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Applications of Artificial Intelligence and Their Relationship to Spatial Thinking and Academic Emotions Towards Mathematics: Perspectives from Educational Supervisors

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ABSTRACT

This study explores the perceptions of educational supervisors regarding the relationship between the utilisation of artificial intelligence (AI) applications and spatial thinking as well as academic emotions towards mathematics. The study incorporates cutting-edge AI technologies, including ChatGPT and Metaverse, in accordance with current methods of teaching mathematics. Various methodologies are employed to meet learning needs and align with labour market expectations. These include integrative, historical, systemic, and open approaches. The study employed a descriptive approach, with the research sample consisting of educational supervisors in the mathematics section at the Al-Kharj Education Department during the first semester of 2024 AD. The study used a researcher-developed questionnaire to collect opinions on the utilisation of AI applications and their relationship to spatial thinking abilities and academic emotions towards mathematics. The participants in this study were educational supervisors, who provided valuable insights to address the research questions. The findings revealed a significant correlation (Rank = 5) between their perspectives on the connection between AI applications and spatial cognition. In addition, a significant correlation (Rank = 4) was found in their perspectives regarding the connection between AI applications and the emotional response of students towards mathematics in an academic setting. The findings emphasise the importance of using AI applications to understand the challenges students face in their daily lives, particularly in terms of spatial thinking skills and academic emotions related to mathematics. These skills are crucial for success in the job market.

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1. Introduction

There is a growing fascination with the convergence of artificial intelligence (AI) and education, particularly in the areas of spatial thinking and academic emotions towards mathematics. This indicates a significant change in educational paradigms. The field of AI has seen significant progress, leading to new methods for teaching and learning that have transformed the education sector (Abbas et al., 2022; Baskara, 2023). Research has shown that incorporating AI-driven technologies, like chatbots, into educational environments can greatly improve student engagement and learning outcomes, specifically in the field of mathematics (Chen et al., 2023; Diwanji, Hinkelmann, & Witschel, 2018). When employed effectively, these technologies provide personalised support and adaptive learning environments that address the unique needs of students. As a result, they have a positive impact on students' academic emotions and spatial reasoning abilities (Cotton, Cotton, & Shipway; Huang, Hew, & Fryer, 2022). Likewise, the implementation of the flipped learning model, enhanced by AI, presents a unique chance to revolutionise traditional teaching methods. This approach fosters a student-centred learning environment that promotes active engagement and facilitates a deeper grasp of concepts (Kim et al., 2020; Rossano et al., 2022). This paper seeks to investigate the potential of AI applications for improving spatial thinking and positively influencing students' emotions towards mathematics. Mathematics is often viewed with apprehension and anxiety, but AI has the ability to enhance the learning experience.

The rapid growth of digital technology during the ongoing industrial revolution has led to significant progress in various sectors of society. Meeting labour market demands is of utmost importance, especially in promoting creativity, productivity, problem-solving, and critical thinking in fields like artificial intelligence, robotics, the Internet of Things, and cybersecurity.

Education should prioritise the crucial role of information, technology, and learning in attaining strong economic performance. This involves a strong emphasis on the management, generation, funding, transfer, and investment of knowledge. This emphasis ensures that educational outcomes are in line with the demands of the knowledge economy (Elsayed & Nasef, 2021).

"Learning Future: How Artificial Intelligence and Generative Models Will Shape Education" by ChatGPT emphasises the significance of prompt engineering in the current digital era. In today's rapidly evolving landscape, the skill of formulating questions and seeking information and resources has become increasingly crucial. The efficacy of the responses is closely tied to the calibre of the inquiries and prompts presented (Ng, 2018; Qadir, 2023; Rahman & Watanobe, 2023).

On the other hand, the metaverse utilises technologies that enable multisensory interactions in virtual environments, encompassing digital objects and individuals. XR systems achieve representational fidelity by utilising stereoscopic displays, which effectively create a sense of depth. To achieve this, each eye receives distinct and subtly different visuals that mimic how we perceive our physical environment (El Beheiry et al., 2019).

1.1 Research Problem

The research problem is further expanded by investigating the potential of artificial intelligence (AI) in improving spatial thinking and academic emotions towards mathematics. During field education, the researcher observed students struggling with spatial visualisation and experiencing feelings of boredom and anxiety in their mathematics classes. Previous research has established a decrease in spatial thinking skills, such as spatial perception and mental enlightenment, and has emphasised the need for their improvement in mathematics education (Kim & Bednarz, 2013; Kompridis, 2000; Lee & Bednarz, 2009; Salem, 2021; Wai, Lubinski, & Benbow, 2009). Studies indicate a decline in positive academic emotions towards mathematics, emphasising the importance of fostering these emotions as essential educational goals (Ahmed et al., 2013;Park et al., 2023; Hussein, 2018; Mohamed, 2016; Zahran & Judeh, 2021).

There is a noticeable gap in the literature when it comes to exploring the use of AI in spatial thinking and academic emotions towards mathematics, particularly from the perspective of educational supervisors. This lack of extensive research highlights the necessity for AI tools and methodologies that have the potential to transform the approach to spatial thinking and academic emotions towards mathematics. The researcher's interest in this study arises from the lack of existing research on the relationship between AI and the spatial and emotional aspects of mathematics learning, specifically from the viewpoint of an educational supervisor. This study will examine the perceptions of educational supervisors regarding the relationship of AI on enhancing spatial thinking and influencing academic emotions towards mathematics during the first semester of 2024 AD. The aim is to gain a better understanding of AI's role in these areas.

1.2 Research Objectives

1. To investigate the perceived relationship between the use of artificial intelligence applications and the development of spatial thinking in mathematics among students, as assessed by educational supervisors in the first semester of 2024.
2. To explore the perceived impact of artificial intelligence applications on students' academic emotions towards mathematics, as reported by educational supervisors during the first semester of 2024.

