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Artificial intelligence in mathematics education: A systematic literature review

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ABSTRACT

The advancement of technology like artificial intelligence (AI) provides a chance to help teachers and students solve and improve teaching and learning performances. The goal of this review is to add to the conversation by offering a complete overview of AI in mathematics teaching and learning for students at all levels of education. A systematic literature review (SLR) was conducted using established and robust guidelines. We follow the preferred reporting items for systematic reviews and meta-analyses (PRISMA). We searched ScienceDirect, Scopus, Springer Link, ProQuest, and EBSCO Host for 20 AI studies published between 2017 and 2021. The findings of the SLR indicate that AI approach used in mathematics education for the samples studied were through robotics, systems, tools, teachable agent, autonomous agent, and a comprehensive approach. Then, it can be shown that the majority of the collected studies were carried out in the USA and Mexico. The analysis revealed that most of the reviewed studies used quantitative research methods. The types of themes for AI in mathematics education were categorized into advantages and disadvantages, conceptual understanding, factors, role, idea suggestion, strategies and effectiveness.

Keywords: artificial intelligence, mathematics education, PRISMA, robotics, systematic literature review

INTRODUCTION

Artificial intelligence (AI) applications in education are becoming more popular and have gotten a lot of press in recent years. AI is a leap across creative and innovative thinking in various fields, including mathematics education. The current study indicates various research of AI in different context (Chen et al., 2020a; Cope et al., 2020; He et al., 2019; Schiff, 2021; Vaishya et al., 2020). The use of AI can enhance our abilities in living a life covered in increasingly sophisticated technology. According to Gao (2020), based on the development of computer technology, AI continues to expand and innovate. AI enables students to develop and enhance more mathematical skills and cognitive skills in learning. Popenici and Kerr (2017) the role of technology in higher learning is to enhance human thinking and augment the educational process. AI helps students in finding answers faster and easier. All information about the lesson can be easily accessed by students using this innovative intelligence software. In this generation, students are more inclined to learn and explore new knowledge on their own, so this powerful tool of AI can help students to explore more without waiting for an educator. Cope et al. (2020) indicate, however, the role of AI will never 'take over' the duty of educator in any way. Furthermore, the deployment of these technologies for teaching, learning, student assistance, and administration faces various hurdles (Popenici & Kerr, 2017).

AI is a process that produces human intelligence through machines, especially computer systems. Specific applications of AI include expert systems, natural language processing, speech recognition and machine vision. With the advanced system, AI can perform human-like functions or duties through the level of difficulties that have been set up. A pedagogical agent (teachable agent) is a type of educational software that has human characteristics and/or appearances and are designed to support learners in online learning environments (Song, 2017). Besides, AI machines or systems can perform complex tasks that the human brain cannot do. AI has various perceptions in society. They felt that this AI was wrong because these machines were believed to take over human tasks. A portion of this public awareness refers to the anticipation of likely negative consequences related to the variety of applications of AI as a technology, known as the public perception of risk of AI or merely the risk perception of AI (Neri & Cozman, 2020). Recently, Voskoglou and Salem (2020) summarized the benefits of using AI or machine in teaching and learning. The current finding of studies discussed the use of robotics in learning and teaching mathematics (Casler-Failing, 2018; Harper et

al., 2021; Lopez-Caudana et al., 2020). Learning programming and problem-solving (PS) at a young age is very challenging for them. Francis and Davis (2018), for example, also indicate that the learning process has become more interactive using the AI approach.

Concerning existing systematic literature review (SLR) about exploring the potential of educational robotics in education settings, there are few SLR has been conducted (Chen et al., 2020a; Guan et al., 2020; Zawacki-Richter et al., 2019; Zhong & Xia, 2020), including mathematics education. Zhong and Xia (2020), for example, provides an exciting learning experience with robotics in mathematics learning. It focuses on empirical evidence towards the application of robotic in mathematics education. However, there are some limitations of a SLR conducted about AI in mathematics education. It is because previous studies have only focused on the use of AI in the fields of engineering, computer science and STEM. Therefore, using this opportunity, lots of research about the maximum use of AI in mathematics education can be done. The goal of this review is to add to the conversation by offering a complete overview of AI in mathematics teaching and learning for students at all levels of education. This SLR contributes on the impact of AI and the use of robotics or software as well as machines from AI in the teaching and learning of mathematics to students at all levels of education.

Research Questions

1. What AI approach used in mathematics education for the samples studied?
2. How is AI in education distributed in terms of the country?
3. How is AI in education distributed in terms of the research methodology?
4. How are the AI in mathematics education distributed in terms of publication year?
5. What themes are currently instigated?

Theoretical Foundation

Six years later, in 1956, Marvin Minsky and John McCarthy (a Stanford computer scientist) convened the eight-week-long Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI), which formally originated the term AI. To date, there are diverse concept of AI in the current literature. The problem in defining AI, known as machine intelligence (Poole et al., 1998), is to define artificiality's parameters, or the manners in which computers differ from human intelligence (Cope et al., 2020). AI is clearly the confluence of computer, computer-related technology, machine, and information communication technology advancements and developments, allowing computers to perform activities that are close to or identical to those performed by humans (Chen et al., 2020b). Baker and Smith (2019) defined AI as computers that do cognitive functions, such as learning and PS, that are often associated with human brains. Data mining, natural language processing, machine learning, neural networks, and algorithms are some examples of technologies and methodologies in AI. However, AI in educational contexts may help with teaching, learning, and decision-making (Hwang et al., 2020).

