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Educational Neuroscience Meets AI: A Framework for Secondary Science Teaching

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Abstract

This study investigates the transformative potential of integrating artificial intelligence (AI) into secondary school science education from an educational neuroscience perspective. A literature review of studies published between 2013 and 2024 was conducted to identify key trends, challenges, and opportunities. The thematic analysis of selected sources informed the development of a practical framework that highlights applications and ethical considerations for educators. Findings indicate that AI can personalise learning, promote critical thinking, and enhance teacher-student interactions. However, successful implementation requires alignment with neuroscientific principles, ethical safeguards, and comprehensive teacher training. Challenges include data privacy concerns, algorithmic bias, and ensuring equitable access to AI technologies. The proposed framework offers actionable strategies for effectively integrating AI into science education, emphasising teacher preparedness, ethical practices, and ongoing evaluation to optimize AI's impact on student learning. This novel framework bridges AI technology and educational neuroscience, providing valuable insights for educators and policymakers.

Keywords

Artificial intelligence, educational neuroscience, secondary school, science education, teacher framework

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Introduction

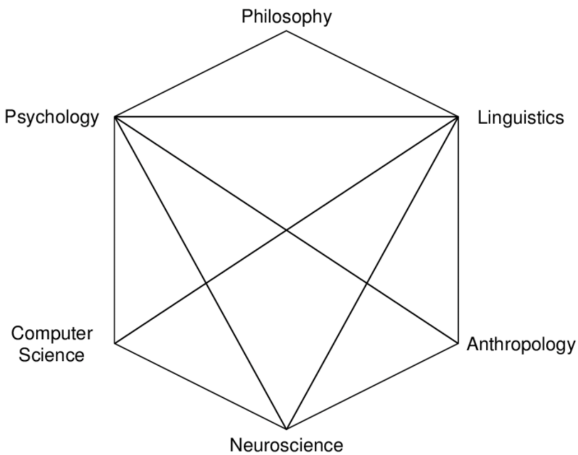
"Artificial intelligence is not a substitute for human intelligence; it is a tool to amplify human creativity and ingenuity". - Dr. Li, Stanford University Professor

Cognitive science is a field that bridges various disciplines and aims to decode the brain's mechanisms that support human cognitive and affective functions, including attention, perception, memory, reasoning, problem-solving, and decision-making (Piwowarski et al., 2019; Palmeri et al., 2017). As reflected in Figure 1, originally the main contributing fields comprised of philosophy, linguistics, anthropology, neuroscience, artificial intelligence, and psychology. However, over time, various areas of application have been included in order to cater for the needs of an everchanging society. One such important area is education.

Within the educational sphere, educational neuroscience refers to the link between brain-based mechanisms of mental activities and behaviours, particularly those related to learning (Howard-Jones et al., 2016). The objective of this particular area of study is to deepen our understanding of how humans learn and perform by merging the latest insights from brain imaging technology with the empirical evidence resulting from behavioural and psychological testing. As an emerging discipline, educational neuroscience finds itself at a pivotal juncture, between those who see great promise in integrating neuroscience and education and those who see the disciplinary divide as insurmountable (Wilcox et al., 2021). Some sceptics, like Bowers (2016), question the potential of neuroscience to enhance teaching methods. On the

Figure 1

The Original Cognitive Science Hexagon According to the Sloan Report (1978) Representing the Links Between Various Fields (Gentner, 2010)



teaching methods. On the other hand, proponents argue that insights into brain function, complemented by behavioural analysis, can indeed enrich our comprehension of learning processes, and potentially foster advancements in teaching and learning strategies (Howard-Jones et al., 2018). This paper proceeds with the argument that, as the brain is the central organ of learning, acquiring a more detailed understanding of its functions holds substantial significance for educational practices.