1.3 Study Questions

the study questions can be formulated as follows:

1. What is the extent of the connection between mathematical spatial thinking and artificial intelligence applications, according to educational supervisors in the first semester of 2024 AD?
2. What degree of a connection do educational supervisors in the first semester of 2024 AD perceive between artificial intelligence applications and academic emotions toward mathematics?

1.4 Study Significance

The significance can be categorized into theoretical and practical significances:

1.5 Theoretical Significance

1. **Advancement in Educational Research**: Offers novel perspectives on the incorporation of AI in educational environments, namely in the field of mathematics, so enriching the academic discourse on the use of technology to aid learning.

2. **Enhancement of Learning Theories**: Enhances comprehension of how AI technologies can influence spatial thinking and academic emotions, potentially leading to refinements in existing educational theories or the development of new ones.
3. **Bridging Research Gaps**: Seeks to address a significant vacuum in the existing literature by examining the relationship between artificial intelligence (AI), spatial thinking, and academic emotions towards mathematics.
4. **Cross-disciplinary Insights**: Integrates principles from educational technology, psychology, and mathematics education, enhancing interdisciplinary research and promoting a comprehensive comprehension of learning processes.

1.6 Practical Significance

1. **Innovative Educational Practices**: Findings of this study have the potential to facilitate the creation of innovative teaching approaches and technologies that use artificial intelligence, resulting in enhanced student engagement in mathematics.
2. **Enhanced Student Engagement and Outcomes**: Application of AI has the potential to revolutionise conventional mathematics instruction, resulting in enhanced student involvement, comprehension, and scholastic achievement.
3. **Policy and Curriculum Development**: Results could have an impact on educational policies and the development of curriculum, promoting the incorporation of AI technologies in mathematics education to improve learning results.
4. **Professional Development of Educators**: Offers educational supervisors and teachers' useful insights on the optimal integration of AI in teaching, facilitating professional growth and instructional methods.
5. **Adaptation to Diverse Learning Needs**: Study's results could assist in developing highly customised and flexible learning environments that address the unique demands of each student in mathematics, accommodating a diverse array of learning preferences and aptitudes.

2. Theoretical Framework

2.1 Artificial Intelligence Applications

Artificial intelligence applications refer to practical technical applications that include speech recognition, summarization, language translation, scientific linguistic text synthesis, and the ability to retain a conversational style like that of a human (OpenAI Team, 2022). In the context of this research, they are precisely described as technical applications that provide both real-time and delayed communication for students. These programmes utilise algorithms to optimise mathematics education in accordance with the demands of the Fifth Industrial Revolution. The objective is to cultivate spatial reasoning abilities and cultivate positive academic attitudes towards mathematics.

2.2 Spatial Thinking in Mathematics

Spatial thinking refers to the series of mental treatments and practical practices that students employ to solve complex problems involving shapes in two and three dimensions inside a given space. These treatments encompass the capacity to comprehend spatial relationships, visualise spatial relationships, and mentally rotate objects. The assessment of spatial thinking is determined by the students' performance on a specially designed examination (Ramful, Lowrie, & Logan, 2017; Salem, 2021).

In this research, spatial thinking is operationally defined as the student's ability to mentally visualise spatial perception, spatial awareness, and achieve mental enlightenment. This involves processes, procedures, and mental manipulations of geometric concepts This includes a mental rotation, spatial perception, and spatial visualization specifically focused on the first intermediate grade during the first semester.

Academic Emotions Towards Mathematics

Academic emotions in mathematics refer to the subjective experiences that students have when studying mathematics, encompassing emotions such as enjoyment, pride, anxiety, and boredom (Abdel Hamid, 2021). Procedurally, in the present research, these emotions are cultivation of positive feelings in students during their mathematics learning. This includes fostering a love of ability, perseverance, and enjoyment, as well as reducing negative feelings such as boredom, fatigue, and anxiety.

2.3 4.Artificial Intelligence Applications in Mathematics Learning

The current epoch of industrial revolutions is characterised by notable digital proliferation, resulting in enormous advancements in several societal domains. Meeting labour market demands is essential for promoting creativity, productivity, problem-solving, and critical thinking, especially in fields like artificial intelligence, robots, the Internet of Things, and cybersecurity.

The Future of Jobs Report by the World Economic Forum (2020) emphasised the crucial competencies required in today's labour market in the modern industrial period. These skills encompass the capacity to tackle intricate challenges, employ research to find solutions, exhibit critical thinking, and showcase creativity and ingenuity. Additionally, there is a strong emphasis on developing proficiency in people management, effective collaboration, emotional intelligence, decision-making, customer service, negotiating, and cognitive flexibility.

Considering the crucial importance of mathematics in everyday life, it is imperative to enhance students' proficiency in this subject to optimise teaching and learning outcomes and to address societal demands. This highlights the significance of prioritising the emerging role of information technology and education in attaining exceptional economic success. Improving abilities in overseeing the creation, transmission, funding, and allocation of knowledge is crucial. Ultimately, this guarantees that educational results are to the demands of the knowledge economy (Elsayed & Nasef, 2021).

2.4 ChatGPT

Acquiring the ability to ask impactful questions is an essential proficiency in the modern age of technological advancements, particularly with the emergence of ChatGPT and other artificial intelligence (AI) applications. When utilising ChatGPT, it is crucial to set community principles and standards to ensure fair usage, especially as these tools have the potential to generate comprehensive responses for assessments aimed at evaluating human learning. As mathematics education and the profession start to incorporate new tools, it is necessary for assessment methodologies to adapt to prevent unethical behaviour and take advantage of the productivity advantages these tools provide (Qadir, 2023).

ChatGPT offered valuable insights, including a speculative piece by a well-known enthusiast of MOOCs and edtech, AI scientist Andrew Ng, titled "Learning Future: How Artificial Intelligence and Generative Models Will Shape Education" (Ng, 2018). In this context, the significance of timely engineering is apparent. In today's rapidly changing world, it is increasingly important to possess the skills to ask thoughtful questions and independently seek out information and resources. It is essential to engage in critical thinking and resourcefulness, utilising a range of tools and strategies to find and assess information. Individuals who possess a talent for formulating inquiries possess a notable edge, as the calibre of responses is heavily influenced by the calibre of the inquiries. This is a crucial element of prompt engineering (Qadir, 2023; Rahman & Watanobe, 2023).