The basic mathematics teaching based on AI adapts and pays attention to the cultivation of students' personality development under the existing education conditions (Wu, 2021). In mathematics education in particular, the animation of figure and of mathematical representations, obtained by using the proper software, increases the student imagination and PS skills (Voskoglou & Salem, 2020). The incorporation of AI technologies into education settings enables computer-based learning system to play roles of intelligent tutor, tools or tutees as well as policy-making facilitators (Basel, 2021). Since its origin, the holy grail of AI has been to understand the nature of intelligence and to engineer systems that exhibit such intelligence through vision, language, emotion, motion, and reasoning. In such context, AI researchers have always looked for challenges to push forward the limit of what computers can do autonomously and to measure the level of "intelligence" achieved (Chesani et al., 2017). The concept of ICT has emerged as a technological convergence of electronics, software, and telecommunications infrastructure. Robotics is one of the expressions of technology whose application has extended to various life contexts. The importance of showing how technology allows for significant improvements in attention and motivation towards mathematics, which, in turn, allows for an improvement in training programs and teaching practices; thus, achieving a positive impact on student learning (Basel, 2020).

AI has promoted the social development, and has gradually been applied to the education and teaching with its innovation and epochal characters. Mathematics teacher educators and teachers should consider using innovative tools not typically seen in classrooms, such as robotics, in mathematics instruction as they work to support a focus on reasoning and sense making and make connections to children's community and cultural funds of knowledge (Harper et al., 2021). There is a positive predisposition towards the addition of robots in the learning and teaching of mathematic processes during the first years of school, even though teachers claim there is a struggle to incorporate robots in their lessons due to the high number of students and the reduced space in their classrooms (Seckel et al., 2021). One form of technology that has been shown to be beneficial to the learning of mathematics is LEGO robotics, namely EV3 Mindstorms. Select children and educators have had access to LEGO robotics for the past 20 years however, robotics has not experienced widespread use in the mathematics classroom, in a middle-school mathematics classroom working with LEGO robotics demonstrated that robotics could provide richer learning and engagement than traditional 'I do, we do, you do' instruction (Casler-Failing, 2021). Therefore, in the current work, we follow the idea of Ouyang and Jiao (2021) as conceptual framework namely AI-directed (learner-as-recipient), AI-supported (learner-as-collaborator), and AI-empowered 9 learner-as-leader). **Figure 1** indicates conceptual framework in the current SLR.

According to recent studies, AI has a positive impact on student accomplishment (Min et al., 2021), creative PS skills and computing thinking (Kim & Han, 2021), and learning attitude (Liao & Gu, 2022) from kindergarten to higher education settings (Ma & Siau, 2018). For example, the role and importance of wisdom classroom instruction can be understood by early childhood via AI context. Other possibilities in higher education settings involve the usage of AI assistants and AI instructors in the classroom. Chen et al. (2020b) also found the impact of IA toward education such as environments in the classroom, conceptual understanding, advanced deep learning algorithms' adoption and the integration of AI technologies with educational philosophies. However,

