focuses on AI and teaching; and the third section is dedicated to AI and learning. The final section spotlights a case study on how AI has thus far been implemented in basic education in South Africa; as well as the role that the Sci-Bono Discovery Centre plays in the initiative.

2. AI and Educational Policy

The United Nations 17 Sustainable Development Goals are tailored to advance various areas of society including the goal of quality education. Thus, policymakers, scientists, educators, communities, and civil society at large are required to contribute their expertise and experience to facilitate the required development. Those who are specifically involved in education in various capacities have the opportunity to contribute to teaching and learning at a policy level by firstly helping educators and students to understand the socio-political context within which education takes place. This can be achieved by combining STEM or applied sciences, social science and humanities subjects that afford both technical and human knowledge. The teaching and learning of artificial intelligence are no different. The technical proficiencies have to be gained simultaneously with interpersonal competencies. The use of AI tools helps to enhance the learning process; however, it is robust policies that are responsive to cultural expectations which facilitate ethical and effective integration (Yusuf et. al., 2024).

A major task for all states and their education departments is to develop comprehensive AI-ready policies and curriculums. This is not only a process of developing policy and programme documents, but it also entails forging relevant partnerships with other sectors, as well as raising and allocating funds to the entire process. Thus, collaborations between government policymakers, educational institutions, researchers, educators, industry, and communities are crucial.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has formulated several policies, guidelines and recommendations pertaining to AI in education in service to its member countries. The "Beijing Consensus on Artificial Intelligence in Education" (2019) is the product of the International Conference on Artificial Intelligence and Education 'held from 16 to 18 May 2019 in Beijing. The actions that came out of the conference can serve as helpful guidelines for members to develop their own domestic policies, while benefiting from the resources provided by UNESCO. The six stipulated actions are the following:

1. Establish an 'AI for Education' platform to act as a clearinghouse for open-source AI courses, AI tools, examples of AI in education policies, regulatory frameworks and best practices on AI in education, with a view towards promoting the use of AI for SDG 4, supporting debate on the future of education and learning, and making open-source AI resources and courses accessible to all.
2. Develop guidelines and resources in consultation with Member States to support the development of policies and strategies for effective and equitable use of AI in education. Support the capacity-building of education policymakers.
3. Reinforce the leading role of UNESCO in AI in education across concerned sectors, divisions, or departments, and mobilize the Organization's institutes and networks.
4. Support the integration of AI skills into ICT competency frameworks for teachers and support countries in training teaching staff on working in AI-rich education settings.
5. Further expand UNESCO's cooperation in the field of AI in education with relevant United Nations and multilateral partners, as well as with regional development banks and organizations and with the private sector.
6. Undertake appropriate regional and international follow-up actions to the Conference, acting in cooperation with development partners active in this field, to build on and extend the outreach of the Consensus (UNESCO, 2019:10-11).

The Beijing Consensus actions have been quoted at length above because in combination they encompass the key policy undertakings that are required from any government, as well as the envisages outcomes of such AI in education policies. Subsequent to the Consensus, UNESCO developed the "Recommendation on the Ethics of Artificial Intelligence" (2021) to address a shared concern about the unintended consequences of utilising AI irresponsibly and unethically.

UNESCO (2021:5) explains AI ethics as a systemic reflection of norms based on the holistic, comprehensive, and multicultural framework of interdependent values, principles and actions that guide societies. These ethics are the basis of the normative guidance and evaluation of AI technologies that consider human dignity, well-being, and protection for harm (UNESCO, 2021:5). As a result, ethical questions pertaining to AI arise throughout the system's life cycle from research, design, development; to use or operation, financing, trade, maintenance, monitoring, evaluation; and finally, disassembly and termination (UNESCO, 2021:5). AI actors participate in at least one of the stages of the cycle and are situated in various systems of society. These actors are confronted with ethical questions across all sectors of industry, business, civil society, and community as well, as in the political domains of democracy, rule of law, human rights, and freedoms.