Building on the foundation laid by cognitive science, it becomes critical to explore the burgeoning interface between neuroscience and the field of computer science that deals with Artificial Intelligence (AI). Broadly defined, AI embodies the development of computer systems capable of performing tasks that typically require human intelligence, encompassing functions like perceptions, recognition, decision-making and control (Russell & Norvig, 2021). Neuroscience and AI share a long history (Macpherson et al., 2021) and the intersection of these disciplines heralds a new era in which the deep, nuanced understanding of brain functions and learning processes afforded by neuroscience converges with the dynamic, data-driven capabilities of AI. In fact, it is argued that a better understanding of the biological brain plays a vital role in building intelligent machines (Hassabis et al., 2017). Beyond this, in a recent scoping review, Surianarayanan et al. (2023) discuss the mutual relationship between neuroscience and AI and argue how neuroscience has in fact been instrumental in building complex applications like robot-based surgery, autonomous vehicles, and gaming applications across a wide range of fields. In turn, the power of AI to analyse complex data and extract patterns has been priceless in supporting and advancing multiple facets of cognitive science research, including an enhanced efficiency of testing hypothesis and interfacing with the brain to control electronic devices like robotic arms (Surianarayanan et al., 2023).

In recent years, as interactive technologies have advanced and become more widespread, their use both in and out of the classroom has increasingly gained popularity. Following this trajectory, the integration of AI within educational settings emerges as a natural progression, leveraging the confluence of neuroscience, AI, and interactive technologies to redefine the landscape of learning and teaching. From its beginnings, AI has been closely linked with education, viewed as a means for understanding human learning processes and applying these insights to advance AI itself (Doroudi, 2023). The infusion of AI into education capitalizes on the deep insights into human cognition provided by neuroscience and the advanced analytical prowess of AI.

The aim of this paper is to adopt an educational neuroscientific perspective in investigating the impact of AI in education, with a particular focus on the teaching and learning of science to secondary school students. It also seeks to propose a working framework to guide teachers through the successful pedagogical integration of AI in their practice.

Methodology

This study employs a narrative literature review approach to synthesise existing research on the intersection of AI, educational neuroscience, and secondary school STEM education. The purpose of this review is to explore key trends, challenges, and opportunities that inform the development of an evidence-based framework for integrating AI into science education.

The review draws from peer-reviewed journal articles, conference proceedings, and authoritative reports published between 2013 and 2024. Sources were identified through targeted searches in Scopus, Web of Science, and Google Scholar to ensure comprehensive coverage. The search terms included combinations of: *"Artificial Intelligence in Education", "Educational Neuroscience", "STEM education and AI", "Cognitive science in learning", and "AI and teacher-student interactions".*

Studies were included in this review if they:

- Examined AI's impact on cognitive and learning processes in education
- Addressed the integration of AI within STEM classrooms
- Discussed the role of teachers in AI-enhanced education
- Highlighted ethical, pedagogical, or accessibility considerations of AI in schools.

Studies were excluded if they:

- Focused on AI applications outside educational settings
- Did not include a neuroscience or pedagogical perspective
- Lacked empirical or theoretical contributions to AI in education.

The selected studies were analysed using thematic analysis (Braun & Clarke, 2006), which allowed for the identification of patterns related to personalised learning, neuroeducation, teacher-student interactions, ethical concerns, and the role of AI in fostering higher-order cognitive skills. To ensure rigour, two researchers independently reviewed and coded the literature, reconciling any discrepancies through discussion.

Results

As computer science technologies have advanced, coherent and adaptive AI technologies have found widespread application across numerous fields. In this process of deploying AI to enhance innovation, elevate our living standards and safeguard us from danger, it has become essential to also prioritise the implementation of AI in the field of education (Wang et al., 2022). In educational environments, AI technologies have had an extensive impact in supporting educators' teaching methods, enhancing students' learning experiences, and facilitating the transformation of educational systems (Chen et al., 2020; Ouyang & Jiao, 2021). One of the biggest educational challenges of the 21st century, as described by sustainable development goal 4 (UNESCO, 2015), is to develop innovative teaching and learning practices that promote inclusive and equitable quality education and promote lifelong learning. It is firmly believed that AI has the potential of greatly supporting this endeavour. Furthermore, AI is seen to lead a central role in both Education 4.0 and Education 5.0, heralding a pedagogical revolution that is transforming the educational paradigm (Rane et al., 2023).