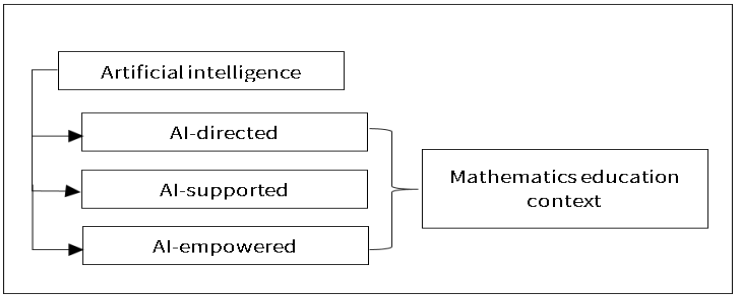

Figure 1. Conceptual framework

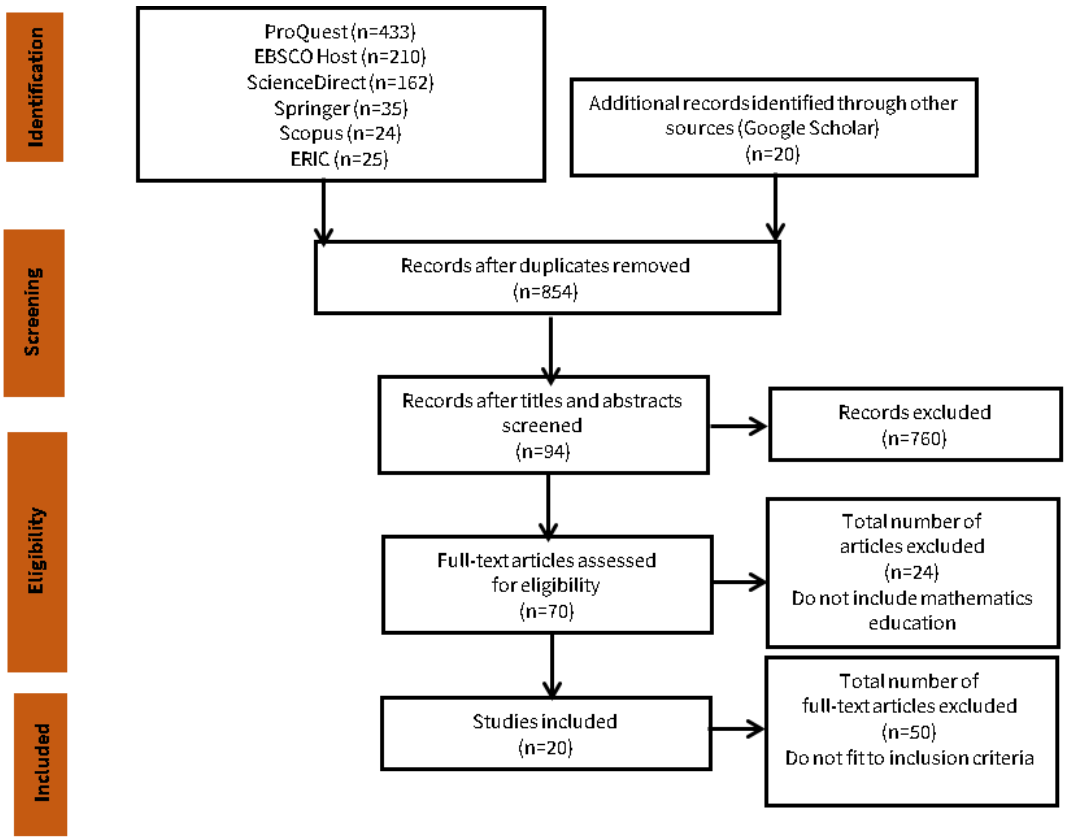

Figure 2. PRISMA flow diagram

applying AI to education appears to be a new challenge (Hwang et al., 2020; Pedro et al., 2019). Zawacki-Richter et al. (2019) found the low connection between AI and theoretical pedagogical views. Moreover, for educational scholars, not only computer programming abilities, but also ways for replicating the intellect of human specialists are hurdles in designing intelligent tutoring and adaptive learning education systems (Hwang et al., 2020). In brief, although AI has the potential to improve students' learning outcomes, it remains a problem for most educational academics, educators and practitioners.

METHODOLOGY

Research Design

We conducted a comprehensive SLR to answer our research questions. SLR is a method of gathering appropriate data on a certain topic that meets pre-determined eligibility criteria (Mengist et al., 2020). This study only looked at journal publications published between 2017 and 2021; no older articles were included. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) approach analyzed the collected journal articles. PRISMA establishes a standardized, peer-reviewed methodology that employs guideline checklists to contribute to the revision process's quality assurance and replicability (Conde et al., 2020; Moher et al., 2015). PRISMA is based on four steps: identification, screening, eligibility, and inclusion. Identification is the first phase. These steps are detailed in the sub-sections that follow. This technique was chosen because it can assist us in synthesizing important journal publications. By following PRISMA guidelines, we could conduct an accurate search for best practices in AI in mathematics education. **Figure 2** displays the PRISMA flow chart in this study adapted and modified from Moher et al. (2009).

Table 1. Synonyms and alternatives terms for main search terms

Artificial intelligence	Math
AI	Math
Robotics	Maths
Machine learning	Mathematics
Neural networks	Mathematics education
Fuzzy logic	Mathematical
Natural language processing	Math education
Expert systems	

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published between 2017 and 2021	<2017
Indexed journal	Non-indexed journals, review journals, chapter in book, conference proceeding, master dissertation, prefaces, and opinion
English language	Non-English
Specific application for mathematics or mathematics education	General application for professional learning (e.g., medical, public health, environmental science, and engineering)

Systematic Review Process

Identification

The search took place on ScienceDirect, Scopus, Springer Link, ProQuest, and EBSCO Host. We came up with two mains search terms based on our fundamental research topics: AI and mathematics education. We compiled a list of synonyms and alternate terms based on the most popular search terms (**Table 1**).

Therefore, we expanded our search terms and strategies in exploring as many potentially relevant studies as possible. To search, we used a key search term that was created by combining the words discovered from (**Table 1**), as follows: TITLE-ABS-KEY. Through ProQuest, EBSCOHost, ScienceDirect, Springer, Scopus, 864 results were identified using search strategies, while additional papers (n=20) were identified from other sources. As a result, a total of 885 journal articles had been classified at this stage in the process.

Screening

As displayed in **Figure 1**, the selection process followed the PRISMA principles (Moher et al., 2009). We used a variety of inclusion and exclusion criteria in this approach. There were no systematic review articles or books, book chapters, or conference proceedings included in the selection of literature. And, we were only concentrating on English-language journal articles made it less likely that complex or uncertain translations would be required. Then, we looked at articles published within the previous five years (between 2017 and 2021). There were no exclusions for specific countries or regions. In the final stage of the screening process, we focused their attention on publications that contained at least one reference to mathematics. Following the screening phase, 909 papers were identified as not meeting the study's criteria, while 55 articles were identified as duplicates. Additionally, there are just 845 articles remaining.

Eligibility

As illustrated in **Figure 1**, the eligibility phase resulted from incomplete articles. First, journal articles that did not meet the criteria for best practices in AI in mathematics were rejected. Then, to ensure that all 845 articles fit the study's selection criteria and objectives, each article's title, abstract, methodology, results, and discussion were thoroughly reviewed. At this point, 834 articles have been rejected because they do not fully explain AI in mathematics education or do not clearly explain and review the findings data in the study findings section. As a result, 20 articles were selected for publication in the final stage of the review process (see **Figure 1**).