A future ethical concern about AI is the new world that it is creating where children of today will grow up in an entirely different world. This raises further existential questions about human experience, self-understanding, interaction, autonomy, agency, and dignity (UNESCO, 2021:6). In this respect, Giannini (2023:3) cautions: "We must not only look at what is happening today with these technologies but also project ourselves 20 or 30 years into the future. How do we balance the need to equip young people for a human-machine society, without undermining the human mind as we outsource certain cognitive functions? We cannot afford to experiment on a whole generation. Digital innovations can – and must – be designed to protect human agency."

In light of the in-progress revolution of education in the age of AI, companies that provide digital educational services are mushrooming, meaning that they too should be subject to AI ethics. In tandem to the growth of the AI sector, urgent regulations are required for the protection of children given the disruptions that accompany the innovations. To this end, UNESCO published the first-ever Guidance for Generative AI in Education and Research (September 2023), which complements the Recommendation on the Ethics of Artificial Intelligence (2021) and A guidance for Policy-Makers on AI and Education (2021).

3. AI and Teaching

Whereas this paper focuses on primary education, it is important to note the increasing adoption of AI in higher education. This has resulted in a growing demand for AI courses and programmes at universities and other institutions of higher learning (Goel & Joyner, 2017). Additionally, the use of generative AI (GenAI) which helps to automate teaching and research processes has become topical given its productivity, research, and ethical implications. Within a multicultural context, there is a strong correlation between cultural dimensions and the adoption and use of GenAI (Yusuf, Pervin & Román-González, 2024). In other words, cultural contexts and expectations inform the extent to which students are exposed to and comfortable with GenAI, as well as the potential for academic dishonesty and unethical behaviour. Above and beyond GenAI, Fitria (2021) outlines several tools and educational technology platforms that are widely applied across various levels of education:

1) Virtual Mentor;
2) Voice Assistant, for example, Google Assistant (Google), Siri (Apple), and Cortana (Microsoft);
3) Smart Content;
4) Presentation Translator;
5) Global Courses, for example, MOOCs, Udemy, Google AI, Alison, Khan Academy, edX, Udacity, Coursera;
6) Automatic Assessment;
7) Personalized Learning for examples Ruangguru;
8) Educational games; and
9) Intelligent Tutoring System (ITS) or Intelligent Computer Aided Instruction (ICAI) (2021:134).

It is important to note that many of the mentioned AI tools are used more readily in developed countries and developing countries have yet to catch up. This challenge does not detract from the exciting revolution taking place in the teaching components of education, which is the focus of this section. For example, in terms of pedagogy and curriculum delivery, AI is used for explaining knowledge. It is used for assessments and grading, and from an administration perspective, for attendance registers, reports, and various other systemic tasks.

Administrative tasks consume much time for teachers and usually contain elements of human error. With the integration of AI for administrative work, registers, grading, record-keeping, reports, and other daily tasks can be automated. The precision of AI also ensures a systematic approach to these tasks that are often cumbersome and time consuming. This effectively helps to reduce the workload for teachers. Virtual assistants for teachers also

facilitate efficiency by providing easy access to relevant information which cuts down on manual processes of sourcing such information.

AI can be used in a variety of ways to enhance the learning experience for students and teachers alike. AI can be particularly useful in primary schools to improve student engagement and motivation that enhances the teaching experience as well (CAPS 123, August 2023). Teachers can benefit from automated feedback because they receive feedback in real time and can thus make necessary adjustments in their teaching methods, sooner rather than later. This AI tool facilitates quality teaching that produces better learning outcomes (CAPS 123, August 2023).

AI-driven assessment tools have begun to augment or even replace traditional assessment methods. Some of the benefits of these tools are automation of the grading process, instant feedback on assessments to students, and generation of detailed analytics on student performance. AI-powered assessments offer a more holistic evaluation of student learning outcomes by measuring knowledge retention, critical thinking skills, problem-solving abilities, and creativity. Al these interventions aid the teaching process in ways that improve quality, efficiency, and effectiveness.

