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The Relationship Between the Use of AI in Mathematics Education and Connectivism Theory

Bakri M. Awaji[(1)]

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Abstract: Artificial intelligence (AI) is increasingly shaping the educational landscape, offering new opportunities for personalized and interactive learning. This study explores the relationship between the use of AI in mathematics education and the principles of connectivism. Employing a qualitative, phenomenological research design, the study gathered insights from 19 participants, including mathematics educators and educational technology experts, through written responses to open-ended questions. Thematic analysis revealed four key themes: the impact of AI on mathematics learning, the enhancement of communication and learning communities, the role of AI in fostering critical thinking, and the alignment of AI usage with connectivist principles. The findings illustrate a significant alignment between the use of AI tools in mathematics education and the principles of connectivism. In addition, they suggest that AI tools enhance personalized and interactive learning experiences, support collaboration and promote the integration of diverse perspectives. However, the participants stressed the importance of maintaining human interaction to ensure meaningful learning and highlighted challenges, such as misinformation, the need for expert verification of AI-generated content and the importance of fostering AI literacy. . Further research is recommended to address ethical concerns, explore long-term impacts and ensure effective AI integration across diverse educational contexts.

Keywords: AI, Connectivism theory, Learning theory, Mathematics education.

العلاقة بين استخدام الذكاء الاصطناعي في تعليم الرياضيات والنظرية الاتصالية

د. بكري محمد عواجي[(1)]

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المستخلص: يُساهم الذكاء الاصطناعي بشكل متزايد في تشكيل المشهد التعليمي، مُتيحًا فرصًا جديدة للتعلم الذاتي والتفاعلي. تهدف هذه الدراسة إلى استكشاف العلاقة بين استخدام الذكاء الاصطناعي في تعليم الرياضيات ومبادئ النظرية الاتصالية. استخدمت هذه الدراسة المنهج النوعي، حيث تكونت عينة الدراسة من 19 مشاركًا، من بينهم مُعلمو رياضيات وخبراء في تعليم الرياضيات اوتكنولوجيا التعليم. استخدم البحث استبانة تحتوي على مجموع من الأسئلة المفتوحة وذلك للإجابة عليها كتابيا من خلال المشاركين. تم تحليل البيانات باستخدام تحليل الموضوعات. حيث توصلت نتائج التحليل النوعي إلى أربعة موضوعات رئيسية وهي: تأثير الذكاء الاصطناعي على تعلم الرياضيات، وتعزيز التواصل ومجتمعات التعلم، ودور الذكاء الاصطناعي في تعزيز التفكير النقدي، ومواءمة استخدام الذكاء الاصطناعي مع مبادئ الاتصالية. حيث بينت النتائج وجود توافق كبير بين استخدام أدوات الذكاء الاصطناعي في تعليم الرياضيات ومبادئ الاتصالية. بالإضافة إلى ذلك، تُشير النتائج إلى أن أدوات الذكاء الاصطناعي تُعزز تجارب التعلم الذاتي والتفاعلي، وتدعم التعاون، وتُعزز تكامل وجهات النظر المُتنوعة. ومع ذلك، شدّد المشاركون على أهمية الحفاظ على التفاعل البشري لضمان تعلّم هادف، وسلطوا الضوء على تحديات مثل المعلومات المضللة، والحاجة إلى التحقق من صحة المحتوى المُنتج بواسطة الذكاء الاصطناعي، وأهمية تعزيز استخدام ادوات الذكاء الاصطناعي. وتوصي الدراسة بإجراء المزيد من البحوث لمعالجة المخاوف الأخلاقية، واستكشاف الآثار طويلة المدى، وضمان تكامل فعال للذكاء الاصطناعي في سياقات تعليمية متنوعة.

الكلمات المفتاحية: الذكاء الاصطناعي، النظرية الاتصالية، نظرية التعلم، تعليم الرياضيات.

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(1) College of Education and Human Development - University of Bisha

(1) كلية التربية والتنمية البشرية - جامعة بيشة

E-mail: Bakri39@hotmail.com

Introduction

Artificial intelligence (AI) is fundamentally transforming education by offering personalized learning experiences, refining assessment techniques and alleviating teachers' workloads (Ayala-Pazmiño, 2023). The advantages of employing AI in education are manifold, encompassing enhanced learning experiences, global classroom accessibility and data-driven decision-making (Tambuskar, 2022; Younas et al., 2023). AI-driven systems, such as virtual classrooms, smart campuses and adaptive learning platforms, are reshaping the educational landscape (Younas et al., 2023).