Inclusion and exclusion criteria

After gathering all of the results from all identified sources, we used the selection criteria such as timeline, document type, language, and subject area to filter out the articles that were not relevant to our research. When selecting pieces for inclusion and exclusion, the inclusion and exclusion criteria must be clearly defined to ensure that the studies selected are relevant to the primary research purpose. **Table 2** shows the inclusion and exclusion criteria for this review study and the findings of the research. It was determined that 20 articles were relevant, and the full-text articles of these publications were obtained.

FINDINGS

A total number of AI studies (n=20) are analyzed, published between 2017 and 2021. This section discusses the following research questions:

1. What AI approach used in mathematics education for the samples studied?

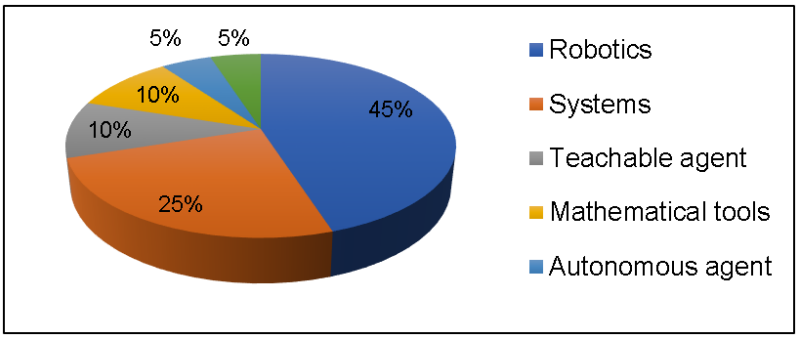

Figure 3. Distribution of AI approach

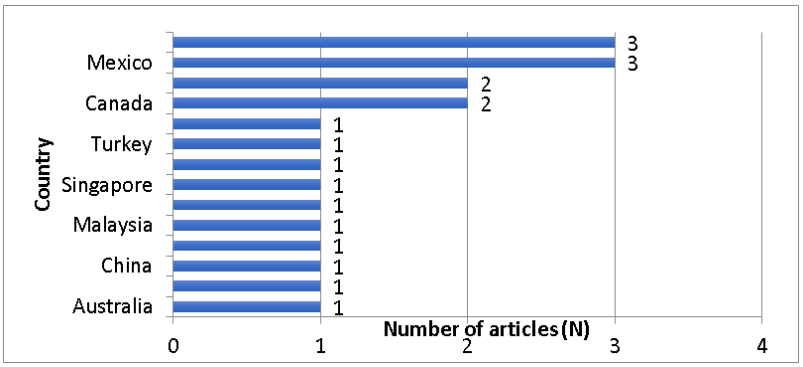

Figure 4. Distribution of research studies by country

2. How is AI in education distributed in terms of the country?
3. How is AI in education distributed in terms of the research methodology?
4. How are the AI in mathematics education distributed in terms of publication year?
5. What themes are currently instigated?

AI Approach Used in Mathematics Education for the Samples Studied

The first research question was concerned with the AI approach used in mathematics education for the samples studied. The AI approach used in mathematics education for the samples studied were through robotics, systems, tools, teachable agent, autonomous agent, and a comprehensive approach. As seen in **Figure 3**, the majority of AI approach used for the samples studied were through robotics (45%, n=9) (Casler-Failing, 2018, 2021; Forsström & Afdal., 2019; Francis & Davis, 2018; Harper et al., 2021; Lopez-Caudana et al., 2020; Rico-Bautista et al., 2019; Sáez-López, 2019; Seckel et al., 2021) and followed by systems (15%, n=5) (Moreno-Esteva et al., 2018; Mills, 2021; Rojano & Garcia-Campos, 2017; Saha et al., 2020; Zakaria et al., 2021). There were two researches that practiced teachable agent's (Gulz et al., 2020; Song, 2017) and also two research mathematical tools' (Dunzhin & Gustafsson, 2018; Salas-Rueda et al., 2020) approach of AI in mathematics education. The AI approach through an autonomous agent (Chesani et al., 2017) and comprehensive approach (Wu, 2021) each only have one research discussion. In addition, programming also was introduced alongside robotics with the aim of gaining the advantages that arise from manipulation and experimentation in these types of activities; such benefits include developing logical thinking in algorithms, sequences and different computational concepts (Sáez-López et al., 2019) because computer programming aligns closely with concepts and structures in mathematics (Francis & Davis, 2018).

The Distribution of Research Studies in Term of Country

The geographic distribution of the authors was the subject of the second research question. **Figure 4** shows the categorization of the selected studies according to the countries they were carried out. Even though our systematic review only included publications published in English, the research was carried out in various cultural contexts throughout the world. It can be shown that the majority of the collected studies (n=3) were carried out in the USA (Casler-Failing, 2018; Harper et al., 2021; Mills, 2021) and Mexico (Lopez-Caudana et al., 2020; Rojano & Garcia-Campos, 2017; Salas-Rueda et al., 2020). There are two articles in each of the following categories: studies conducted Spain (Sáez-López et al., 2019; Seckel et al., 2021) and Canada (Chesani et al., 2017; Francis & Davis, 2018).