3. Metaverse

The metaverse, often called extended reality or cross-reality (XR), is a groundbreaking advancement in the realm of the Internet. This term covers various immersive technologies, such as 3D spaces, augmented reality (AR), virtual reality (VR), mixed reality (MR), and advanced communications. The metaverse is dependent on technologies that enable multisensory interactions with virtual environments, digital objects, and individuals. XR systems achieve precise representations through the utilisation of stereoscopic displays, which create a sense of depth. To achieve this, each eye receives a slightly different display that mimics the way we see objects in the real world (El Beheiry et al., 2019).

Displays in XR with high resolutions offer a wide user field of view, ranging from 90 to 180 degrees, and provide enhanced auditory experiences compared to 2D systems. Utilising 3D spatial or binaural audio in these systems creates soundscapes that greatly enhance immersion in AR and VR (Hong et al., 2017). In addition to receiving sensory inputs, XR systems allow users to actively interact with virtual elements using motion controllers and handheld input devices that include grips, buttons, triggers, and thumb sticks. These controllers enable users to interact with virtual objects, actively engaging them in educational experiences. Advancements in full hand tracking and the exploration of wearable devices such as haptic suits and gloves that can detect touch have the potential to greatly improve user experience by creating more intuitive interfaces (Maereg et al., 2017).

Initially, headsets only allowed for three rotational head movements. However, modern high-fidelity headsets have advanced to support all six degrees of freedom, enabling lateral body movement along the x, y, and z axes (Atsikpasi & Fokides, 2022). Multiple studies have verified that AI applications play a significant role in fostering technological advancements, enhancing mathematics education through diverse learning resources, and promoting student engagement in the learning process. Teachers who have undergone training and certification in digital and contemporary technology-based teaching strategies (Abdel Hamid, 2021; Abdel Raouf, 2020; Qadir, 2023; Rahman & Watanobe, 2023) guide students in engaging learning and discovery activities. These activities are facilitated by smart learning techniques and AI, providing digital interactive experiences.

Nevertheless, the provision of digital skills to students is often insufficient, leading to compromised learning outcomes. These skills are crucial in today's digital era for conducting research, fostering creativity and innovation, generating knowledge, and facilitating lifelong learning to address scientific and technological challenges (Abualrob, 2019; Atsikpasi & Fokides, 2022; Bedir, 2019; Ibrahim et al., 2019; Maereg et al., 2017; Zarrouqi & Falta, 2020)

3.1 Spatial Thinking

Thinking plays a crucial role in educational systems across the globe. It emphasises the importance of involving the younger generation's expertise by incorporating critical thinking into education. This is because thinking is a cognitive process utilised in diverse academic disciplines (Sigit et al., 2020).

Prior research and studies have emphasised the significance of spatial thinking in the process of learning mathematics. The significance of this lies in its function in the rough sketching of concepts and mental representations, as well as its capacity to visually depict the relative positioning of objects in each space (Abdel Rahman, 2014; Khairallah, 2007).

3.2 Spatial Thinking Skills

Spatial thinking skills are delineated in Newcombe (2013) as follows:

1. Spatial perception, which involves recognizing the spatial relationships of each object or entity,
2. Spatial visualization, or the capacity to envision two- and three-dimensional objects.
3. Mental rotation is the skill of rapidly and accurately rotating multi-dimensional shapes.

González et al. (2013) further classify these into five fundamental skills:

1. Spatial relations.
2. Spatial perception.
3. Spatial visualization.
4. Mental rotation.
5. Spatial guidance.

Spatial awareness refers to a student's capacity to perceive direction, whether it be horizontally or vertically. The ability to quickly and creatively rotate shapes in both two and three dimensions is known as spatial rotation. Spatial orientation skill involves the capacity to visualize or imagine a shape or scene from various viewpoints or to describe the body's position from different angles (Ramful et al., 2017).

3.3 The Importance of Spatial Thinking

Experts have emphasised the importance of developing spatial thinking in students during the early years of education (Gersmehl & Gersmehl, 2007; Taylor & Hutton, 2013). The National Research Council (2006) has also recommended the integration of this mode of thinking across the curriculum. Boakes (2006) further emphasises the importance of spatial thinking in mathematical learning, stating that it "plays a strong role in learning any aspect of mathematics, but it is even more important in learning geometry, especially if we want geometric concepts to become useful to students."

3.4 Academic Emotions

Academic emotions provide a thorough theoretical framework for comprehending the significance of emotions in the process of learning. The Control-Value Theory suggests that emotions in academic settings are complex and involve various aspects such as cognitive, motivational, expressive, and physiological processes. This theory has direct implications for learning, teaching, and performance (Pekrun, 2006).

The Control-Value Theory classifies academic emotions into four categories. These include positive activating emotions like pleasure, excitement, hope, and pride, as well as positive deactivating emotions like comfort and relaxation. On the other hand, negative activating emotions encompass anxiety, anger, and shame, while negative deactivating emotions include hopelessness and boredom (Pekrun, 2006). Students' positive emotions are linked to their sense of control, value assessment, self-efficacy, competence beliefs, grade expectations, and academic self-concepts. Conversely, negative academic emotions display a contrasting pattern (Peixoto et al., 2017).

The assessments of value and control can be influenced by interactions, feedback, educational quality, and the expectations of significant others in both school and social environments (Peixoto et al., 2017).

3.5 Academic Emotions Towards Mathematics

Academic emotions play a crucial role in attaining exceptional performance in mathematics and acquiring knowledge and abilities. They enhance determination in pursuing specified objectives (Hussein, 2018).

The academic emotions of students have an impact on their mathematical achievement (Hanin & Van Nieuwenhoven, 2016). Furthermore, the academic emotions pertaining to mathematics can forecast students' mathematics grades as time progresses (Camacho-Morles et al., 2021; Pekrun et al., 2017).