In Science, Technology, Engineering and Mathematics (STEM) education specifically, automated AI technologies like intelligent tutors, automated assessments, data mining and learning analytics have all been employed to improve the quality of teaching and learning (Hwang et al., 2020; Chen et al., 2020). A systematic review of the application of AI technologies in STEM education conducted by Xu and Ouyang (2022) revealed STEM education as a complex system engaging with the emerging challenges of integrating diverse AI techniques. The paper discusses the potential transformation of teacher-student relationships, the promotion of student-centred learning and the possibilities of using AI to assist teachers in detecting learning patterns and behaviours. They also report on positive impacts of AI technologies on students' academic performance, affective perception, higher-order thinking and learning behaviours (Xu & Ouyang, 2022). Similarly, in a more recent bibliometric analysis of publications on AI in STEM education by Fatimah et al. (2024), the authors continue to confirm the strong, growing trend of AI tools to significantly help teachers automate and optimise teaching and learning activities and analyse students' learning processes to improve teaching patterns. The next section briefly delves into some of the most notable impacts of AI in STEM education as reported in the literature.

Teacher-Student Relationships

One of the areas in which AI has made a major impact is in redefining the roles of teachers and students within the learning environment. Interestingly, Xu and Ouyang (2022) revealed a predominant inclination towards teacher-centred strategies in AI-integrated STEM education, with a scant 5 out of 50 articles highlighting the adoption of project-based learning methodologies. This suggests a slower than anticipated shift from traditional teaching methods to more interactive, student-driven learning experiences. In contrast, findings from a more recent study by Huang and Qiao (2024) illustrate a significant pivot towards project-based initiatives in AI courses that incorporate Science, Technology, Engineering, Arts and Mathematics (STEAM, signalling a move towards more student-centred approaches. Such methodologies empower students to take the helm of their educational journey, engaging them in hands-on projects that not only enhance their understanding of STEM subjects but also nurture their AI literacy which is an increasingly essential skill in the digital age (Holstein and Doroudi, 2022)

Personalised Learning

Advancements in AI have paved the way for personalized learning, a tailored educational approach that accommodates the unique abilities, interests, and specific learning needs of each student (Kaswan et al., 2024). By harnessing the power of AI, educational platforms can now deliver customized content, adjust difficulty levels in real time, and provide targeted feedback, all of which contribute to a more individualized learning experience (Chassignol et al., 2018). The major impact here lies in the possibility of moving from the traditional "one size fits all" model of education, to a system which strives to adapt teaching and learning to fit the individual needs of students and supports them in reaching their full potential, at their own pace. Furthermore, rather than just focusing on extrinsic factors like a reward system, recent adaptive systems are also shifting their focus on learners' emotions (Taurah et al., 2020). An example of such a system studied in a STEM context is described by Walker et al. (2014), who developed an adaptive system to support students during peer tutoring in high school mathematics classes. More recently, a literature review carried out by Alabdulhadi and Faisal (2021) on the use of self-study simulator-based intelligent tutoring systems in STEM highlighted the importance of feedback and described the feedback traits required to determine positive learning outcomes.

Student Performance

The utilization of AI in educational settings has notably enhanced learner outcomes and attitudes, particularly in fostering creativity, accountability, and critical thinking skills (Zhai et al., 2021). Additionally, these systems excel in streamlining the assessment of student academic performance, significantly increasing the evaluation process's efficiency (Fatimah et al., 2024). Findings from a study by Su et al. (2024), which incorporated STEM principles in the development of an AI educational instrument, demonstrate enhanced student learning outcomes and a deeper comprehension of the taught concepts among students. Their findings also revealed a gender disparity, with girls achieving more substantial learning outcomes compared to boys (Su et al., 2024). In their 2023 study, García-Martínez et al. examined the effects of integrating AI with computational sciences on student performance. Their findings affirm the beneficial influence this integration has on student outcomes, noting an increase in students' enthusiasm for learning and their motivation, particularly within STEM disciplines (García-Martínez et al., 2023). These outcomes align with findings from Huang and Qiao (2024), whose research into the merger of AI with STEAM education revealed that it not only heightened students' enthusiasm for learning but also reinforced their computational thinking skills and boosted their self-efficacy. Other research has similarly highlighted the enhancement of skills such as problem-solving, critical thinking, and creativity, strongly affirming the significant role of AI in elevating the educational experiences of students. (Shumiye, 2024; Wang et al., 2022).

As any other emerging technology, AI also poses various challenges in education in addition to the benefits it offers educators and students alike (Akgun & Greenhow, 2022). It is of utmost importance that awareness is raised about such drawbacks before AI is implemented further within our schools and our classrooms, specifically in science and other STEM subjects.