In contrast, AI in mathematics education is the least frequently discussed among scholars in various countries, such as United Kingdom (Casler-Failing, 2021), Turkey (Song, 2017), Sweden (Gulz et al., 2020), Singapore (Duzhin & Gustafsson, 2018), Norway (Forsström & Afdal, 2019), Malaysia (Zakaria et al., 2021), Colombia (Rico-Bautista et al., 2019), China (Wu, 2021), Bangladesh (Saha et al., 2020), and Australia (Moreno-Esteva et al., 2018). As a result of this finding, it is possible that scholars in the USA and Mexico are becoming increasingly interested in exploring the topic of AI in mathematics teaching. Therefore, additional research into this topic is still required in other countries, among other things.

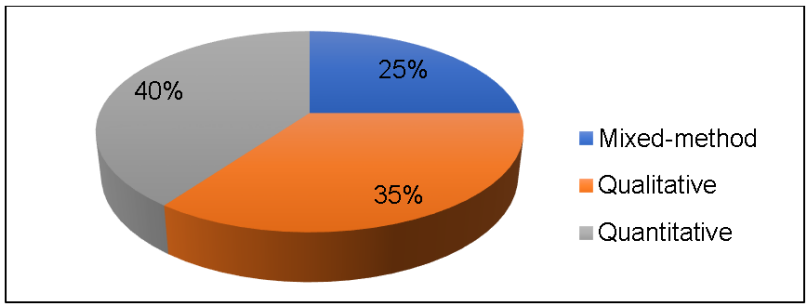

Figure 5. Distribution of AI in term of research methodology

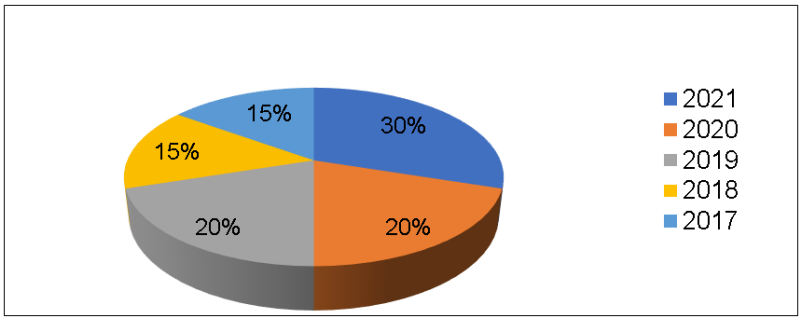

Figure 6. Distribution of research studies in term of publication year

The Distribution of AI in Term of Research Methodology

The third research question was about research methodologies. **Figure 5** illustrates the distribution of research methodologies used in the reviewed studies. According to the study's findings, only three research method approaches were used in this reviewed study: qualitative, quantitative, and mixed methods. The analysis revealed that most of the studies reviewed (40%, n=8) used quantitative research methods (Duzhin & Gustafsson, 2017; Gulz et al., 2020; Mills, 2021; Moreno-Esteva et al., 2018; Rico-Bautista et al., 2019; Rojano & Garcia-Campos, 2017; Sáez-López et al., 2019; Zakaria et al., 2021). Subsequently (35%, n=7) of the reviewed studies used the qualitative research method approach in the study (Casler-Failing, 2018, 2021; Francis & Davis, 2018; Forsström & Afdal, 2019; Harper et al., 2021; Song, 2017; Wu, 2021;), while the remaining (25 %, n=5) used the mixed method approach (Caudana et al., 2020; Chesani et al., 2017; Saha et al., 2020; Salas-Rueda et al., 2020; Seckel et al., 2021). However, there are multiple of data collection method has been used in certain reviewed studies. The various data collection methods in the findings of this study show that the researchers use a variety of data collection methods to ensure that the study does not have high errors on the data obtained and the information obtained is appropriate according to the topic of study.

The Distribution of AI in Term of Publication Year

The fourth research question was concerned with distribution AI in term of publication year (**Figure 6**). In 2021 the percentage number of articles published on AI is the highest compared to other years (30%) (Casler-Failing, 2021; Harper et al., 2021; Mills, 2021; Seckel et al., 2021; Wu, 2021; Zakaria et al., 2021). This was followed by percentage in 2020 (20%) (Gulz et al., 2020; Lopez-Caudana et al., 2020; Saha et al., 2020; Salas-Rueda et al., 2020), while in 2019 has the same number of percentage of articles published as in 2020 (20%) (Forsström & Afdal, 2019; Rico-Bautista et. al., 2019; Sáez-López et al., 2019). The percentage of articles published in 2018 began to decline (15%) (Duzhin & Gustafsson, 2018; Francis & Davis, 2018; Moreno-Esteva et al., 2018) and the percentage remained in 2017 (15%) (Chesani et al., 2017; Rojano & Garcia-Campos, 2017; Song, 2017).