In terms of pedagogy, the first aim for teachers is to develop AI literacy. Educators have increasingly adopted various collaborative and project-based approaches to this end, including problem solving, software development, experimenting with robots and employing game elements (Ng et. al., 2022). AI-powered educational games and simulations help with engaging and interactive learning, which enables learner to participate proactively in their own education (CAPS 123, August 2023). However, the programming prerequisites make it difficult to scaffold the AI understanding of students. Thus, Ng et. al (2022) recommend suitable teaching tools, pedagogical strategies and support that shifts AI teaching from being technology-oriented to interdisciplinary design.

An area of research that is still underdeveloped is the extent to which technology supports pedagogies (Druga, Otero, & Ko, 2022). Through a Technological Pedagogical Content Knowledge (TPACK) framework, Druga et. al. (2022) analysed 50 AI resources to address this gap. They found that while most of the resources support active learning and have digital dependencies, they do not all include the “five big ideas defined by AI4K12 guidelines” and “do not offer built-in support for assessment or feedback” (Druga et. al., 2022:96). Furthermore, they discovered that many teaching guides are not accessible or require technical knowledge. Their recommendation was that AI curricula should move beyond singular activities and instead become more holistic by being more flexible to support pedagogy.

The advent of education in AI and AI for education has facilitated the use of the internet and cloud computing to scale up teaching in a way that reaches large population segments and has led to the development of “massive open online courses” (MOOCs) (Goel & Joyner, 2017:48). Key and successful examples of MOOCs include those developed by Peter Norvig and Sebastian Thrun’s “Introduction to Artificial Intelligence,” and Andrew Ng’s “MOOC on machine learning” (Goel & Joyner, 2017:48; Leckart, 2012; Raith, 2011).

All these AI tools and interventions do not mean that AI will usurp the teaching role. Instead, the time freed by the above technologies allows teachers to focus on non-systemic work which enables them to deliver quality teaching based on natural intelligence, which gives rise to new knowledge (Fitria, 2021). Thus, AI helps teachers to focus on providing individualised instruction to learners by automating routine tasks, while freeing them to deliver personalised learning. In this way, AI does not replace teachers, but is only a tool to enhance and complement what they already do. Separate SLAs should be entered into, covering the following below-stated areas with an incremental implementation approach:

The implementation of AI in and for teaching has not been without challenges. One overarching concern is the trustworthiness of AI in education in terms of ethics, bias of algorithms, privacy, transparency, and data ownership (Niemi, 2021). Moreover, in the context of human learning the issues of explainability and explicability are crucial. An ongoing challenge for the employment of AI in teaching is the lack of trained personnel to implement and maintain AI processes and programmes, as well as the insufficient training for teachers to operate and integrate AI in the classroom. With respect to training, Niemi (2021) finds that the role of the teacher in digital pedagogy usually involves only facilitation and coaching. Related to this practice, Guilherme (2019:47) speaks of the process of "learnification" which considers teachers to be mere facilitators of learning, rather than holders of certain expertise. This outcome usually arises from insufficient training in AI for curriculum use, where teachers only learn basic operations and do not know how to apply creativity in curriculum delivery by using AI.

In conclusion of this section, below is an illustration by UNESCO that provides an overview of the AI competencies recommended for teachers, which is included in the AI Competency Framework for Teachers to be launched during Digital Learning Week (2024):

Aspects	Progression		
	Acquire	Deepen	Create
Human-centred Mindset	Human agency	Human accountability	AI social responsibility
Ethics of AI	Ethical principles	Safe and responsible use	Co-creating AI ethics
AI Foundations & Applications	Basic AI techniques and applications	Application skills	Creating with AI
AI Pedagogy	AI-assisted teaching	AI-pedagogy integration	AI-enhanced pedagogical transformation
AI for Professional Development	AI enabling lifelong professional learning	AI to enhance organizational learning	AI to support professional transformation

AI competency framework for teachers (AI CFT) ***under development***

Source: UNESCO (2024)

