Artificial Intelligence In The Classroom: Experimental Research On Innovative Approaches To Mathematics Instruction

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Abstract
This paper explores the integration of Artificial Intelligence (AI) in mathematics instruction, examining their impact on student engagement, understanding, and performance. The study provides an overview of AI technologies, their historical development, and theoretical frameworks supporting their use in education, including constructivism, cognitivism, behaviorism, and project-based learning. By leveraging AI's ability to superimpose digital content onto the real world and AI's capacity for personalized learning, educators can create interactive, adaptive, and immersive learning environments. Experimental research and case studies demonstrate the effectiveness of these technologies in enhancing mathematical learning outcomes. For instance, AI provides personalized feedback and adaptive learning paths, fostering critical thinking and problem-solving skills. Despite their potential, the implementation of AI faces significant challenges, including technical issues, cost, accessibility, and the need for comprehensive teacher training. Addressing these challenges is crucial for equitable and effective integration in educational settings. Future research should focus on the long-term impacts, scalability, and integration of these technologies with other educational tools. This study underscores the transformative potential of AI in mathematics education and calls for continued innovation and research to optimize their use.

Keywords: Artificial Intelligence (AI), Educational Technology, Personalized Learning, Adaptive Learning Platforms, Mathematics Instruction

1. Introduction
In the case of mathematics education specifically, AI-based learning methods have become increasingly popular over the course of the last few years as approaches to enhance the traditional teaching methodology. The main reason why the application of AI as the technologies of Math education is growing exponentially is the fact that these applications engage, interact, and enhance learning.

AI can complement each other in solving two significant issues of mathematics learning and teaching: making abstract concepts more tangible using simulations and using technologies in order to individualize students' learning with considering the differs in abilities. The effectiveness in increasing the level of learners' interest and understanding has elicited promising enthusiasm on their roles as strategic technologies that are revolutionizing traditional applicable mass methods of mathematics teaching in the 21st century. Future research should be focused on the identification of effective practices for implementation as well as on the documentation of learning effects in the long run.

1.1 Overview of Augmented Reality and Artificial Intelligence Technologies.
Artificial Intelligence (AI): Artificial Intelligence (AI) encompasses a broad range of technologies designed to simulate human intelligence, including learning, reasoning, and problem-solving. In educational settings, AI is applied to create personalized learning environments, provide timely feedback, and develop Intelligent Tutoring Systems tailored to individual learner needs (Russell & Norvig, 2016; Luckin et al., 2016).

Innovative Approach: An innovative approach refers to the implementation of novel and creative methods or technologies that aim to improve educational outcomes. In this context, it specifically pertains to the use of AI technologies to enhance the teaching and learning of mathematics.

Experimental Study: An experimental study is a research method that involves the manipulation of one or more variables to determine their effect on a dependent variable. This type of study is conducted under controlled conditions to establish cause-and-effect relationships.

Design-Based Study: A design-based study is a research approach that combines the iterative design of interventions with the empirical investigation of their impact. This method involves the development, implementation, and refinement of educational practices or technologies, with the aim of generating practical solutions and advancing theoretical understanding.

1.2 Significance of Innovative approaches in Mathematics instruction
Measures like the use of AI are significant in the mathematics education of the present day because they are capable of interacting with several learning needs and capturing the students' interest on a high level according to Hattie (2009). The

traditional method of teaching Mathematics comprises textbooks and teachers'/lecturers' talking heads and does not fulfill the needs of the learners. AI present inherent enjoyment and entertainment in learning to allow the students to analyze further the content and to receive feedback from the same (Klopfer et. al., 2017).

The value of these technologies lies in the features that allow educators to interact with learners and observe the learning styles they have acquired through their life experiences. For instance, applications such as augmented reality can be used to display notations of mathematical formulas, enabling users to solve and practice more personalized questions based on their performance through the use of AI (Johnson et al., 2020; Pérez & Gómez, 2019).

1.3 Objectives

In this review, an analysis of the literature regarding the experimental studies of the impact of AI in teaching mathematics is done.

The primary objectives of this review are to:

- Examine the current state of AI technologies in educational settings, with a focus on their applications in mathematics instruction.
- Conduct experimental studies to evaluate the impact of AI technologies on student engagement, understanding, and performance in mathematics.
- Empirically identify best practices and challenges of integrating AI into mathematics curricula through experimental research.