Increasingly recognized as a powerful tool, AI has the potential to revolutionize education (Chen et al., 2020). Through leveraging AI technologies, educators can enhance learning experiences, improve student outcomes, streamline administrative processes and create immersive learning environments. This paper examines such opportunities. One of the most transformative aspects of AI integration in education is its ability to provide personalized learning experiences (Chen et al., 2022). Traditional one-size-fits-all educational approaches often fall short in accommodating the diverse learning styles and paces of individual students. In contrast, AI-powered adaptive learning systems can analyse extensive data on student performance and preferences, enabling tailored instruction to meet each student's unique needs (Gligorea et al., 2023). Thus, by offering personalized and data-driven learning opportunities, AI ensures that education is more inclusive and effective, catering to the varied needs and potentials of students. This adaptability can not only enhance learning outcomes but may also foster an engaging and dynamic educational experience.

Recent research has examined the potential of AI chatbots, particularly ChatGPT, to enhance mathematics education. Studies have demonstrated that ChatGPT can offer personalized learning experiences, aid in problem solving and provide comprehensive instruction across various mathematical topics (Supriyadi & Kuncoro, 2023). Students generally perceive ChatGPT positively, reporting increased engagement and improved learning experiences (Gouia-Zarrad & Gunn, 2024; Serhan & Welcome, 2024). It demonstrates high accuracy in solving mathematical problems and holds potential for enhancing self-regulated learning (Li et al., 2023). Notably, students' interest in mathematics greatly influences the relationship between ChatGPT usage and mathematics achievement (Asare et al., 2023).

However, concerns persist regarding the impact of using ChatGPT on the development of critical thinking and problem-solving skills (Sánchez-Ruiz et al., 2023), as occasional inaccuracies may occur (Remoto, 2023). Thus, maximizing its effectiveness and addressing potential drawbacks requires careful implementation and ongoing research (Santos et al., 2024). Moreover, despite its potential benefits, challenges remain, such as improving internet connectivity and developing proactive strategies to boost student participation (Auna & Hamzah, 2024). Overall, studies advocate a cautious yet optimistic integration of AI tools like ChatGPT in mathematics education.

Moreover, while the integration of AI shows promise as a means of enhancing mathematical abilities, nurturing critical thinking skills and fostering creativity (Nguyen et al., 2024; Rane, 2023), further investigation is needed to understand its impact on assessment approaches and curriculum adaptation (Magtoto et al., 2023) and its integration poses challenges in terms of accuracy, ethical considerations and balancing AI assistance with human instruction (Rane, 2023).

Researchers stress the significance of thoughtful implementation, continuous professional development and adapting teaching methodologies to optimize learning outcomes (Santos et al., 2024; Supriyadi & Kuncoro, 2023). Moreover, some studies propose frameworks for the ethical and responsible use of AI chatbots in education, focusing on support for cognitive flexibility and self-regulation (Chauncey & McKenna, 2023).

As artificial intelligence continues to permeate educational contexts, understanding how students learn via these technologies is paramount. Educators require relevant theoretical frameworks to maximize the impact of AI and provide optimal learning experiences. Connectivism – a learning theory developed for the digital age – offers important insights for examining knowledge construction in AI-enabled environments (Siemens, 2005). As education evolves in the digital age, connectivism provides a framework for understanding how students learn and interact with information, highlighting the importance of social networks and knowledge sharing in the learning process (Khatibi & Fouladchang, 2015; Strong and Hutchins, 2009).

Connectivism

Connectivism, proposed as a learning theory for the digital age, focuses on knowledge distribution across networks and the ability to navigate them (Khatibi & Fouladchang, 2015). The application of connectivism has shown potential in mathematics education, with studies indicating improved performance in blended learning environments (Naidoo et al., 2016) and addressing mathematics anxiety (Klinger, 2011). In higher education, connectivism offers opportunities for expanding course content and integrating digital technologies (Kondrashova & Solokhin, 2021).

Connectivism conceptualizes knowledge as disseminated across networks and learning as the proficiency to form and navigate these networks (Chatti et al., 2010; Khatibi & Fouladchang, 2015). Originated by George Siemens and Stephen Downes, connectivism challenges traditional learning paradigms, such as behaviourism, cognitivism and constructivism (Hendricks, 2019). This theory accentuates the significance of social interaction, knowledge sharing and personal learning environments in the educational process (Wang, 2014). It has garnered recognition within the realms of Web 2.0 technologies, e-learning, and open distance education (Goldie, 2016; Strong and Hutchins, 2009). The theory posits that learners must develop the capability to access, critically evaluate and create knowledge within an ever-evolving information landscape (Dogan, 2014).

Initially formulated in 2005 in response to the challenge posed by the vast amount of knowledge available in the Internet era, connectivism offers a novel interpretation of learning and knowledge generation, arguing that knowledge is a dynamic, invisible and generative network phenomenon (Downes, 2005). According to this theory, the goal of learning is not merely the possession and grasp of knowledge, but rather the continuous process of building connections and developing networks (Siemens, 2005). The interplay between three levels of networks – individual, group and collective – and among three types of networks – cognitive neural networks, concept networks and social networks – is crucial in enhancing learning development and fostering knowledge innovation.