4. AI and Learning

There are many AI-driven solutions for the classroom, including among others multimedia content, natural language processing (NLP), subject-specific software, and virtual assistants. Multimedia content such as interactive videos, animations and simulations help to enhance the learning experience. The specific AI technologies that help to personalise student learning are usually embodied in intelligent tutoring systems as well as intelligent learning environments (Goel & Joyner, 2017; Azevedo and Aleven, 2013; Koedinger and Corbett, 2006). These AI technologies also enable the scaling of teaching, while providing cognitive technology support for learning. According to the South African Department of Education (DOE) there are several AI applications in education that relate directly to learning:

1. Personalised learning: AI tools can adapt learning materials to individual students' needs, creating targeted learning experiences that are tailored to their abilities and preferences.
2. Adaptive assessment: Machine learning algorithms can analyse student performance and adjust future lessons, accordingly, ensuring they receive the optimal level of challenge and support.
3. Predictive analytics: AI-powered analytics can help educators identify students at risk of falling behind or disengaging, allowing for timely intervention and support.
4. Automated feedback: AI systems can provide real-time, personalised feedback to students, guiding them through the learning process and facilitating their growth (CAPS 123, July 2023)

Personalised learning is a pedagogical approach that tailor's instruction to the learner's needs and preferences, and capabilities. Through AI algorithms that analyse large amounts of data, customised learning pathways, adaptive content recommendations, and interactive simulations can be created for each learner. AI for personalised learning, helps educators to address diverse learning styles, foster individual pace, and adapt learning materials, in order to foster a more inclusive and effective learning environment. This approach helps learners who struggle with traditional teaching methods, by adapting to their learning style and customising their learning experience.

The study of an Indonesian primary school (grade 4-6) by Pardamean et.al. (2022) was aimed at measuring the impact of online AI-based learning in terms of its style prediction model. The personalised learning approach was followed to assess how the online learning portal recommended materials that matched the student's learning style. The authors subsequently formulated an AI algorithm that enables collaborative filtering-based AI models that are driven by learning style prediction and that can thus recommend material that is tailored to each learner (Pardamean et.al., 2022). They found that the developed model achieved satisfactory results and learner performance was also improved.

Additional and more advanced AI technologies in the classroom that can help learners include computers, software, coding, robotics, and machine learning. While the use of computers in South African primary schools is on the rise, incorporating AI in teaching and learning has revolutionary implications. The use of AI algorithms, for example, helps to analyse student performance data and to provide personalised recommendations. Virtual assistants, chatbots or intelligent tutoring systems (ITS) are also a revolutionary method of learning, as they assist students with answering questions, homework, and assignments and to provide personalised guidance and feedback.

Furthermore, AI software facilitates targeted and personalised adaptive learning that adapts to the knowledge of the student and enables them to engage concepts at their unique level, while their strengths and weaknesses are evaluated and supported (CAPS 123, July 2023). Moreover, NLP algorithms enable AI systems to understand and interpret human language, which allows for personalised feedback, responses to learner queries and assessment of learner understanding based on their responses (CAPS 123, July 2023).

Data analytics are an additional means to empower both teachers and learners (CAPS 123, August 2023). AI gathers and analyses data on student performance which can help the teacher to identify and resolve the learner's challenges in real time, instead of at the end of the term after assessments. In this way, the teacher develops targeted interventions that can improve performance earlier rather than later.

Deep learning is a growing technological approach in AI, and it uses the applied AI or machine learning approach, where neural networks are used as a method of training computers to function independently of human intervention (Perrotta & Selwyn, 2019). Within the ambit of education deep learning is also used by data scientists for creating online learning environments. The technology helps with predicting student educational performance. However, several issues and consequences with the use of deep learning, have been identified, namely:

> [R]elations between various (problematic) units of analysis: flawed data, partially incomprehensible computational methods, narrow forms of educational knowledge baked into the online environments, and a reductionist discourse of data science with evident economic ramifications. These relations can be framed ethnographically as a 'controversy' that casts doubt on AI as an objective scientific endeavour, whilst illuminating the confusions, the disagreements and the economic interests that surround its implementations (Perrotta & Selwyn, 2019:2).