Kim and Pekrun (2014) conducted a study to look at the effects of motivational, emotional, and cognitive factors on mathematical performance in an online mathematics course. The study revealed that emotions such as anger, boredom, and pleasure had a significant impact on mathematical achievement. It was observed that students in mathematics tend to experience boredom as the most negative emotion, while pride emerges as one of the most positive emotions during their studies. Students place a significant emphasis on their mathematics grades in comparison to other subjects. As a result, they experience a sense of accomplishment when they successfully overcome difficult tasks.

3.6 *Developing Academic Emotions*

proposed several strategies for fostering students' academic emotions, including:

1. Providing superior instruction and assignments to develop self-assurance, amplify the pleasure of studying, and alleviate negative feelings.
2. Employing captivating assignments to ignite students' curiosity.
3. Granting students authority to govern their own learning will increase their happiness.
4. Creating educational settings that facilitate students' social interaction requirements.
5. Exhibiting fervour and optimistic sentiments while instructing and imparting them to students.
6. Improving feedback on mathematics performance to boost academic attitude (Pekrun, 2014).

Therefore, it is imperative to develop intelligent learning programmes that utilise artificial intelligence to address the current industrial revolution. These programmes can help students develop knowledge, skills, and attitudes, whether it's in nurturing spatial thinking or fostering academic emotions towards mathematics. This will assist in meeting the educational needs and career aspirations of individuals, taking into account these significant transformations.

In summary, the previous overview of these studies reveals that:

1. The present study is in line with its objective, which highlights the significance of spatial thinking and academic emotions in the process of learning.
2. It diverges from previous research in the following ways:

a. The researcher uses a questionnaire to foster spatial thinking.

b. The researcher utilises a self-designed questionnaire to assess academic emotions towards mathematics.

c. This study focuses on specific variables, research methods, and subtraction mechanisms that have not been explored in previous studies.

d. It is worth noting that previous studies did not thoroughly explore the specific objectives of the current study. They did not examine the relationship between artificial intelligence applications, spatial thinking, and academic emotions towards mathematics from the viewpoint of educational supervisors. The aspects discussed form the fundamental basis for the present study.

4. Literature Review

In a study conducted by Thiel (2008), the author examined the emotions experienced by undergraduate students in relation to their precalculus course activities and assignments. The study specifically looked at non-traditional assessments. Carried out across three semesters at a rural liberal arts college, the study consisted of a survey administered to primarily first-year students who were not pursuing a mathematics major. The objective was to evaluate their emotional reactions towards various types of assignments (individual, collaborative, or computer-oriented). Based on the findings, it was observed that students frequently encountered a combination of positive and negative emotions. However, it was noted that positive sentiments such as satisfaction and determination were more prevalent. Thiel's study emphasises the impact of emotional responses on learning experiences in mathematics. It acknowledges that positive emotions have a significant role, even in the face of frustration and dread.

In a study conducted by Barrón, Zatarain, and Hernández (2014), an Intelligent Tutoring System (ITS) for third-grade mathematics was examined. The system was designed to identify and regulate student emotions. The ITS is embedded in a social network and utilises an artificial neural network to accurately detect facial expressions. This enables the system to identify the emotional states of students and offer them valuable feedback. The system yielded positive results when tested in both public and private elementary schools. This study emphasises the importance of considering emotional states in online education and intelligent tutoring systems, as they have a significant impact on computer-mediated learning.

The study conducted by Baskara (2023) explores the impact of chatbots on student engagement and learning outcomes in flipped learning environments. The study seeks to evaluate the benefits, constraints, and ethical considerations of chatbots in this context. Baskara's methodology involves conducting a thorough analysis of literature sourced from reputable databases such as Scopus and World of Science. The research findings indicate that chatbots have a substantial impact on enhancing personalised support, group collaboration, feedback, and self-learning. However, they also give rise to ethical and privacy concerns concerning data security and student anonymity. This study enhances the comprehension of chatbots in the field of education, emphasising the importance of addressing ethical and privacy concerns. It also proposes potential areas for future research in this domain.

In a recent study by Van Doc et al. (2023), the focus was on exploring the potential of AI chatbots in enhancing mathematical thinking skills in high school mathematics education. Their research centres on utilising chatbots to establish learning objectives, identify tasks, and help with problem-solving, application, and assessment. This study highlights the significance of creating a dynamic learning environment that utilises chatbots to foster student curiosity and creativity. By applying mathematical concepts to real-life situations, students can enhance their mathematical thinking and problem-solving skills.

In his paper, Gu (2022) explores the correlation between human memory systems and AI in "The Application of Artificial Emotions in Artificial Intelligence." In Gu's study, the focus is on the potential for AI to replicate human behaviour through the comparison of human cognition to a computational process. The paper explores important psychological studies, including Pavlovian conditioning and Lashley's Law of Mass Action, as well as concepts from the philosophy of mind and neuro-philosophy. According to Gu, computational processes play a fundamental role in shaping human behaviour daily, suggesting that AI has the capacity to imitate human actions. The study concludes that the development of AI with human-like capabilities does not necessitate a comprehensive understanding of brain science. This suggests that it is possible for AI to approximate human cognition and emotion.

In their study, Angelin Rosy, Felix Xavier Muthu, and Alfiya (2023) delved into the intricate connection between different aspects of human intelligence, including critical and emotional intelligence, and how these qualities can be replicated in artificial intelligence (AI). In their study published in the REST Journal on Data Analytics and Artificial Intelligence, the authors conducted a thorough literature review to analyse the alignment between human intelligence aspects and AI development and applications. The study emphasises the wide range of intelligence types, such as linguistic, musical, logical-mathematical, spatial, and interpersonal, and discusses the potential of AI to replicate these abilities. The conclusion highlights the intricate and interconnected aspects of intelligence, emphasising the continuous requirement for technological progress to effectively mimic human intelligence in AI.