The primary epistemological insight of connectivism is that knowledge is distributed across networks (Downes, 2005; Siemens, 2008). Contrary to traditional views, which view knowledge as a mental state, such as a belief or as pertaining solely to individual knowers, connectivism conceptualizes knowledge as an emergent property of an activated pattern of connections within a network. The fundamental structural element of these networks is the node, which is not a singular, indivisible entity like a person or mind, but rather a locus or bundle of connections (Bates, 2019). The extent of a node's connections amplifies its "profile" (Siemens, 2005).

Whereas traditional categorizations of knowledge have been qualitative and quantitative, Siemens introduces a third category: connective knowledge (Hung, 2014). He critiques behaviourism, cognitivism and constructivism on three key points: their emphasis on individual-centric learning, their disregard for non-human learning dimensions and their focus on the mechanics of learning rather than the value of the content learned (Chetty, 2013). The evolving nature of contemporary knowledge production and dissemination underscores the need for diverse perspectives on information (Clarà & Barberà, 2013).

Consequently, learners must actively engage in the educational process, moving beyond the passive receipt and storage of information to influencing and shaping their learning contexts (Downes, 2022). Modern learners play a role in deciding when and how to learn, ensuring that their interaction with information is contextually relevant (Downes, 2022). In contrast to traditional education, which focuses on the accumulation of static knowledge, contemporary educational approaches require learners to construct meaning collaboratively using both constructivist and connectivist methods. Knowledge acquisition is thus redefined as an interactive process involving problem solving and contextual application (Grooms & Reid-Martinez, 2014).

This interactive process is based on four key principles: autonomy, connectedness, diversity and openness (Tschofen & Mackness, 2012). Connectivism views learning as a network creation process, one that aims to provide "learning ecologies" which meet the needs of learners (Marhan, 2006). Despite there being some debate about its status as a learning theory (Gutiérrez, 2012), connectivism offers a framework for understanding how students develop information literacy within networked information landscapes (Dunaway, 2011). It challenges traditional learning theories and broadens our understanding of how, why and when learning occurs, having significant implications for organizational learning and e-learning design (Strong and Hutchins, 2009).

The theory outlines eight principles applicable to both K-12 and higher education settings to engage learners in today's technologically connected landscape (Utecht & Keller, 2019): (i) learning and knowledge rest in the diversity of opinions; (ii) learning is a process of connecting specialized nodes or information sources; (iii) learning may reside in non-human appliances; (iv) the capacity to know more is more critical than what is currently known; (v) nurturing and maintaining connections is necessary to facilitate continual learning; (vi) the ability to see connections between fields, ideas and concepts is a core skill; (vii) accurate, up-to-date knowledge is the intent of all connectivist learning activities; (viii) decision making is in itself a learning process (Siemens, 2005).

Central to these principles is the notion that learners generate new meanings rather than merely memorizing facts, with knowledge residing not in the facts themselves but in the ability to learn, unlearn and relearn information and effectively apply this knowledge in a constantly evolving information landscape (Dunaway, 2011; Goldie, 2016; Utecht & Keller, 2019). Learning involves the discovery of new concepts, unlearning entails critically assessing prior information and relearning reflects embracing a new understanding and replacing outdated beliefs or experiences with new information (Utecht & Keller, 2019).

Some scholars argue that connectivism is a natural extension of existing library practices (Guder, 2010), while others debate whether it qualifies as a learning theory or is merely a pedagogical approach (Gutiérrez, 2012). Critics question its uniqueness and its relationship to social constructivism (Wang, 2014). They argue that the theory overemphasizes technology and social networks, overlooking important factors, such as motivation, individual learning differences and the role of the teacher (Alam, 2023). Nonetheless, advocates of connectivism argue that it offers a novel and innovative approach to learning, recognizing the changing nature of knowledge and the critical role of technology in modern society (Alam, 2023). Despite critiques, connectivism has seen rapid development and application in educational settings (Downes, 2020). However, while offering a valuable perspective on learning in digital contexts, the theory requires further refinement and empirical validation to address critiques and affirm its status as a comprehensive learning theory (Goldie, 2016). In particular, further research is needed to fully understand its benefits and drawbacks in both formal and informal learning contexts (Khatibi & Fouladchang, 2015).