Skill development is an essential component of preparing students for the demands of the future workforce that include industry-relevant technical skills, as well as critical thinking, problem solving, creativity, and communication. The early adoption of AI technologies can assist in identifying individual skill gaps, recommending personalised learning resources, and tracking skill progression over time. Other AI tools such as virtual reality simulations, gamified exercises, and AI interactive platforms can enhance skill acquisition and mastery, enabling students to develop competencies that are required for success in the 21st century. Some competencies that are needed for a wide range of AI-related careers and industries are coding and robotics.

Coding skills are crucial in the digital world they can be taught from primary school level. As with personalised learning of the educational curriculum, machine learning algorithms are able to analyse the coding abilities of the student and guide them in according to the needs and proficiency (CAPS 123, July 2023). Students are given real-time feedback on their coding, their errors are corrected quickly, and they are provided with tailored coding tutorials and exercises. AI-supported coding platforms can also facilitate collaborative work, idea sharing, troubleshooting and a sense of community among learners (CAPS 123, July 2023).

With regard to robotics, when robots are incorporated into the learning process, they facilitate hands-on learning experiences, foster critical thinking, and cultivate problem-solving skills. Part of the hands-on experience is programming the robots to perform certain tasks which teaches critical thinking and problem-solving skills. Robots that are AI-powered are engaging and practical, which provides an accessible way for learning about robotics from building robots to programming them (CAPS 123, July 2023).

Education has indeed been transformed by technologies such as mobile internet, cloud computing, big data, and AI in revolutionary ways. While they have been useful for facilitating student needs, they still fall short of addressing some concerns of many learners. Kabudi, Pappas and Olsen (2021) studied 147 publications from 2014 to 2020 to assess the extent and success of AI-enabled adaptive learning systems. As a guide to improving design of AI learning systems, they identified several types of interventions, major themes in the literature, common analytical methods, and techniques (Kabudi et. al., 2021). Further to Kabuti et. al. (2021), how AI impacts of learner styles and disabilities, demonstrates that it does not address all challenges. This requires more research and innovation in AI design to ensure that some students are not discriminated against (CAPS 123, August 2023). Thus, AI systems should be trained using diverse datasets that avoid bias and ensure inclusivity.

To conclude this section, below is an illustration by UNESCO that provides an overview of the AI competencies recommended for students, which is included in the AI Competency Framework for School Students to be launched during Digital Learning Week (2024):

AI competency framework for school students (AI CFS) *under development*

Aspects	Progression		
	Understand	Apply	Create
Human-centred mindset	Human agency	Human advancement	Citizenship in the AI era
Ethics of AI	Critical reflections on AI	Safe and responsible Use	Ethics by design
AI techniques and applications	AI foundations	Application skills	Creating with AI
AI system design	Problem scoping	Architecture design	Iteration and feedback loops

Source: UNESCO (2024)

5. Case Study

In the South African context, McNulty (2024) notes that there are some concerns regarding the role of AI in the classroom. As is the case with much of the literature, the concerns pertain to privacy, data security and the possible loss of the human touch in teaching and learning. The ethical considerations of using AI in education also arise from biased decision-making due to algorithms that are trained to be biased, and that assess students unfairly and inaccurately. Thus, there is a need for transparent and auditable use of AI systems that can safeguard against any potential misuse of student data. Therefore, a culture of collaboration between schools and the community is a key factor in a more humane approach to AI that integrates societal expectations, values, and needs.

In addition, the issue of inequality in terms of access to AI technologies requires equitable investment in infrastructure, to surmount the digital divide between well-resourced and disadvantaged schools (McNulty, 2024). However, McNulty (2024) acknowledges that investment in AI technologies requires an acceptance of the high immediate financial burden that should be considered in relation to the long-term benefit for learners. This cost analysis accounts for the potential of improving educational outcomes up against restricted budgets.

4.1. South African Primary Schools

The adoption of AI in South African schools is still limited and due to insufficient access to basic technology, and lack of infrastructure and resources (CAPS 123, August 2023). Even prior to engaging with AI, schools do not always have even basic or foundational technologies such as computers, tablets, and internet connectivity. As a result, these schools are left behind in the AI education revolution. The South Africa Department of Education acknowledges the infrastructure and digital divide and specifies internet connectivity as a particular challenge for the adequate functioning of AI technologies in schools (CAPS 123, July 2023). The Presidential Youth Employment Initiative (PYEI) in South Africa trains thousands of teacher assistants to promote and monitor reading programmes that use AI techniques and tools (CAPS 123, July 2023).