To summarise Commonalities can be observed among the previous studies examined. Multiple studies have emphasised the important role that emotions play in the process of learning, particularly in the context of mathematics education (Barrón et al., 2014; Thiel, 2008). Emotions, whether positive or negative, have an impact on students' experiences and outcomes. In addition, several researchers have investigated the use of AI, particularly chatbots, to offer personalised and collaborative assistance in the field of education (Baskara, 2023; Van Doc et al., 2023). These technologies have the potential to improve engagement, feedback, and the development of critical thinking skills.

Nevertheless, there are discernible distinctions among the studies. Some scholars have examined undergraduates' emotional responses (Thiel, 2008), while others have explored the use of chatbots in high school and higher education (Baskara, 2023; Van Doc et al., 2023). In addition, the areas of study vary, encompassing assessment types, intelligent tutoring systems, flipped classrooms, mathematical thinking skills, and other related topics.

While reviewing the literature, it becomes apparent that there are several research gaps that deserve attention. There is a lack of in-depth analysis regarding the ethical considerations surrounding the use of AI technologies such as chatbots in educational settings. Further research is necessary to investigate the efficacy of simulated emotions in AI systems for promoting learning. Furthermore, there seems to be a dearth of longitudinal studies examining the long-term effects of chatbots and similar tools.

To summarise, it is important to acknowledge the significance of emotions in the learning process and the potential of AI technologies to offer personalised assistance. However, further research is required to fully explore these areas. To advance the field, it is imperative that future research focuses on ethical considerations, thoroughly evaluates the integration of simulated emotions in AI, and carefully examines the long-term effects of implementing these innovations. This analysis of agreements, discrepancies, and areas for further exploration provides valuable insights to inform future research endeavours.

5. Methodology

The study employed both the correlational method and the descriptive-analytical method to align with the research topic and achieve its objectives.

5.1 Study Scopes

1. Spatial determinants: Mathematics Section, Al-Kharj Education Administration, Riyadh.
2. Human determinants: A sample of educational mathematics supervisors.
3. Objective boundaries: focused on specific geometric concepts within mathematics for the first secondary grade (within the spaces and shapes domain). This choice was made to align with spatial thinking skills and academic emotions.
4. Time constraints: conducted during the first semester of the academic year 2024 AD.

5.2 Research Tools

1. Survey questionnaire covering: 1–1. Spatial thinking in mathematics. 1-2. Academic emotions towards mathematics. The questionnaire items were designed using a five-point Likert scale, assigning numerical values (5, 4, 3, 2, 1) to indicate the responses' strengths, ranging from very strong to very weak.

The questionnaires were evaluated by a panel of experts in their respective fields to ensure their finalisation. The validation and reliability of the measures were confirmed through administration to a sample of 30 individuals who were not part of the research sample but belonged to the study community. The assessment of internal consistency and validity was conducted through the peripheral comparison method, while internal stability was measured using Cronbach's alpha coefficient. The criteria for assessing sample members' responses were determined using the following formula: (upper value minus lower value) / number of levels = (5 minus 1) / 3 = 1.33. This criterion was adopted for evaluating the study sample's responses.

5.3 Mathematics Spatial Thinking Assessment Questionnaire

Table 1

The Validity of The Questionnaire by Using The "T" Value to Assess the Difference Between the Upper and Lower Groups

Significance Level	Value of "T"	Freedom Degree	Average	Sample volume.	Groups
Significance at α= 0.01	9.55	20	2.6364	11	**High group**
			0.5455	11	**Low group**

Based on the data presented in Table 1, the "T" value reached statistical significance at the α = 0.01 level of significance. There is a clear difference in the scores of the higher and lower groups on the questionnaire, suggesting a satisfactory level of validity. As a result, the questionnaire is considered appropriate for research purposes.

Table 2

Internal Consistency Stability (Cronbach's Alpha)

Tool	Number of Items	Stability Through Alpha- Cronbach (A)
Questionnaire	12	0.86

The data in Table 2 clearly shows that the researcher found a stability coefficient of 0.86, which is an acceptable value. The value suggests that the questionnaire is highly stable and appropriate for research purposes.

5.4 Emotional Responses in Mathematics Education

Table 3 displays the validity of the questionnaire by utilising the "T" value to assess the distinction between the upper and lower groups.

Table 3

The Validity of The Questionnaire by Using The "T" Value for The Difference Between the Upper and Lower Group

Significance Level	Value of "T"	Freedom Degree	Average	Sample Volume	Groups
Significance at α= 0.01	9.17	20	3.2358	11	**High group**
			0.7019	11	**Low group**

From the data presented in Table 3, the "T" value reached statistical significance at the α = 0.01 significance level. There is a clear difference in scores between the higher and lower groups on the questionnaire, suggesting a satisfactory level of validity. As a result, the questionnaire is considered appropriate for research purposes.

Table 4

Internal Consistency Stability (Cronbach's Alpha)

Tool	Number of Items	Stability Through Alpha- Cronbach (A)
Questionnaire	24	0.89

The data in Table 4 clearly shows that the researcher found a stability coefficient of 0.89, which is an acceptable value. The value suggests that the questionnaire is highly stable and appropriate for research purposes.

Table 5

Relative Weight, Categories, and Verbal Estimates

No.	Extent	Verbal Estimates
1	From1.00-1.80	Very small
2	From1.81-2.60	Small
3	From2.61-3.40	Medium
4	From3.41-4.20	Large
5	From4.21-5.00	Very Large

6. Results

To examine the research questions, the analysis involved using arithmetic means, standard deviations, rankings, and verbal estimates. The data analysis was conducted using SPSS 29.

To address the first research question: "What is the extent of the connection between mathematical spatial thinking and artificial intelligence applications, according to educational supervisors in the first semester of 2024 AD?"