Research Importance

The increasing integration of AI in mathematics education highlights the need for a robust theoretical framework to guide its application. By examining the relationship between AI and connectivism, this study addresses a critical gap in the literature, as connectivism emphasizes networked learning, knowledge creation, and distributed cognition—principles that are highly relevant in the context of AI-enhanced education. While previous research has explored AI's potential to personalize learning, foster critical thinking, and facilitate collaborative knowledge construction, a systematic understanding of how these AI applications align with established educational theories remains largely unexplored

Research problem and Question

The increasing integration of AI within mathematics education necessitates a robust theoretical grounding. In this context, connectivism, characterized by its emphasis on networked learning, knowledge creation, and distributed cognition, offers a particularly pertinent lens for understanding the pedagogical implications of AI. While existing scholarship has commenced an examination of AI's capacity to enhance personalized learning experiences, foster critical thinking, and facilitate collaborative knowledge construction, thereby supporting core connectivist principles (Baskara, 2023; Liang & Bai, 2024), a significant conceptual void persists. Specifically, there is an insufficient systematic understanding of the precise alignment and interplay between evolving AI applications in mathematics education and the nuanced tenets of established educational theories and pedagogical practices (Chen et al., 2020; Díaz & Nussbaum, 2024)). Consequently, the present study is designed to meticulously investigate the intricate relationship between the utilization of artificial intelligence in mathematics education and the foundational principles of connectivism by answering the following question:

"In what ways does the use of AI in mathematics education align with the principles of connectivism?"

Research Limits

This study is confined to the specific objectives established regarding the examination AI in mathematics education and its relationship to communicative theory and its underlying principles. The research seeks to address this focus by formulating and exploring the research question.

Methods and Methodology

Research Design

The study employed a qualitative research design aimed at exploring the perspectives of educators and experts in mathematics education and educational technology concerning the use of AI tools in mathematics education. In line with the study's objectives, a phenomenological design was employed as this approach seeks to attain a shared understanding of the experiences of a specific group of individuals regarding a particular phenomenon or concept (Creswell, 2013).

Participants

The study employed purposive sampling and recruited 19 participants from various educational institutions, including mathematics educators, mathematics education experts and educational technology experts. This approach ensured a diverse representation of experiences and viewpoints. They were selected based on their willingness to participate by responding in writing to open-ended questions that were sent to them via an electronic link. The first 19 responses were considered.

Table (1)

participants' Information

Participants	Job	Degree
P1	Academic	PHD
P2	Teacher	PHD
P3	Teacher	Bachelor
P4	Academic	PHD
P5	Teacher	Bachelor
P6	Academic	PHD
P7	Supervisor	Bachelor
P8	Teacher	Bachelor
P9	Teacher	Bachelor
P10	Teacher	Bachelor
P11	Teacher	Bachelor
P12	Teacher	Bachelor
P13	Teacher	Bachelor
P14	students	Master
P15	Lecturer	Master
P16	Teacher	Bachelor
P17	Teacher	Bachelor

P18	Lecturer	Master
P19	Teacher	PHD

Data Collection

Data were collected through written responses to an electronic questionnaire consisting of 13 open-ended questions. This questionnaire was disseminated via a specially prepared electronic link, which facilitated flexibility in exploration of the topic and enabled participants to articulate their ideas freely.

Data Analysis

The qualitative data were analysed using thematic analysis, incorporating both deductive and inductive approaches, following the steps outlined by Braun and Clarke (2006). The study adhered to the quality standards defined for qualitative research, drawing on the works of Shenton (2004) and Hammarberg et al. (2016), to ensure the credibility and dependability of the findings.

Ethical Considerations

The participants were informed of their rights, including the right to withdraw from the study at any time without consequence, and gave written informed consent prior to completing the questionnaire. Confidentiality was ensured by anonymizing their identities in all reports and publications.

Results

The thematic analysis yielded four principal themes:

1. The impact of AI on mathematics learning
2. The impact of AI on mathematical knowledge
3. Enhancing communication and learning communities through the use of AI tools in mathematics education
4. The relationship between AI tools and critical thinking in mathematics education.

The Impact of AI on Mathematics Learning

This theme concerns the participants' perspectives on the role of AI in enhancing the mathematics learning process. The participants believed that AI contributes significantly to making mathematics learning easier through various dimensions, such as providing personalized support for students and facilitating connections to diverse resources for mathematical knowledge and experience. Moreover, AI can analyse common errors and offer tailored exercises to address weaknesses.

The participants addressed the use of AI and its educational tools, recounting that it offers numerous opportunities for support and improvement for learners. One participant, P5, stated:

> AI-supported learning tools and platforms play a vital role in enhancing the learning process. For instance, AI-driven mathematics tutoring programmes can provide personalized support for students, aiding them in overcoming obstacles and deepening their understanding of mathematical concepts.

In addition, the use of AI can create opportunities beyond personal support, such as providing an interactive learning environment that makes mathematics more engaging and enjoyable for young students. As P8 put it:

> In my view, the use of AI can positively impact the learning experience, especially in making mathematics more enjoyable and appealing to younger students. Educational games and interactive applications can encourage them to engage and learn fundamental concepts in a fun way. However, we must be cautious about over-reliance.