The Distribution of Themes Instigated in the Research

The fifth research question was concerned with the themes are instigated in the previous studies. The types of themes for AI in mathematics education were categorized into advantages and disadvantages, conceptual understanding, factors, role, idea suggestion, strategies, and effectiveness. The data of the themes are collected in order to explore how AI can impact and enhance the performance of mathematics students along their teaching and learning process. As seen in **Figure 7**, the most studied theme (60%, n=12) was about effectiveness (Casler-Failing, 2018, 2021; Duzhin & Gustafsson, 2018; Francis & Davis, 2018; Gulz et al., 2020; Lopez-Caudana et al., 2020; Moreno-Esteva et al., 2018; Rico-Bautista, et al., 2019; Sáez-López et al., 2019; Saha et al., 2020; Wu, 2021; Zakaria et al., 2021). Two of the research subjects (10%) were about strategies (Forsström & Afdal, 2019; Harper et al., 2021) and three of the research subjects (15%) were about idea suggestion (Chesani et al., 2017; Salas-Rueda et al., 2020; Song, 2017). Meanwhile, factor (Mills, 2021), role (Rojano & Garcia-Campos, 2017), and conceptual understanding (Seckel et al., 2021) have one for each of them (5% for each). Additional research of AI other than effectiveness should be done more.

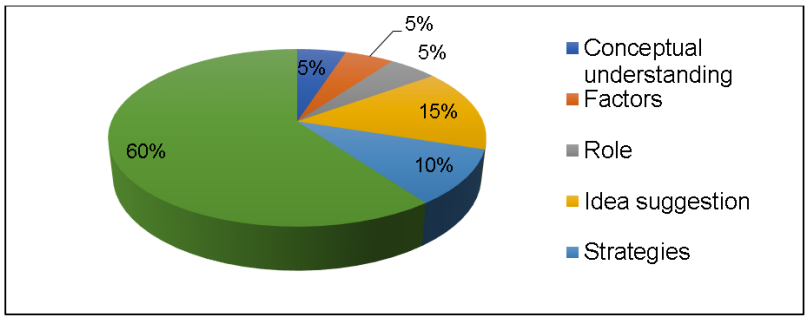

Figure 7. Distribution of themes instigated in the research studies

DISCUSSION

Our finding indicated that robotics was the most popular approach of AI in mathematics education among other approaches which were systems, tools, teachable agent, autonomous agent and a comprehensive approach. The result was in line with Zhong and Xia (2020) who conducted a systematic review that stated that there is a potential for future research and the rapid development of evidence-based research on teaching and learning mathematical content knowledge through robotics. With nine papers discussing robotics in mathematics education, it happened to give more of a positive impact than the other way around just like Seckel et. al (2021) concluded from their research that primary school teachers have conceptions that entail positive dispositions about the introduction of robots for teaching mathematics.

Based on our findings, systems and tools were the second approaches of AI in mathematics education. There are many systems of AI used in mathematics education but Duzhin and Gustafsson (2018) used R and MATLAB software on their research. Based on our finding, tutoring system and integrated system (micro-intelligence support) were also one of the systems that has been implemented in mathematics education. An intelligent tutoring system (Hasanein & Abu-Naser, 2018) is a computer program designed to simulate the behavior and guidance of a human teacher while an integrated system here refers to the integration of a microworld system with the intelligent support system. This integrated system was still a new approach of AI and has limitations. As seen in Rojano and Garcia-Campos (2017) research, the integrated system responds differently to different learner approaches (algebra-like (formulae) or numerical) and also that the system has limitations in light of the fact that at times the answers given by students are not included in the system's repertoire.

On the other hand, the comprehensive approach of AI in mathematics education is believed to affect the learning process positively just like the result of Wu (2021) research which concludes that the introduction of AI-assisted teaching has an extremely effective effect on basic mathematics education and teaching. This statement is in line with Zawacki-Richter et al. (2019) on their systematic review which concludes that even though AI has the potential to advance the capabilities of learning analytics, but on other hand, such systems require huge amounts of data, including confidential information about students and faculty, which raises serious issues of privacy and data protection. Therefore, researchers found out that robotics was the most used approach of AI in mathematics education. Hence, future research should consider focusing on the implementation of robotics in mathematics education.

The majority of researchers in evaluated studies were from the USA and Mexico; and only one author came from as United Kingdom, Turkey, Sweden, Singapore, Norway, Malaysia, Colombia, China, Bangladesh, and Australia (see Casler-Failing, 2018; Harper et al., 2021; Mills, 2021). Several countries integrate programming into their mathematics curricula, thereby making robotics an interesting aspect of mathematics education (Forsström & Afdal, 2019). On the one hand, we must analyze the cultural contexts of studies examining AI concerning mathematics education, and there are several prospects for future intercultural study on AI concerning mathematics education. This research may help to explain why researchers in the USA and Mexico were eager to improve mathematics students' performance throughout the teaching and learning process.

Students can reach this goal with the help of AI, which can improve the educational process. AI can have a substantial impact on students' educational experiences by making relevant courses more accessible, boosting teacher-student communication, and allowing students more time to pursue interests outside of school. According to Wu (2021), the research structure found that through the teaching of AI, students' mathematics scores are about 30% higher than the traditional teaching methods, the sense of cooperation between students' reaches. As countries build national AI strategies, the importance of mathematics education becomes apparent. According to Forsström and Afdal (2019), education systems in various countries are integrating the teaching of programming into their curricula in various ways, both by including general information and communication technology courses and by integrating programming into individual subjects. In addition, the results indicated a lack of variation among countries, particularly in the Asian perspective, about how AI might affect and increase mathematics students' performance, particularly in the teaching and learning processes. As a result, this problem has to be researched further in different countries, emphasizing studies exploring AI in mathematics education.