Table 6

AI Applications' Relationship to Spatial Thinking in Mathematics (Educational Supervisors' View)

Themes	Items	Average	Stdeva	Rank	Estimates
Mental rotation	Rotate a 2D or 3D shape, clockwise and counterclockwise.	4.60	0.58	5	Very Large
	Arrange a group of pattern pieces to form a circular pattern without leaving any space between them.	4.24	0.83	5	Very Large
	Distinguish between the coordinates of shapes around the vertical and diagonal lines of symmetry.	4.40	0.91	5	Very Large
	Distinguish between reflection and rotation.	4.56	0.87	5	Very Large
	Total Mental rotation	4.45	0.15	5	Very Large
Spatial perception	Locate 2D and 3D shapes from multiple angles.	4.64	0.49	5	Very Large
	Determine the origin of the point when the north is not in the straight vertical direction.	4.56	0.65	5	Very Large
	Read coordinates of 2D and 3D shapes in different directions.	4.56	0.58	5	Very Large
	Determine orthogonal views of 2D and 3D shapes.	4.60	0.71	5	Very Large
	Total Spatial perception	4.59	0.09	5	Very Large
Spatial visualization	Visualize the result of folding 2D and 3D shapes.	4.64	0.57	5	Very Large
	Skillfully distinguish between congruence and symmetry.	4.48	0.92	5	Very Large
	Inferring symmetry through reflection of 2D and 3D shapes.	4.56	0.51	5	Very Large
	Matching pieces and parts to a number of some shapes precisely.	4.44	0.77	5	Very Large
	Total Spatial visualization	4.53	0.19	5	Very Large
	Total spatial thinking degree	4.52	0.05	5	Very Large

It is evident from Table 6 that:

1. The level of spatial cognition in mental rotation items was as follows: (Average = 4.60, 4.24, 4.40, 4.56), and (SD = 0.58, 0.83, 0.91, 0.87), with a total of (Average = 4.45) and (SD = 0.15). A very large estimate was observed (rank = 5) for the correlation between artificial intelligence applications and spatial cognition in mental rotation within the realm of mathematics as perceived by educational supervisors.
2. The degree of spatial cognition in spatial perception items was as follows: (Average = 4.64, 4.56, 4.56, 4.44), and (SD = 0.49, 0.92, 0.58, 0.71), with a total of (Average = 4.59) and (SD = 0.09). A very large estimate was observed (rank = 5) for the correlation between artificial intelligence applications and spatial cognition in spatial perception within the realm of mathematics as perceived by educational supervisors.
3. The degree of spatial cognition in spatial visualization items was as follows: (average = 4.64, 4.48, 4.56, 4.60) and (SD = 0.57, 0.65, 0.51, 0.77), for a total of (average = 4.53) and (SD = 0.19). A very large estimate was observed (rank = 5) for the correlation between artificial intelligence applications and spatial cognition in spatial visualization within the realm of mathematics as perceived by educational supervisors.
4. The overall degree of spatial cognition was (average = 4.52) and (SD = 0.05). A very large estimate was observed (rank = 5) for the correlation between artificial intelligence applications and overall spatial cognition within the realm of mathematics as perceived by educational supervisors.

To address the second research question: "What degree of a connection do educational supervisors in the first semester of 2024 AD perceive between artificial intelligence applications and academic emotions toward mathematics?"

Table 7

AI Applications' Relationship to Academic Emotions Toward Mathematics (Educational Supervisors' View)

Themes	Items	Average	Stdeva	Rank	Estimates
Curiosity	The tendency to solve questions in order to learn how to answer them, not because they were assigned to do so.	4.04	0.80	5	Very Large
	Exchange opinions and ask each other questions before they start any work in mathematics.	4.04	0.68	5	Very Large
	Preferring to complete mathematics tasks using artificial intelligence applications rather than watching electronic games.	3.84	1.11	4	Large
	Ask the teacher various questions out of a desire to learn everything new.	4.28	0.74	5	Very Large
	Total Curiosity	4.05	0.19	5	Very Large
Perseverance	Continuing to complete mathematics tasks using artificial intelligence applications from inception until completion.	4.20	0.82	5	Very Large
	Difficult mathematical problems appeal to them more than moderately difficult problems.	3.41	1.00	4	Large
	Continue doing math projects even if they take a long time to complete.	3.60	1.12	4	Large
	Preferring math situations that include some creativity over traditional matters.	3.92	1.12	4	Large
	Total Perseverance	3.78	0.14	4	Large
Enjoyment	Enjoy being innovators or makers of new things.	4.40	0.65	5	Very Large
	Take the initiative to participate in mathematics activities that rely on the power of observation with classmates.	4.08	1.04	5	Very Large
	Needing very short periods of rest whenever they successfully complete part of their work.	4.12	0.97	5	Very Large
	Enjoy presenting important activities, examples, and exercises using artificial intelligence applications in front of their colleagues.	4.32	0.75	5	Very Large
	Total Perseverance	4.23	0.18	5	Very Large
Avoid boredom	Contributing motivational teaching methods to their love of learning mathematics.	4.52	0.51	5	Very Large
	Communicate effectively with teachers because of their effective teaching methods that use artificial intelligence applications.	4.21	0.71	5	Very Large
	In classes shared through artificial intelligence applications, the feeling is that time is passing quickly.	4.40	0.65	5	Very Large
	Most of the teaching methods used cause personal happiness.	3.76	1.17	4	Large
	Total Avoid boredom	4.22	0.29	5	Very Large
Avoid fatigue	Complete mathematics projects under the supervision of the teacher to the fullest extent without fatigue.	3.60	1.00	4	Large
	The determination and resolve to win the mathematics competition using artificial intelligence applications.	3.92	0.91	4	Large
	Feeling happy and satisfied very soon after starting the tasks assigned to them by the mathematics teacher.	3.84	0.99	4	Large
	Their primary goal is to succeed in performing any mathematics task.	4.16	0.80	4	Large
	Total Avoid fatigue	3.88	0.09	4	Large
Avoid anxiety	Feeling anxious while completing math projects is due to the lack of effort expended on them.	3.36	1.08	3	Medium
	Put too much effort into learning any topic that is difficult for them to understand right away while they are studying mathematics.	3.48	0.96	4	Large
	Put too much effort into whatever they do for fear of anxiety.	3.32	0.90	3	Medium
	The importance of completing any mathematics task smoothly using artificial intelligence applications.	4.00	0.96	4	Large
	Total Avoid anxiety	3.54	0.08	4	Large
	Total degree	3.95	0.08	4	Large

It is evident from Table 7 that:

1. The level of academic emotions towards mathematics in Curiosity items were as

follows: (Average = 4.04, 4.04, 3.84, 4.28), and (SD = 0.80, 0.68, 1.11, 0.74), with a total of (Average = 4.05) and (SD = 0.19). A very large estimate was found (rank = 5) for the correlation between artificial intelligence applications and academic emotions towards mathematics in Curiosity from the perspective of educational supervisors.