Other participants also viewed complete reliance on AI as a concern that warrants attention, noting that it cannot replace classroom discussions and human interaction. As P9 remarked:

> The integration of AI tools in mathematics education has significant benefits, particularly in teaching mathematics. However, AI should not replace human interaction or classroom discussions; it should be a complementary tool to enhance deep understanding of the subject.

From the above, it can be concluded that although many participants believed in the importance of utilizing AI in mathematics education, some felt caution was warranted regarding its use, as it cannot substitute for human discussions. AI offers various resources that facilitate students' connections to diverse sources of mathematical knowledge and experience, such as chat applications like ChatGPT and other interactive platforms.

Many educators expressed the belief that AI eases the process of linking students to multiple learning resources. P7 stated "I think AI tools facilitate students' connections to diverse sources. For example, intelligent platforms like Khan Academy and Coursera offer varied educational content suited to different levels". However, the question that remains is: "Can these sources of mathematical knowledge replace teachers, or can students learn independently through them?"

Generally, most participants believed that while students can gain mathematical knowledge and learn using AI, this is not absolute and depends on the type of knowledge, the students' age and their ability to discern information. P9 pointed out, "Yes, students can learn mathematics using AI tools, but it depends on the student's level. Platforms like Khan Academy or Photomath provide interactive explanations and tailored exercises". These tools can be effective for independent learners, but it is important to have guidance from teachers or parents initially to ensure understanding of fundamental concepts.

In summary, this theme addresses participants' views of the role of AI in enhancing mathematics education, highlighting its potential for personalized support and interactive learning experiences. While many participants acknowledged the benefits of AI, such as making learning more engaging and accessible, they also emphasized the importance of maintaining human interaction and guidance to ensure deep understanding.

The Impact of AI on Mathematical Knowledge

This theme discusses the effects of using AI technologies on mathematical knowledge and problem-solving skills. The participants believed that AI tools and platforms facilitate students' acquisition of mathematical knowledge and enhance their focus on continuous learning. They viewed AI as a means of connecting mathematical concepts more effectively.

Many participants agreed that AI technologies create a dynamic and interactive learning environment, offering opportunities for practice and repetition without the fear of embarrassment. As P1 stated, "Yes, they are stimulating tools that enhance hard work, aiding in problem-solving and sharing diverse knowledge during learning". The use of AI can provide learning opportunities not available in real life, reducing the pressure on students from making mistakes and allowing them to continue learning in an engaging manner. According to P10, "AI gives students the freedom to express mathematical ideas and exchange opinions without feeling embarrassed, enabling interaction anytime and anywhere". AI can help students learn through simulations and making connections to real-life experiences. They can utilize platforms like Wolfram Alpha to solve calculus problems. For instance, they can enter the equation $f(X)=2+3xf(X) = 2 + 3xf(X)=2+3x$ to calculate derivatives, with AI providing step-by-step explanations that enhance understanding.

The interviews indicated that the opportunities offered by AI tools in learning mathematics encourage students to seek more knowledge and improve their learning skills. The participants believed that the optimal use of AI applications in mathematics education supports active information searching rather than settling for what is readily available, thereby promoting continuous learning. P5 explained:

> Focusing on learning skills instead of static knowledge allows students to be more curious and ready to explore mathematical concepts. When using AI tools, students can seek new information and interact with content that goes beyond the curriculum.

Overall, the educators believed that AI enhances the depth of learning and helps students develop personalized strategies, making them more proactive in their quest for understanding rather than relying solely on pre-existing information. P15 reinforced, stating, "Focusing on developing learning skills using AI enhances students' understanding of mathematical concepts through interactive explanations and challenges that emphasize critical thinking".

The type of information students can acquire with the help of AI fosters the continuous pursuit of knowledge, since newer and more relevant knowledge may encourage ongoing learning. However, evaluating the accuracy and recency of such information, while potentially straightforward for educators, can be challenging for students. Regarding the provision of information, the participants asserted that AI can be used to deliver accurate and up-to-date content, although caution is warranted. As P2 stated:

> Yes, I believe that integrating AI can provide students with modern and accurate information. Many educational platforms use advanced algorithms to periodically update content, allowing students to access the latest concepts and applications in mathematics.

Some participants stressed the need to trust certain specialized sources for learning mathematics that are consistently updated. For instance, P5 remarked, "I completely agree; AI-based technology allows students to access a wide range of updated educational resources. For example, students can use tools like Wolfram Alpha to access accurate mathematical information and the latest research".

The participants also believed that integrating AI in mathematics education enhances the ability to see connections between mathematical concepts, whether through interactive graphics, concept maps, or innovative designs. P15 noted:

> AI can contribute to strengthening the links between mathematical concepts by providing interactive educational content. For example, smart platforms can demonstrate how algebra relates to geometry through applied problems. When students see how algebraic equations affect geometric shapes, their understanding of the concepts deepens.