The Role of the Teacher

First of all, we are living in very particular times in which cycles of innovative technologies are much shorter than the average modern human lifespan (Chng et al., 2023). Thus, unlike previous generations of educators, current STEM teachers need to adapt to the constant fast-paced changes which are not only impacting their lives in general, but also the subjects being taught, their students, and the way they teach. Shifting such mentality might be rather challenging, especially amongst generations of educators who are more experienced, and thus, more used to their own ways of teaching and learning of STEM subjects (Morrison et al., 2021).

It is essential to start by ensuring that the traditional idea of the teacher as the expert who leads students to passively absorb and regurgitate content in exams is not only discouraged theoretically, but also in practice. Despite the numerous research studies backing up active, student-centred teaching and learning in STEM subjects and beyond (Felder & Brent, 2024), conventional practices are still evident, especially when the system adopted remains pretty much exam- and content-oriented. Thus, prior to implementing AI as a pedagogical tool, such fundamental changes need to take place.

Educational neuroscientific research also confirms the importance of fully involving students in their own learning process. This allows for the activation of synapses, which in turn promotes neuroplasticity in the brain, allowing for further connections to be created (Drivas & Doukakis, 2022). Rees et al. (2016) describes neuroplasticity as the brain's capacity to change in a structural and functional manner through the lifespan due to numerous aspects including biological, genetic and even experiential factors. Therefore, as students spend most of their time at school, it is essential that the educational experience offered is conducive to learning and engaging. Despite the fact that the concept of neuroplasticity dates back to the 1890s (James, 1892), only recently was it possible for the living brain to be observed and studied in action due to the advancements in non-invasive neuroimaging techniques. As reflected in the review carried out by Kelly et al., (2008), empirical evidence confirms that such neuroplasticity is driven by experience, especially during adolescence, when the brain is highly susceptible to change, both on a structural and functional level (Lenroot & Giedd, 2006). This confirms that learning is the result of the dynamic interaction between the brain and the individual's environment and experiences (Rees et al., 2016).

Professional Training

It is essential to focus on the teacher's agency in the digitalised STEM classroom (Albion & Tondeur, 2018). A lack of sufficient, high-quality professional development training in the use of AI as a pedagogical tool might lead to more harm than good. Sufficient time needs to be dedicated to such training in order for teachers to feel confident in using AI to teach STEM subjects in their classroom. Additionally, the idea that AI is considered as a replacement to the teacher should be challenged. Importance needs to be given to the educators' self-efficacy as this will ensure that the teacher feels empowered enough to make the best of AI as a useful tool to support their teaching practices.

Costs and Access to Resources

There are various costs associated with the implementation of AI in education. Besides providing professional training to educators, resources such as necessary software, hardware and reliable internet connections all lead to a lot of costs to schools, which at times have limited funding. On the other hand, Martins (2024) highlights how AI can also be used as a cost reduction management tool. Therefore, it is essential to analyse the balance between benefits and costs related to the implementation of AI in schools.

Inclusion and Equity

The costs associated with the adoption of AI as a digital tool can only be one of the factors which can lead to further the divide between education systems, schools and even particular groups of students. Not all schools or families have the same resources and support. Additionally, disadvantaged children might not be provided with the opportunity to learn and use AI which might enable other more privileged children to flourish in their education (Edeni et al., 2024). This can apply to both the home environment and to the opportunities offered at school. On another note, AI can also be the tool which reaches particular students and offers them a personalised learning experience, as highlighted by Holstein & Doroudi (2022). Thus, it is essential for educational institutes to explore this field further.

Privacy

Despite current legislations which exist in order to protect sensitive personal data, violations by AI-based tech companies have led to concerns regarding the security of one's personal data (Murphy, 2019). This is more of an issue in educational settings which involve minors. Despite having various security measures in place, such as consent request, many individuals end up giving their consent without knowing or sharing more detail than they intend to (also known as metadata). This can include geolocation, racial identity and even the preferred language spoken (Regan & Jesse, 2019). Human agency and confidentiality are undermined if not enough attention is given to such matters, even if such data might not be given its due importance. In a school setting, parents and legal guardians also need to be fully aware of any AI system used in order to give their consent.