2. The level of academic emotions towards mathematics in Perseverance items were as follows: (Average = 4.20, 3.41, 3.60, 3.92), and (SD = 0.82, 1.00, 1.12, 1.12), with a total of (Average = 3.78) and (SD = 0.14). A large estimate was found (rank = 4) for the correlation between artificial intelligence applications and academic emotions towards mathematics in Perseverance from the perspective of educational supervisors.
3. The level of academic emotions towards mathematics in Enjoyment items were as follows: (Average = 4.40, 4.08, 4.12, 4.32), and (SD = 0.57, 0.65, 0.51, 0.77), with a total of (Average = 4.23) and (SD = 0.18). A very large estimate was found (rank = 5) for the correlation between artificial intelligence applications and academic emotions towards mathematics in Perseverance from the perspective of educational supervisors.
4. The level of academic emotions towards mathematics in avoiding boredom items were as follows: (Average = 4.52, 4.21, 4.40, 3.76), and (SD = 0.51, 0.71, 0.65, 1.17), with a total of (Average = 4.22) and (SD = 0.29). A very large estimate was found (rank = 5) for the correlation between artificial intelligence applications and academic emotions towards mathematics in avoiding boredom from the perspective of educational supervisors.
5. The level of academic emotions towards mathematics in avoiding fatigue items were as follows: (Average = 3.60, 3.92, 3.84, 4.16), and (SD = 1.00, 0.91, 0.99, 0.80), with a total of (Average = 3.88) and (SD = 0.09). A large estimate was found (rank = 4) for the correlation between artificial intelligence applications and academic emotions towards mathematics in avoiding fatigue from the perspective of educational supervisors.
6. The level of academic emotions towards mathematics in avoiding anxiety items were as follows: (Average = 3.36, 3.48, 3.32, 4.00), and (SD = 1.08, 0.96, 0.90, 0.96), with a total of (Average = 3.54) and (SD = 0.08). A large estimate was found (rank = 4) for the correlation between artificial intelligence applications and academic emotions towards mathematics in avoiding anxiety from the perspective of educational supervisors.
7. The overall academic emotions towards mathematics degree were (Average = 3.95) and (SD = 0.08). A Large Estimate was found (rank = 4) for the correlation between artificial intelligence applications and overall academic emotions towards mathematics from the perspective of educational supervisors.

The present study examines the correlation between AI applications, spatial thinking, and students' emotions towards mathematics, as observed by educational supervisors. The text also demonstrates the effectiveness of students' productivity in self-paced, participatory, and interactive learning. Several examples of ChatGPT and Metaverse photos demonstrate the direct correlation between the advancements achieved and the specific tasks performed by artificial intelligence applications.

By incorporating artificial intelligence into mathematics education, it is possible to introduce a range of improvements to 2D and 3D shapes. This allows for the exploration of the relationships between their coordinates in different positions and the comparison of the various geometric transformations they undergo. Incorporating audio commentary into videos and presentations can make them more interactive and appealing to students, fostering their academic emotions towards mathematics. This discovery aligns with previous investigations (Abdel Hamid, 2021; Abdel Rahman, 2014; Abdel Raouf, 2020; Abualrob, 2019; Atsikpasi & Fokides, 2022; Bedir, 2019; Camacho-Morles et al., 2021; Hanin & Van Nieuwenhoven, 2016; Ibrahim et al., 2019; Khairallah, 2007; Kim & Pekrun, 2014; Maereg et al., 2017; Pekrun et al., 2017; Rahman & Watanobe, 2023; Ramful et al., 2017; Zarrouqi & Falta, 2020).