Regarding basic or primary education, the CAPS document is a set of guidelines established by the Department of Basic Education in South Africa for teaching and learning. It outlines each subject's curriculum and assessment policies across all phases, starting from foundation phase to Further Education and Training (FET). The CAPS 123 site also offers extensive resources for using AI in the classroom as well as guidelines for integrating AI based on how it

can revolutionise primary education, particularly for the South African context. CAPS 123 also provides current information on the progress of integrating AI in South African classrooms and below is a brief summary of promising advancements.

From a partnership perspective, South Africa boasts collaborations with global technology companies such as Microsoft and Google that help to facilitate the integration of AI into the classroom (CAPS 123, July 2023). These companies contribute AI tools for personalised learning, AI resources that include Math and Science learning applications, and technologies for tracking student progress.

In addition to the international partners, some local startups that specialize in AI education are on the rise. For example, Deep Learning Indaba helps to cultivate a community of AI researchers; and Zindi works with data scientists to solve continental problems using AI machine learning (CAPS 123, July 2023). The combination of both global and local partners is integral to enhancing the classroom experience and teaching and learning outcomes through AI by leveraging expertise that is at the cutting-edge of technology.

The ADvTech Group is the first company in South Africa to roll out, on a wide scale, its own AI-powered digital platform known as ADvLEARN (CAPS 123, August 2023). It enhances learning of Mathematics, Physical Science and Mathematical Literacy at the learner's pace by providing a personalised learning experience. DreamBox Learning is another example that assists students with Mathematics by using adaptive learning technology that matches the learner's skill level. Both platforms provide teachers with real-time data on student progress.

An example of an AI-powered tool currently used in South Africa for literacy and mathematics is Read to Lead (CAPS 123, August 2023). The tool employs NLP, machine learning and pattern recognition to facilitate the improvement of reading comprehension skills. Additionally, it provides interactive stories and quizzes tailored to each learner's reading level. Teachers are subsequently provided with real-time data on student reading progress, so that they may give learners additional support (CAPS 123, August 2023).

4.2. Sci-Bono Discovery Centre

Sci-Bono Discovery Centre is the largest Science Centre in the Southern Hemisphere, situated in the Gauteng Province and city of Johannesburg. It was established in 2004 for the promotion of Science, Technology, Engineering, Arts and Mathematics (STEAM) education. There are thirty-five (35) South Africa Agency for Science and Technology Advancement (SAASTA) accredited science centres, in South Africa's eight of its nine provinces. A science centre is a unique and valuable educational tool for school children in South Africa, as it provides an interactive learning environment that allows them to explore science and technology, and to develop their knowledge and understanding of the subject matter. Science centres are a great way to engage and motivate students, as they provide an environment in which students can explore, experiment, and interact with the material they are learning. In South Africa, science centres have been proven to be an effective way to enhance education and teaching.

In this case study, focus is on the Sci-Bono Discovery Centre (Sci-Bono), owing to the centre's long-term relationship with the Department of Basic Education (DBE), and specifically, the Gauteng Department of Education (GDE). The Sci-Bono is a hands-on facility that offers a variety of interactive exhibits, activities, and programs for all ages. The centre has a wide range of permanent exhibitions that focus on sciences, mathematics, and technology. It also features a variety of temporary exhibitions and educational programs that are specifically designed to engage visitors in the sciences. This includes lectures, workshops, and demonstrations that help visitors understand the science behind various topics. Sci-Bono also offers a variety of programs designed to foster science education in Gauteng Province. The centre also offers a range of after-school programs and summer camps that help to foster a culture of science and technology in the province.