A research methodology is a specific process or approach for identifying, selecting, processing, and analyzing information about a specific topic. This study employs three research methods: quantitative, qualitative, and mixed methods. Our results indicate that the use of quantitative and qualitative research methods is approximately equal when the difference between the number of uses of quantitative research methods is eight compared to the number of uses of qualitative research methods is seven

and the use of mixed methods is the least which is five. Most researcher in reviewed study choose to used quantitative method approach as it places an emphasis on the objective measurement and analysis of statistical, mathematical, or numerical data gathered through questionnaires and surveys for the used AI in mathematics education (Duzhin & Gustafsson, 2017; Gulz et al., 2020; Mills, 2021; Moreno-Esteva et al., 2018; Rico-Bautista et al., 2019; Rojano & Garcia-Campos, 2017; Sáez-López et al., 2019; Zakaria et al., 2021). Next, qualitative research entails gathering and analyzing non-numerical data in order to better understand concepts, opinions, or experiences. It is providing flexible approach as its suitable for the data collected in the study about the observation and behavior. For example, to see the instruction of LEGO robotics technology (Casler-Failing, 2021), the effects of incorporating LEGO robotics into a seventh-grade mathematics curriculum (Casler-Failing, 2018), and etc.

When researchers conduct a mixed method study, they collect and analyze both quantitative and qualitative data in the same study. The methods are useful for understanding conflicts between quantitative and qualitative results, and they enhance the problem by comparing data results, such as WGODS, which improves the learning system on quantitative and qualitative data through a pleasant, attractive, simple, easy, and useful web interface (Salas-Rueda et al., 2020). Not only that, mixed method research will foster scholarly interaction and flexibility as the researcher can expand the distribution of data on AI in education. The reviewed studies used a variety of data collection methods, and some of them utilized more than one data collection approach, which aided in the growth of a reliable data collection system which are analysis, questionnaires, behavior observation, survey, case study and etc. For example a correlational predictive design was applied to assess the data of a purposive sample of 265 struggling students at the study site and multiple regression analysis to investigate the predictability of these variables (Mills, 2021), a quasi-experimental design, descriptive analysis and participant observation were applied across various dimensions to 93 sixth-grade students in four primary education schools (Sáez-López et al., 2019) and comparing the control and treatment groups for all scenarios through examinations, direct observations, and testimonials (Caudana et al., 2020). Hence, the data collection for AI become diverged.

Our findings on AI in education in terms of years of publication indicate that 2021 have the highest percentage of publications on AI over other years. In 2021, most articles are published by authors from Europe. Most authors state about AI in assisting students and teachers in further improving the quality and effectiveness in learning and teaching. According to Lopez-Caudana et al. (2020), which focused the use of robots in mathematics learning which studies evaluated how much attention the students paid to the class, if they retained more information with the help of the robot, and results were compared with a class without robotic help. The more prepared and comfortable to use the robot, the better they can plan and adapt their strategy, based on the feedback and outcomes that were provided by the students. This allows for the flexibility needed to customize learning strategies to each student and makes them responsible for their own learning. Most authors will publish articles on AI in areas of learning other than mathematics learning, which is why the number of articles published per year is not so much per year.

Our findings indicated that 12 reviewed papers used the themes of effectiveness. These findings show that most of the previous studies were interested to find out how AI can affect mathematics educations. AI is a sophisticated system that has many beneficial effects on our life especially mathematics education. Using Robotics to teach mathematics to seventh graders or as a way to go deeper into mathematics topics, it is possible to identify many interesting situations such as; The use of LEGO® education prototypes opened an interaction of the students and a way to develop creativity and problem solving and mathematical thinking (Rico-Bautista et al., 2019). The importance of showing how technology allows for significant improvements in attention and motivation towards mathematics, which, in turn, allows for an improvement in training programs and teaching practices; thus, achieving a positive impact on student learning (Lopez-Caudana et al., 2020).

Studies on the effectiveness are very important to be conducted. If the majority of studies show unsatisfactory results, then the use of AI may not be fully effective. So, it is a good way to do more research on effectiveness. Using AI in mathematics education will enhance creative and critical thinking skills for students as well as educators. The positive effects of incorporating robotics in mathematics classes as a means to promote student understanding and skill development (Casler-Failing, 2018). However, the strategies at the beginning to use AI need to be emphasized. The robotic solution will never result in significant learning improvement unless accompanied by the right strategy (Lopez-Caudana et al., 2020).

Our findings also indicated that two of reviewed papers were focused on the strategies of using AI, followed by three of reviewed papers that used the theme of idea suggestion. The good effectiveness of AI can be observed through the use of good and appropriate strategies. Mathematics educators and teachers should consider using innovative tools not typically seen in classrooms, such as robotics, in mathematics instruction as they work to support a focus on reasoning and sense-making and make connections to children's community and cultural funds of knowledge (Harper et al., 2021). Mathematics educators need to explore more about AI to apply technologies during the classes. Teachers' programming skill is what needs to be considered in mathematics teacher education and teachers' further education (Forsström & Afdal, 2020). Therefore, teachers need to know the strategies to use AI during the teaching and learning process.

Other than that, our findings also indicated the factors, role, and conceptual understanding of AI. AI has its own role in mathematics education. Traditional teaching and learning method such as inductive learning and discussion is important to enhance one's knowledge and skills. However, the use of AI during the teaching and learning process will make the learning journey more interactive. Therefore, students will be more understanding and enjoy the class. The factor of using AI during the class is to make educators and students more creative and innovative. These skills very useful in the future because life is now heading towards a sophisticated technological life. Educators need to have a good conceptual understanding of AI. So that, it will be easy to deliver the knowledge to the students. Among the global results, it can be concluded that the participants have conceptions that entails positive dispositions about the introduction of robots for teaching mathematics (Seckel et al., 2021).