Surveillance

Most AI systems are equipped with tracking mechanisms based on algorithms and machine-learning models which enable the gathering of data in relation to the preferences and actions of the user (Regan & Jesse, 2019). In an educational setting, such surveillance systems can be useful in identifying students' strengths and weaknesses, as well as foreseeing specific learning patterns and even performances. Additionally, it can also be useful in detecting dangerous online activity, such as cyberbullying or exposure to inappropriate content (Akgun & Greenhow, 2022). Despite it being part of a teacher's duty to monitor and safeguard students from harm, using an AI tracking system might breach ethical boundaries.

Autonomy

As observed by the latest generative AI tools, such as Chat GPT, which can be very powerful in conducting a range of tasks from writing an essay to analysing a data set or even to creating artwork, a user's autonomy can be at risk. First of all, students might not have the necessary skills to sift through the information provided and be critical about what to accept as fact and what to identify as incorrect or misleading. In this case, the prompt used makes a huge difference in the output given. Students might be at risk of blindly plagiarising information which is provided to them based on previous patterns of data. Thus, algorithmpowered predictive systems can skew an individual's way of thinking and their decision-making process (Kerr & Earle, 2013).

Bias and Discrimination

Issues of bias and discrimination are considered fundamental in debates of AI in education. Various biases are embedded into the machine-learning models upon which AI systems are based (Krutka et al., 2019). These include, but are not limited to, racial bias and gender bias, which can lead to discrimination of a trait over another. Even if they are not included intentionally, these can be observed in numerous AI-based platforms (Stahl & Wright, 2018).

Such challenges should not discourage the implementation of AI in STEM education. However, key stakeholders should not only be aware of these issues but seek to actively solve them and turn these drawbacks into opportunities.

Teaching Science with the Brain in Mind

As reflected in the label associated with the end of the twentieth century, "The Decade of the Brain" (Zeer & Symanyuk, 2021), a lot of prominence has been given to the use and application of the knowledge we have acquired regarding the nervous system, the brain and its functions. Therefore, this application of knowledge has also been proposed in the context of our educational system in order to improve our teaching and learning processes (Piddubna et al., 2023), especially in the field of science and STEM education. Similar to the considerations required for AI to be applied to education effectively, applying neuroeducational principles, or neuropedagogy as it is sometimes referred to, also requires numerous deliberations. The right conditions are essential for the effective implementation of such principles to take place (Mynbayeva et al., 2017). This is based on a number of factors, varying from the social and cultural upbringing of children in our current globalised and everchanging world to the advancements in science and technology around us which impact the way we live and communicate. All of these factors impact the developing brain in various ways. Therefore, knowing the basics of how our brain functions is just a stepping stone to understanding the impact that all these changes have on various brain processes, especially in case of children whose brain might not be developed enough to deal with such changes. In fact, this has been reflected in the heightened rate of psychological, behavioural and emotional disorders that educators need to deal with on a daily basis in their classrooms (Peterson, 2018). Neuroeducation should equip educators with the right tools for them to be able to reach each and every student despite all the challenges.

First of all, science educators need to understand that, by nature, learning is driven by a sense of curiosity and inquiry (Voznyuk, 2019). We tend to focus on eliciting curiosity in early childhood education. However, this remains an essential starting point for learning through the years, even in adulthood and old age. This is what makes an educator grasp an individual's attention and interest them in learning a particular topic, be it in science, mathematics or any other subject. Thus, as educators we need to ensure that all our students are presented with the right environment and with the appropriate learning tasks which are conducive to an effective learning journey.

Furthermore, as educators we need to keep in mind the role emotions play in the learning experience. Despite the misconceptions, emotional processes are as important as cognitive ones and are strong precursors of learning achievement (Li et al., 2020). Brain imaging techniques have shown that specific parts of the brain, including the amygdala and the hypothalamus, are responsible for feelings which help us make sense of our surroundings and experiences (Šimić et al., 2021). Therefore, these should not be given any less importance in the learning process. Ensuring that a good rapport is built on trust and care with all students is the first step towards identifying any unmet needs which might not allow learning to take place. Therefore, if for example, a child is having issues at home, a teacher cannot expect that child to be able to focus on learning a scientific concept before regulating his emotions and tackling more basic issues first (Blake et al., 2003). It is also essential that the educator is also in touch with their own emotions as this impacts attention and the ability to think, problem-solve and reason things out. Furthermore, eliciting of emotions should be part and parcel of the teaching process. Research shows that positive emotions such as surprise, awe and humour can stimulate attention, motivate students and enhance the learning process (Immordino-Yang & Damasio, 2007; Porcelli et al., 2019). For example, Amran and Bakar (2020) found a strong positive correlation between positive emotions, like enjoyment, hope and pride, and memory in the learning of mathematics.