In summary, the participants were of the view that AI can provide up-to-date and accurate information, but caution is advised in verifying sources. Overall, the integration of AI in mathematics education enhances students' learning experiences, fosters independent exploration and helps them see the relationships between different mathematical concepts through the use of interactive tools and visual representations.

Enhancing Communication and Learning Communities Through the Use of AI Tools in Mathematics Education

This theme addresses the contribution made by AI tools in strengthening connections and communication among learners, experts and resources to facilitate the learning process and create learning communities. The participants believed that AI enhances students' acceptance of diverse perspectives, although its effectiveness as a communicative medium may vary. Nonetheless, most participants viewed AI as providing valuable opportunities to improve communication during mathematics learning.

They generally agreed that AI tools simplify communication in mathematics education through interactive learning platforms, allowing students to connect with peers at various levels. P2 noted:

> AI can recommend appropriate educational resources based on students' interests and levels. Platforms like Coursera and edX use algorithms to guide students to suitable courses and experts, facilitating access to knowledge and enhancing the learning experience.

P3 considered that "AI can provide diverse and customized content. By analysing performance data, AI can make personalized resource recommendations, helping students engage with each other and seek support from experts". Furthermore, P17 emphasized that:

> AI tools support connections between learners and experts through interactive platforms, offering access to lessons from specialists and recommending tailored educational resources,

> creating spaces for discussion and collaborative learning.

Moreover, the communication opportunities facilitated by AI can help form communities of learners with shared interests. As P1 noted, "AI offers students new opportunities for peer learning", and P9 believed that:

> AI tools can significantly contribute to forming learning communities. By providing interactive platforms, students can connect and share ideas, solving problems collaboratively. This cooperative environment fosters peer learning, allowing students to exchange experiences and knowledge.

P18 also averred that "forming learning communities benefits the sharing of experiences and peer education through communication and discussions".

In addition, AI tools can develop users' debating and dialogic skills, enabling them to appreciate diverse opinions. One participant noted:

> AI can enhance acceptance of diverse viewpoints by presenting multiple problem-solving methods. When students encounter various approaches, they learn to value different insights and become more open to new ideas, fostering collaboration and mutual understanding.

This exposure to diverse experiences may not only benefit learners but also all users of AI tools across society. P13 affirmed this, stating:

> AI can indeed play a role in promoting acceptance of different perspectives. By using interactive educational tools, students can see how different solutions can lead to the same outcomes. This understanding helps them recognize the importance of diversity in ideas and how to leverage it in problem-solving.

In conclusion, the effective use of AI tools in mathematics education not only facilitates communication and collaboration among students and experts but also fosters a culture of inclusivity and appreciation for diverse viewpoints.

The Relationship Between AI Tools and Critical Thinking in Mathematics Learning

This theme explores the relationship between the use of AI tools and critical thinking, information filtering and decision-making skills in mathematics education. The participants generally agreed that interacting with AI-based learning tools can enhance critical thinking skills. P3 stated:

> Yes, interacting with AI tools can improve students' critical thinking skills. These tools present complex challenges and data analysis, requiring students to think deeply and evaluate different solutions. When faced with problems that require critical thinking, students become more adept at analysing situations and making informed decisions.

Similarly, P9 noted that "AI tools encourage critical thinking by posing open-ended questions and complex challenges. When students are asked to analyse data or solve multi-step problems, they learn to evaluate information and use it creatively, significantly enhancing their critical thinking skills". P17 echoed this view, emphasizing that these tools provide challenges that require analysis and evaluation, thereby improving students' critical thinking and innovative problem-solving abilities.

However, some participants, like P4, expressed concerns, stating, "The use of AI tools can make learners passive recipients of information, taking in ready-made solutions without critical thought". In this respect, the volume of information available through AI tools can be both positive and negative, presenting a challenge in filtering this information effectively. Most participants agreed that AI enhances users' ability to evaluate information. As P8 remarked:

> AI can enhance students' ability to assess information by providing immediate feedback. When students solve math problems on AI platforms, they receive accurate evaluations of

> their answers, helping them understand their strengths and weaknesses and allowing them to make informed decisions about how to improve their skills.

P17 considered that integrating AI in mathematics education fosters students' ability to filter and evaluate information through precise analyses of concepts and smart resource recommendations. However, despite the benefits noted, P17 also pointed out that filtering information can be challenging for all users, requiring a certain level of knowledge and experience.

In addition, the participants believed that integrating AI in mathematics learning can aid in fostering decision-making skills. P17 explained, "In presenting various scenarios and case studies that require the analysis of options and selecting appropriate solutions, AI tools provide immediate feedback that helps students evaluate their decision outcomes". P18 stated that "the vast amount of information provided by AI, presented in diverse ways, deepens understanding of mathematical concepts".