CONCLUSION

AI is a simulation of humans' intelligence modelled in a machine and programmed to think like humans. In other words, AI is a computer system that can-do jobs that generally require human resources or human intelligence to complete the job. AI needs experience and data so that its intelligence can run smoothly. Humans do not always order the process of learning AI, but AI will learn by itself based on the experience of AI when used by humans. There are several advantages in the use of AI in mathematics learning, among which is that students become more critical and responsible in facing daily solutions and a better understanding of fundamental problems of geometry, mathematics, and statistics. In addition, students also learn about and improve interpersonal abilities and better social interaction; it also allows effective learning to create a better environment to enhance the acquisition of mathematical concepts. Throughout this paper, we provide the findings of an analysis of 20 research publications published between 2017 and 2021, which explored how AI might impact and enhance the performance of mathematics students throughout the teaching and learning process. AI can be implemented in mathematics education through various approaches: systems, teachable agents, autonomous agents, machine learning models, digital technology devices, and comprehensive approaches. However, it seems that robotics was the most often used for mathematics students, teachers, and educational researchers from all those approaches.

AI in teaching and learning mathematics has spread throughout the country. Most countries use AI to help improve the quality of learning. Compared to other nations such as Mexico, Canada, and others, the United States has published the most significant number of publications on the application of AI in the last five years. Most aspects of AI, such as advantages, limitations, strategies to use it and others, the most observed aspect is its effectiveness in teaching and learning process, especially mathematics education. Compared to other aspects, it is still observed but not as widespread as the observation on effectiveness. It is crucial to know the extent of the effectiveness of AI in education. So, AI can be applied more widely in the future if it brings positive effectiveness. We should not expect robotics to be the primary influence on mathematical learning, but rather if educators and students can fully explore the educational potentials of robotics to focus and enhance mathematical knowledge. As a result, students' workload in math classes could be worsened by adding "seductive details" introduced by robots. In summary, with the help of AI, teaching and learning are more effective because it is exciting and creative has made it easier for students to understand a subject.

Limitation

Each study is limited in some way. There may be limitations to your study due to limitations on the research design or technique, which may affect the study's findings. While this analysis identifies numerous significant trends and future research objectives for AI in mathematics education, it has several limitations. The first limitation is that only a limited number of articles are available for research. Because AI is a topic that is rarely investigated in mathematics education, the results gained are limited, making it difficult to draw broad conclusions from the findings. A small number of studies, on the other hand, only scratch the surface of what is being learned about how AI is being used in the teaching and learning of mathematics education in their research without providing in-depth explanations. Therefore, the conclusions of this review were confined to a small number of other researches that provided explicit explication of their findings. As previously stated, AI topics have a limited number of studies; therefore, eliminating duplicate articles amongst search engines decreases the acquisition of relevant research studies. Lastly, each of the papers under consideration in this review contains a significant variety of examples to choose from. Because research is carried out in large variations, the results are skewed due to bias

Implication

Several implications resulted from this study. According to Wu (2021), the application of AI technology has penetrated all aspects of people's daily life and has had a profound impact on the development of society. Mathematics education is one of the aspects that is well developing with AI. People have been implementing AI in mathematics education for many years now, either by teachers or students. From the study, the robotic approach was widely used among them and positively impacted their mathematics knowledge. Meanwhile, AI is also difficult to apply comprehensively due to relatively high maintenance costs. Therefore, it is believed that this was why many studies were only conducted in developed countries such as the United States, China, and Australia while zero studies in Southeast Asia, especially in Malaysia. Moreover, the AI approach in mathematics education did enhance students' learning experience since the method used was unlike the conventional teaching and learning process, which involves pen and paper. Students' and teachers' creativity will also improve when they practice AI, such as robotics, in teaching and learning. The suitable approach used by the teachers will significantly maximize their students' potential to apply and understand what they are learning. Hence, teachers should implement AI in the teaching and learning process to attract students to understand better besides enjoying learning.

Future Direction

To further advance our understanding and application of AI in education, future researchers must conduct additional research on the implications and benefits of AI in education, particularly regarding the development of students' cognitive skills. If further studies demonstrate the success of AI in learning with low capacity and diverse student populations, it will serve as a positive incentive for teachers to incorporate AI into their classroom instruction. Teachers must be confident in their students' ability to benefit from AI instruction. Once they see student success in their classrooms, teachers will convince them to continue implementing machine intelligence learning. Additionally, researchers should conduct additional research on AI, mainly in the field of mathematics education, so that the findings from this SLR can be supported by more robust evidence, as the study of AI in mathematics education has limitations. Due to limitations, this review could not assess the effectiveness of AI use on students'

cognitive abilities. Additional research could address this gap by examining the effect of AI on students' memory and thinking in this study. The study's scope was also limited to the impact of AI on teaching and learning and its distribution. Future trials will examine additional aspects of AI, particularly the relationship between machine learning and teaching theory. Since the studies included in the analysis focused exclusively on journal articles, future research should consider using conference proceedings and books to enhance the findings and analysis. Additionally, these studies represent high-quality publications, and future efforts may include examining other types of publications, such as books and book chapters.

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