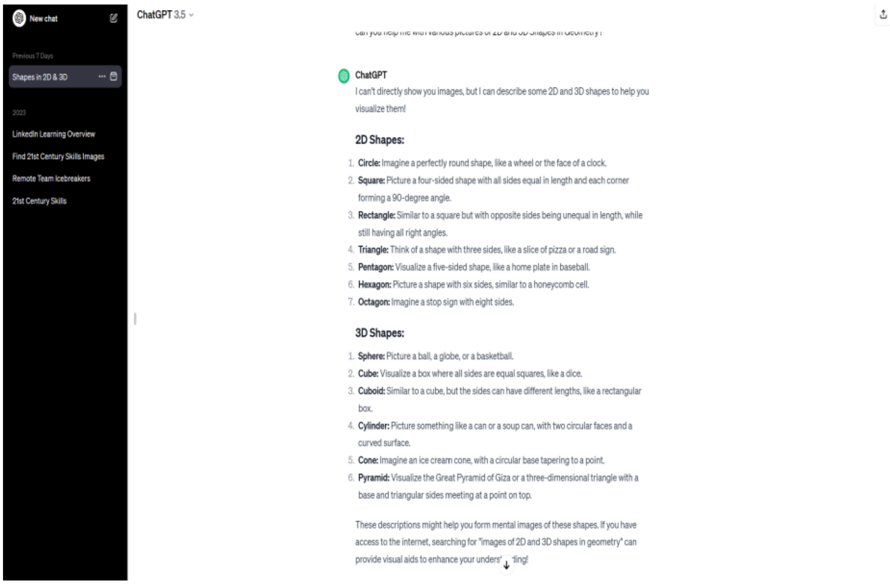

Figure 1: *(ChatGPT) Photo Illustrating 2D and 3D Shape Descriptions.*

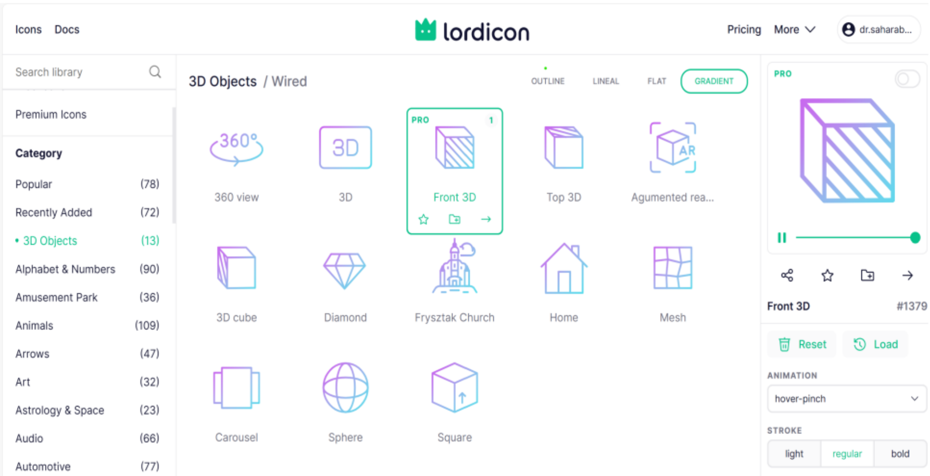

Figure 2: *Designing 2D and 3D Shapes Dimensions by Using (Metaverse) by Lord Icon Program.*

7. Discussion

The latest research indicates a strong link between AI and the improvement of spatial thinking and positive academic emotions towards mathematics (overall ratings of 4.52 and 3.95 out of 5 respectively), These findings support the conclusions made by Thiel (2008) regarding the influential role of emotions in learning. However, Thiel's study primarily examined the emotional responses of undergraduates, whereas the present study takes a more comprehensive approach by considering various aspects of spatial thinking skills and academic emotions.

The potential of AI technologies to enhance engagement, motivation, and thinking abilities aligns with the findings of Baskara (2023) and Van Doc et al. (2023) regarding the use of chatbots for personalised support. However, previous studies have primarily focused on chatbots, rather than the broader range of AI applications that are examined in this study, from the perspective of an educational supervisor.

In a study conducted by Barrón et al. (2014), it was emphasised that intelligent tutoring systems should consider emotional states, which is supported by research on the significant role of academic emotions (Kim & Pekrun, 2014; Mohamed, 2016). However, Barrón et al. (2014) focused specifically on software and did not consider the broader impacts of AI on spatial and affective aspects.

This study builds upon the findings of Angelin Rosy et al. (2023) by examining supervisor perceptions and their implications for multifaceted constructs in learning and intelligence. The statement highlights the potential and ethical implications of AI tools, as well as the necessity for additional research on their long-term effects. Understanding the significant impact that AI can have on mathematics education requires ongoing investigation from a range of perspectives.

Overall, it is worth noting that many of the studies analysed in this analysis focused on limited aspects, despite acknowledging the importance of emotions and the potential of AI technologies for tailored assistance. This study presents the insights of educational supervisors regarding the potential benefits and difficulties of incorporating modern AI applications to reshape the spatial thinking and emotional aspects of secondary mathematics education in the digital age.

8. Recommendations

Considering the findings of the study, the following recommendations are suggested:

1. Incorporate prompt engineering as a fundamental aspect in mathematics education tasks.
2. Establish mathematics resource centres and laboratories at all levels of general education, equipped with state-of-the-art artificial intelligence applications.
3. Provide in-depth training programmes for mathematics teachers and supervisors on effectively using artificial intelligence applications to enhance students' spatial thinking abilities and foster positive academic emotions toward mathematics.

9. Implications and Recommendations

1. **Flexibility in Instruction:** Teachers can seamlessly incorporate AI applications into different teaching styles and learning models, such as project-based learning. This allows them to offer precise and efficient guidance to help students achieve their lesson objectives.

2. **Cultural Relevance in Education:** Integrating local cultural elements into mathematics education, particularly in relation to the metaverse, has the potential to promote culturally relevant teaching and improve students' academic performance.
3. **Limitation Acknowledgement:** The study's extensive reliance on qualitative methods restricts its scope, which must be considered when interpreting the findings.
4. **Focus on Educational Supervisors' Views:** Examining the viewpoints of educational supervisors regarding AI applications in relation to spatial thinking and students' emotions towards maths is crucial for obtaining precise and current insights into the role of AI in mathematics education.
5. **Transformative Educational Practices:** The study proposes the incorporation of prompt engineering into educational programmes and the utilisation of AI for customised instruction that caters to unique spatial abilities and emotions. This approach holds great potential for revolutionising the way mathematics is taught and learned.
6. **Teacher Training and Ethical Policies:** It is imperative to enhance teacher training, establish ethical policies for data privacy, and foster access to AI innovations through partnerships with school-tech companies.
7. **Curriculum Redesign:** To incorporate fundamental spatial perspectives into the curriculum to effectively utilise AI in the field of education.
8. **Potential for Bridging Achievement Gaps:** Successful implementation of AI has the potential to address achievement gaps and foster the development of practical reasoning abilities that are crucial for pursuing STEM professions.

9.1 Suggestions for Further Research

1. Conduct comparative studies to evaluate the long-term effects of integrating AI technologies on spatial thinking ability, academic emotions, and mathematics achievement across different educational levels.
2. Execute interdisciplinary research to examine ethical frameworks, privacy protections, and fair usage standards for implementing AI tools in educational settings
3. Evaluate the efficacy of different teacher training programmes that aim to utilise AI advancements to revolutionise mathematics teaching.
4. Create frameworks, protocols, and policy recommendations to ensure fair, ethical, and privacy-cantered implementation of AI in future educational settings.
5. Explore methods to utilise multisensory AI applications to enhance the accessibility and tangibility of abstract mathematics concepts for a wide range of learners.

9.2 Conflicts of Interest

The author states that there are no conflicts of interest.

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