Another factor contributing to improved decision-making skills is the variety of options and the speed at which data are processed. P5 noted that students encounter situations that require decisions about strategies and methods, enhancing their critical thinking and analysis of available options. Moreover, P12 contended that:

> ...immediate feedback on the decisions made by students allows them to learn from their mistakes and become more aware of the thought processes leading to effective decision-making. This type of learning helps them develop decision-making strategies in mathematical contexts and beyond.

In summary, while AI tools have the potential to enhance critical thinking and decision-making skills in mathematics education, they also pose challenges in relation to information filtering and may lead to passive learning if not used thoughtfully.

Discussion

The primary aim of this study was to explore the relationship between the use of AI in mathematics education and connectionist theory. The thematic analysis of participants' perspectives on this relationship revealed several critical insights. Four main themes emerged from the analysis: the impact of AI on mathematics learning, the effect of AI on mathematical knowledge, enhancing communication and learning communities through the use of AI tools in mathematics education, and the relationship between AI tools and critical thinking in mathematics learning. Although some of these themes may not directly illustrate the relationship between the use of AI in mathematics education and the principles of connectivism, many participants' opinions clearly reflected this connection.

In general, from the participants' viewpoints, there is a clear relationship between the use of AI in mathematics education and the principles of connectionism. For instance, in the first theme, concerning the impact of AI on mathematics learning, this study found that the use of AI facilitates personalized support and interactive learning experiences in mathematics, highlighting its potential in this area. While many participants acknowledged the benefits of AI, such as making learning more engaging and accessible, they also emphasized the importance of maintaining human interaction and guidance to ensure deep understanding. These findings align with previous studies, such as Mustafa et al., (2024) and Inoferio et al. (2024), which found that AI provides tailored content, feedback and support, enhancing student engagement and outcomes. These systems can help alleviate mathematics anxiety and boost confidence by acting as mentors and companions in mathematics (Inoferio et al., 2024). The role of AI in mathematics education includes diagnosing learning problems, providing personalized support and maximizing performance (Hwang & Tu, 2021). AI-enabled interactive video learning can adapt to individual needs, making the learning experience more enjoyable and effective for children (Teresa et al., 2023). Intelligent Tutoring Systems incorporate AI techniques to assess proficiency, provide exercises and offer immediate feedback (Pappas & Drigas, 2016).

The integration of AI, computational thinking and mathematics education highlights key elements, such as agency, the modelling of phenomena and representation of abstract concepts, which can enrich classroom practices and prepare students for future demands (Gadanidis, 2017). Prior studies which align with the current study's findings (Dunaway, 2011; Goldie, 2016; Utecht & Keller, 2019), agree that the use of AI in mathematics education reflects certain principles of connectionism, such as the dependence of learning and knowledge on diverse perspectives, the notion that learning is a process of connecting (specialized learning networks or information sources), and the idea that learning can occur through non-human devices, with learning being more significant than mere knowledge. These views underscore the central role of connectionism, which posits that learners generate new meanings rather than merely memorizing facts. Knowledge resides not in the facts themselves but in the ability to learn, unlearn and relearn, effectively applying knowledge in a continuously evolving information landscape (Dunaway, 2011; Goldie, 2016; Utecht & Keller, 2019). The process entails learning (i.e. the discovery of new concepts), unlearning (i.e. critically assessing prior information) and relearning (i.e. embracing a new understanding and replacing outdated beliefs or experiences with new information) (Utecht & Keller, 2019).

The participants contended that while AI can provide accurate and up-to-date information, they advised caution in verifying sources. Research has shown that AI-generated responses may contain errors, artificial hallucinations and non-existent references (Kumar et al., 2023). In some cases, AI models may produce more compelling misinformation than humans (Spitale et al., 2023). Experts recommend caution when using AI for safety-related information and emphasize the need for expert verification (Oviedo-Trespalacios et al., 2023). While AI models like ChatGPT can provide accurate information in some instances, their limitations and potential to generate erroneous content necessitate careful scrutiny and cross-checking with reliable sources (Daungsupawong & Wiwanitkit, 2024). Importantly, verifying the validity of AI-generated information may be straightforward for educators and experts but would likely pose significant challenges for young learners. The role of AI in mathematics education includes diagnosing individual learning challenges, offering tailored support and enhancing engagement and motivation (Hwang & Tu, 2021). This aligns with the principle of connectionism, which states that accurate and updated knowledge is the goal of all learning activities.