Sci-Bono has been instrumental in helping to advance science education in Gauteng Province. Through its various programs and activities, it has helped to increase interest in science and technology in the province. The centre has also helped to create a culture of science education in Gauteng, providing students with the knowledge and skills necessary to understand the world around them. Since its founding in 2004, the centre has served over 1.5 million visitors and has helped increase the number of students pursuing science in the province. The centre has also received numerous awards, including the South African National Science and Technology Forum (SANSTF) Award for Excellence in Science Education.

With respect to AI in education, Sci-Bono has proven to be a trailblazer in this regard. Though its IT Academy, Youth Club and 4IR exhibit is has provided advanced technology and AI exposure and training. For example, Sci-Bono uses robotics (humanoids) to advance science education interest in a variety of ways as educational tools. Humanoid robots are robots that resemble humans in some form and are capable of performing certain tasks. The centre uses humanoid robots to teach various topics such as science, technology, engineering, and mathematics (STEM) to school-age children. The robots serve as a hands-on way of teaching complex concepts, allowing children to engage with the robots in a tangible way.

Sci-Bono has four main humanoid robots, each of which is programmed to perform a different task. The robots are programmed to interact with visitors and answer questions they may have. They are also programmed to help children learn basic math and science concepts, such as addition, subtraction, and the scientific process. The robots can be programmed to demonstrate experiments to the children, allowing them to interact with the robots and learn the concepts in a more engaging way.

Additionally, the centre also uses humanoid robots to teach coding and programming. The robots can be programmed to move in certain ways and follow specific instructions. This allows children to learn the basics of programming by controlling the robot and seeing the results of their programming in real time. The robots can be

programmed to play games with the children, such as Tic-Tac-Toe, allowing them to learn programming concepts and problem-solving strategies. Sci-Bono's use of humanoid robots as educational tools is an innovative way to engage children and to teach them STEM concepts. The robots allow children to interact with them in a tangible way and are programmed to teach complex concepts in an engaging way. The use of humanoid robots as educational tools has proven to be an effective way to engage children in STEM topics.

Another important initiative at Sci-Bono is the Intel® AI for Youth Programme. The programme was initiated from recognising that increased digitalisation requires investment in digital readiness, for countries to remain competitive in the global economy. Intel® Digital Readiness Programs empower non-technical audiences with the appropriate skillsets, mindsets, toolsets, and opportunities to use technology impactfully and responsibly in the AI-fuelled world. There is a crucial need to address the digital skill crisis, which is the gap emerging between new jobs that require digital skills and workforces that lack the required skills to fill these jobs. This gap is particularly pronounced with AI skills.

Sci-Bono has undertaken to be responsive to both the digital and AI skills gaps and is the GDE implementation partner of the AI for Youth programme that is part of the Intel® Digital Readiness Program. It is aligned with Intel's corporate purpose and RISE 2030 strategies and goals: Responsible; Inclusive; Sustainable; Enabling (IAIFY, 2021:4). Intel has rolled out Intel Digital Readiness Programs globally in partnership with government, academia, civil society, and industry stakeholders as a shared-value initiative to demystify and democratise emerging technologies. AI for Youth It caters to a diverse set of high school students in K-12 schools, in the age group 13-19, it only requires foundational maths and statistics skills, but no coding experience is required.

The AI for Youth learning journey takes place in three domains Statistical Data, Computer Vision (CV), and Natural Language Processing (NLP); and according to the following five levels:

1. Level 0 (Demystify) – Youth are excited by witnessing the possibilities of AI. They get to understand what AI is, and the problems it can address to create social impact. They do so while also keeping in mind potential pitfalls and developing an awareness about ethical & social implications of using AI.
2. Level 100 (Inspire) – Youth are inspired by getting hands on with the AI Project Cycle and various datasets, where they practice data acquisition, exploration, visualization, and mitigating biases.
3. Level 200 (Acquire) – Youth acquire the fundamental skills necessary to build AI Models and use No-Code AI tools. Youth are be exposed to domain specific No-Code tools in Data Analytics, Computer Vision, and Natural Language Processing (NLP).
4. Level 300 (Experience) – Youth experience building their own operational AI modules through computer programming. They are exposed to common AI libraries used for programming some of the most popular techniques in specific AI domains (Data, CV, NLP) through guided hands-on experiences.
5. Level 400 (Empower) – In this final stage, youth are empowered to deploy their projects in teams that use their skills to solve real-world problems while keeping social impact & ethical considerations in mind. They go through domain specific use-cases of AI before eventually developing and deploying their own AI solution (Sci-Bono Intel AI for Youth Briefing Notes, n.d.)