Another important factor is related to the fact that the brain is multifunctional (Piddubna et al., 2023). As the educator varies the type of activities which tap into the various senses, they do not only reach multiple students but also keep the students engaged as they receive information in a multimodal manner. The brain's interconnectivity also entails that a concept is approached in a multidimensional way in order to engage students in a way that is effective and conducive to learning, especially when it comes to problem-solving and application of knowledge to real-life scenarios (Newton & Miah, 2017). The nature of science and other STEM subjects, which promote the importance of a cross-curricular approach, also helps in this aspect.

As the brain analyses new information in light of prior knowledge, experiences and emotions, the importance of linking concepts is of utmost significance. Thus, the revisiting of previous experiences and the encouragement of making connections which consolidate the new knowledge and skills learnt is very beneficial (Terno, 2011). Despite the fact that learning starts as the result of synapses between neurons, the development of concepts or schemas is mostly related to the organisation of processes in neural networks. Such development of schemas has also been linked to extrinsic stimuli such as social interactions, as the human brain is highly capable of learning by modelling the behaviour observed thanks to mirror neural networks. Thus, the social aspect of learning is also an essential component which has been proven by neuroscientific research (Li et al., 2020).

Another important component of teaching and learning is assessment. In order for new knowledge to be merged with prior knowledge, it is essential for students to be presented with diagnostic formative and summative assessment opportunities (Drivas & Doukakis, 2022). In such a way, an educator can identify the prior knowledge that the individual has and build upon it in order to allow for learning and development to take place (Hwang & Chang, 2011). As educators, we need to move away from the idea of prioritising summative exams, which fail from accurately gathering a holistic image of what the learner truly knows. As previously mentioned, emotions play a crucial role in learning. Thus, how can we expect learners to perform well in an anxiety-inducing exam setup? Assessment should be a tool which provides feedback in a constructive manner that improves memory retention.

As clearly portrayed, teaching with the brain in mind helps educators improve their practices in order to reach all students entrusted within their care. However, how can AI support such an approach towards education? What is the connection between all fields involved?

Bridging the Gap

As highlighted by Doroudi (2023), cognitive science has played a crucial role in the intertwined history of AI and education. Most of the initial pioneers of AI were cognitive scientists who, in addition, also spearheaded significant changes in the field of education. Since the 1950s, such scientists have been united in their objective to discover how both humans and machines think and learn. The human brain has been rigorously studied to understand better ways of developing AI. Additionally, the computational models developed have also been used to describe theories of learning and even to simulate various brain processes in humans (Doroudi, 2023). Thus, the link has not merely focused on the application of AI to solving educational challenges but to adopting an interdisciplinary approach towards the fundamental questions linking education and AI. For instance, the AI pioneer and seminal figure in educational technology, Seymour Papert, highlighted how fundamental questions, such as 'How can we make a machine which will help us understand intelligence in general?' have been put aside and replaced by mere functional applications of AI. Similarly, he remarks how the aim of computer scientists was to bring computer science to children in the classroom, not simply get computers to the classrooms (Wright, 2002). Despite his background in the hard sciences, Papert (1980, as cited in Doroudi, 2023) worked closely with the famous psychologist Jean Piaget who helped him adopt a different perspective, as highlighted in his book *Mindstorms:*

> Two worlds could hardly be more different. But I made the transition because I believed that my new world of machines could provide a perspective that might lead to solutions to problems that had eluded us in the old world of children. Looking back, I see that the cross-fertilization has brought benefits in both directions. (p. 208).

Despite shifting apart through the years, such an interdisciplinary approach between AI and education is of utmost importance. The significance of thinking simultaneously about how our human brain functions and how AI-powered machines work is crucial in progressing further. We believe that educational neuroscience, as a specialized category in cognitive science, plays a pivotal role in bridging the gap between researchers and educators alike. Therefore, as educators and researchers in the respective fields, we are hereby presenting an evidence-based framework which will guide educators to implement AI as an essential tool in their classroom with a sound understanding of its effects on the teaching and learning process.