Regarding the principle of connectionism that asserts the importance of nurturing and maintaining connections to facilitate continuous learning, this study found that AI tools were perceived as contributing to strengthening connections and communication among learners, experts and resources, thereby facilitating the learning process and creating educational communities. These tools have the potential to enhance communication skills, facilitate connections among learners and resources and promote social engagement in online learning environments (Ezeanya et al., 2024; Seo et al., 2021). AI can support learner–instructor interactions on a large scale, although there are concerns about privacy and agency (Seo et al., 2021). The integration of AI in education presents opportunities for developing intercultural communicative competence and supporting group learning (McCallum, 2023). However, the most impactful uses of AI in education may not yet have been developed and further research is needed to explore its long-term effects and optimal integration (Roschelle et al., 2020; Rusmiyanto et al., 2023). Educators and students need to develop AI literacy to effectively leverage these tools in the classroom (McCallum, 2023).

AI technologies may have the potential to enhance students' acceptance of diverse perspectives and improve communication in educational settings. AI-based communication tools can offer personalized learning experiences and provide support for large-scale online education (Goldenthal et al., 2021; Seo et al., 2021). However, views on the effectiveness of AI as a medium of communication vary. While some studies report positive perceptions of AI teaching assistants (Kim et al., 2021), others highlight limitations in current chatbot technologies for learning (Gallacher et al., 2018).

The principle of connectionism regarding the development of decision-making skills and its relationship to the learning process aligns with the use of AI in mathematics education. However, this study found that while AI tools have the capacity to enhance critical thinking and decision-making skills in mathematics education, they also pose challenges in terms of information filtering and may lead to passive learning if not used thoughtfully. Nonetheless, the integration of AI tools in mathematics education is increasing, providing personalized learning experiences and enhancing critical-thinking skills (Çeti̇n, 2023). AI applications contribute to developing analytical thinking and problem-solving abilities (Çeti̇n, 2023). Various AI systems, including intelligent tutoring systems and AI-based calculators, are being utilized in mathematics education (Van Vaerenbergh & Pérez-Suay, 2021).

Conclusion

The findings reveal significant alignment between the use of AI tools in mathematics education and the core principles of connectivism. The participants' responses indicated that AI tools enhance personalized and interactive learning experiences, reflecting the connectivist principle that learning occurs through connections within networks of knowledge and resources. AI facilitates the development of learning communities, supports collaboration and promotes the integration of diverse perspectives. Furthermore, AI tools help learners actively construct knowledge by interacting with peers, instructors and digital resources, demonstrating the dynamic nature of connectivist learning environments.

The study identified four major themes: the impact of AI on mathematics learning, the enhancement of communication and learning communities, the role of AI in fostering critical thinking, and the alignment of AI tools with connectivist principles. For example, the participants noted that AI tools provide tailored feedback, help diagnose learning challenges and promote self-directed learning, all of which are central to connectivism. However, while the participants acknowledged the benefits of AI, they also emphasized the importance of maintaining human interaction and engagement to ensure meaningful learning experiences.

The study further highlights the challenges of using AI in education, such as the need for expert verification of AI-generated content, the potential for misinformation and the risk of passive learning if AI tools are not thoughtfully incorporated. These concerns underscore the importance of fostering AI literacy among educators and students to maximize the effective use of these tools.

In conclusion, the findings of this study contribute to the understanding of how AI tools align with connectivism, offering practical insights for educators, researchers and policymakers. AI's ability to support networked learning, strengthen connections and enhance critical thinking illustrates its potential to transform mathematics education. However, further research is needed to explore the long-term impacts of AI integration, address its limitations and ensure its ethical and effective use in diverse educational contexts.

Limitations and Suggestions for Future Research

This study offers meaningful insights into the relationship between the use of AI in mathematics education and connectivism, but it has limitations. The qualitative research design and small sample (19 participants) mean the findings are not generalizability. Seeking written responses to open-ended questions may have restricted the depth of participants' input and the self-report data could reflect biases based on familiarity with AI tools. The study also focused on the theoretical alignment with connectivism and did not directly measure the impact of using AI on learning outcomes. In addition, the rapid evolution of AI technologies may render some findings less relevant over time.

Future research should adopt mixed-methods approaches, combining qualitative and quantitative data and including experimental or longitudinal studies to measure the impact of AI on skills like critical thinking and collaboration. Expanding the sample size and including diverse educational contexts would enhance generalizability. Observational data, such as real-time AI tool usage, could provide practical insights.

Further studies should also address ethical challenges, such as data privacy, misinformation and the digital divide, while also promoting AI literacy among students and educators. Research into advanced AI applications, such as adaptive learning systems and collaborative platforms, could reveal their potential to foster deeper connections, enhance critical thinking and support lifelong learning, aligning with the principles of connectivism.

Conflict of Interest: The author declare no conflict of interest.

Additional Information: Additional information is available for this paper once requested.

Data Availability: The data that support the findings of this study are available from the author upon reasonable request.

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