The executive summary of the Intel® AI For Youth (IAIFY) programme stipulates what the programme is, why it has been initiated and how it is delivered. It is an AI readiness programme for youth to gain demonstrable tech and social skills. It delivered through collaboration with governments, for non-tech K-12 education, currently in 11 countries, with a scaling commitment of 30 countries, 30 000 institutions and 30 million people employed in future jobs (IAIFY, 2021:4).

It aims to empower youth in an inclusive and democratising way with AI skills. It seeks to address long-term AI skilling gaps, while fostering responsible AI development through policy actions and human-centric capacities (IAIFY, 2021:4). In terms of how the programme is delivered, this takes place in Intel-powered AI labs with Intel certified coaches, and it uses hands-on modular learning that is based on experiential methodologies (IAIFY, 2021:4).

Public-Private and local partnerships are forged for scalability, sustainability and impact while undertaking real-world projects that have social impact and are recognised through Intel certifications (IAIFY, 2021:4). The full version of the programme consists of 176 hours of content across 33 modules in 4 stages; while the express version is constituted of 32 Hours of content across 11 modules in 4 stages (IAIFY, 2021:19).

Since 2022, the AI for Youth programme in collaboration with the GDE, has trained nine (9) Sci-Bono Master Trainers. The team started delivering the program in three (3) schools identified by GDE and the Sci-Bono Club House in 2022. In November 2023, there was a worldwide competition called Intel Global Impact festival. Students that created AI projects submitted them to an independent evaluation committee. There were over 1000 projects submitted and 126 projects made it to the actual global compete section of the festival. Three (3) projects out of the four (4) projects submitted by Gauteng students were part of the 126 finalist projects. One of the Gauteng projects received a Regional Country Award. This project is on showcase today at this event. Currently, Sci-Bono and the GDE are working on the expansion of this program to more schools in our province.

6. Conclusion

AI has the potential to revolutionise education in many exciting, complex, and daunting ways. This paper gave an overview of the policy considerations that are necessary to promulgate, implement and maintain AI in education. With resources from UNESCO among other entities, countries can take advantage of guidelines and recommendations for these own policies. In the second section, the actual AI technologies and tools that are used for teaching were discussed. Main advantages such as AI-powered administrative support, assessments, data analytics, algorithms, software, virtual assistants were discussed. By harnessing the power of AI, it was found that educators can create adaptive and inclusive learning environments that cater to the individual needs of every student. Additionally, the challenges that include insufficient funding, lack of AI skills and training, facilitator roles were all notes as areas to be addressed.

In the section on AI and learning, focus was place on the potential beneficial and performance outcomes of personalizing learning experiences, real-time assessments, and enhanced skill development for learners. It was also noted that the digital divide, particularly in developing countries impacts upon access to both traditional technologies such as computers and tablets, as well as the more advanced AI technologies. Moreover, issues of inclusivity and diversity are critical for disabled students, where algorithms have to be trained from a more diverse population. In terms of the ethical dimension of this revolution, it is imperative that as we navigate the digital age, we should embrace AI technologies responsibly and collaboratively to shape the desired future of education for generations to come.

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His scholarship is characterized by his association with research organizations and numerous publications, including book chapters, articles, and presentation in conferences. Professor Ntsobi is passionate about promoting the use of Indigenous knowledge systems for research enquiry, to that end, he has published and presented in conferences advancing Global Southern Epistemologies in knowledge creation.

Ntsobi is continually developing pedagogies for education, its integration with ICT and web-based strategies for optimum functioning of the education system. His PhD, titled “Pedagogical Integration of Technology as an enhancement to Teaching and Learning in Gauteng Public Schools” is a manifestation of his interest in the use of digital applications and scientific approaches for provision of pragmatic solutions.

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