Framework

AI has the potential to transform both teaching methods and student learning experiences. Its successful implementation necessitates a thorough examination of its benefits and challenges. This paper proposes a framework focusing on key areas that can leverage AI for educational excellence:

Creating Inclusive and Equitable Learning Opportunities: Utilizing AI to ensure all students have access to tailored educational resources and support, thereby bridging learning gaps.

Detecting Learning Patterns and Behaviours: Employing AI analytics to identify students' learning needs, strengths, and weaknesses, allowing for timely interventions.

Enhancing Student Engagement: Capitalising on AI-driven interactive tools and simulations to captivate and maintain students' interest, thus fostering deeper engagement.

Customization and Personalization of Learning: Providing personalized learning experiences through adaptive learning platforms that cater to individual student needs.

Promoting 21st-Century Skills: Integrating AI to teach critical thinking, problem-solving, and digital literacy, preparing students for the future workforce.

Evaluation and Assessment: Implementing AI to provide more accurate, efficient, and continuous assessment of student performance, aiding teachers in identifying areas needing improvement.

Facilitating Collaboration: Utilizing AI to encourage collaborative learning not just among students but also between teachers and education stakeholders.

Ethical Considerations: Addressing the ethical implications of AI in education, including data privacy, algorithmic bias, and maintaining human oversight in educational decisions.

Conclusion

The findings of this literature review highlight the transformative potential of integrating AI into secondary school science education through an educational neuroscientific lens. The proposed framework addresses key areas such as personalised learning, enhancing teacher-student interactions, and fostering critical thinking and problem-solving skills. However, these findings prompt several points for discussion.

First, the successful implementation of this framework requires a nuanced understanding of the interplay between AI tools and cognitive processes. While AI can personalise learning experiences, its effectiveness heavily relies on the alignment of AI functionalities with neuroscientific principles, such as promoting neuroeducation and engaging multiple sensory pathways.

Second, ethical considerations remain paramount. The use of AI in classrooms must prioritise data privacy and mitigate potential biases embedded in algorithms. This underscores the need for transparent AI systems and informed consent from all stakeholders, particularly when deploying these technologies with minors.

Finally, the framework emphasises the importance of teacher training and professional development. Teachers must be equipped not only with the technical skills to use AI but also with the pedagogical knowledge to leverage AI in fostering an inclusive and equitable learning environment. Without such preparation, there is a risk of perpetuating existing educational inequities.

Overall, while the framework provides a structured approach to integrating AI in education, further empirical research and iterative feedback from educators are crucial for its refinement and effective implementation.

This study provides a literature-based framework for integrating AI into secondary school science education, grounded in an educational neuroscientific perspective. The framework underscores the potential for AI to foster personalised and engaging learning environments, enhance critical thinking, and improve student-teacher interactions. The discussion highlights that effective implementation depends on aligning AI tools with cognitive and pedagogical principles, addressing ethical concerns, and investing in teacher training.

Despite these promising insights, this study is limited by its reliance on existing literature rather than empirical data. The absence of primary research means that the framework has not been validated in real-world classroom settings. Future research should focus on testing and refining this framework through longitudinal studies and pilot programmes in diverse educational contexts. Additionally, exploring the long-term cognitive and social implications of AI integration will provide a more comprehensive understanding of its impact.

In conclusion, AI has the potential to revolutionise science education by fostering innovative teaching and learning practices. However, realising this potential requires a collaborative effort among educators, policymakers, and researchers to ensure ethical, inclusive, and effective implementation. By addressing the limitations and continuing the dialogue, the educational community can leverage AI to prepare students not only for technological proficiency but also for critical, creative, and collaborative futures.

Notes on Contributors

Clarisse Schembri Frendo is an educator; currently leading the Sciences & VETs department at a local private school. After graduating with a Bachelor of Education, she pursued a Master of Science in Cognitive Science. Besides leading her to a lecturing and supervisory role, this degree also equipped her with the required knowledge and skills to deliver workshops within various entities, such as Esplora. She also graduated with a PGCE in Educational Mentoring which fortified her competences in supporting NQTs. This positive experience has empowered Clarisse to embark on an educational journey leading to a doctoral degree through which she is focusing on science education, technology and educational neuroscience.

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