Thus, the purpose of this review is to examine the success and opportunity of those innovative practices for enhancing the teaching of mathematics.

2. Review of Literature

AI is a branch of computer science that aims at attaining a goal of a building intelligent systems that are capable of solving problems which are thought to be reserved for human beings only (Copeland, 2021). Over the past couple of years, researchers have started to integrate AI tools in education practice in an effort to improve learner engagement and learning outcomes (Luckin et al., 2016). The subject that stands to benefit most from the application of AI is mathematics as AI is in a position to adjust problems and their explanation to suit learners' skills and learning styles (Ozuru et al., 2020).

There have been several research documented to establish the use of intelligent tutoring systems (ITSs) in mathematics classes. ITSs are AI systems that are designed to deliver automated problem sets, as well as feedback and guidance, all of which are personalized according to the individual learner (Ma et al., 2014). For example, Ritter et al. (2007) designed the Animal Watch ITS that will enhance the middle school mathematics lessons teaching. In a Randomized Control Trial done by Ritter and others, the classrooms-learning Animal Watch for one semester outperformed control classrooms – receiving standard instructions only – on tests, with significant differences (Ritter et al., 2007). The ITS was found to offer provides fine-grained scaffolding and the feedback given to the students as the two main strengths. Positive learning effects along the entire spectrum of mathematical topics ranging from algebra through geometry etc have been highlighted through the use of AI based ITS in classrooms (Steenbergen-Hu & Cooper, 2014).

Still, other methods using artificial intelligence are being researched and experimented for mathematics teaching. Mavrikis et al. (2020) proposed an AI teaching agent that could monitor students' solving of fractions problems in real-time and give feedback on the correctness of their actions and ideas, as well as detect errors. Classroom studies determined that the agent helped cut down on the number of errors the Primary school learners made and made the learners think more about the strategies they are employing compared to paper-based workbooks (Mavrikis et al., 2020). Two more promising technologies, which are currently under consideration for application in mathematics education are the AI conversational agents, and virtual reality environment (Bodnar et al., 2019; Richardson et al., 2020).

It is important to note that AI should not try to work as teachers but try to enhance their abilities to deliver the best learning opportunities that can be available to each learner (Latham et al., 2012). Certain research shows that when AI works along with the teacher, its results are even better than if done individually (Ruan et al., 2019). AI is still not perfect, it still has some limitations when it comes to comprehending the thinking of a student like how human teachers can (Käser et al., 2021). Therefore, the achievement of the best design of using AI in classroom environments that can help to take advantage of educators' knowledge is still an open problem. In conclusion, the current body of knowledge indicates positive instructional possibilities for mathematics but points to a necessity to conduct more studies concerning practical application of AI tools and their effectiveness.

2.1 Theoretical frameworks that support the use of AI for learning

Constructivist Theory: Constructivism learning theory which has originated from the theoretical works of both Piaget and Vygotsky posits that knowledge is constructed out of the learner's experiences with the ambiance (Piaget 1973; Vygotsky & Cole, 1978). Close to constructivism, AI also supports learning systems that adapt to the personal special page contents in line with the learning needs and strategies, thus enhancing learning (Jonassen, 2000).

2.1.1 Cognitivism: This framework analyzed the cognitive mechanisms in the learning process as one of the key elements (Mayer, 2002). AI in education improves the knowledge acquisition process of the learners since it provides prompt feedback, and educative guidance on how to execute a particular task, which fosters the learners' reasoning, problem-solving, decision making and ultimately their critical thinking ability as postulated by Schunk (2012).

2.1.2 Behaviorism: Although it is less actively advocated currently than before, behaviorist features are used in the design of learning technologies. Among the educational tools, the major AI strategies are as follows: The reinforcement technique is included in the AI strategies where the student is rewarded or punished for his or her work (Skinner, 1961). AI applications can also use behaviorist strategies as the teaching processes can be supported by the game aspects and motivation to users to complete a particular task at once.

2.1.3 Project-Based Learning (PBL) and Problem-Based Learning (PBL): These theories emphasize learning through engaging with real-world problems and projects. AI enhances PBL by providing immersive and interactive environments where learners can explore and solve problems collaboratively. AI contributes to PBL by offering personalized learning experiences and intelligent tutoring systems that guide students through complex projects and problems, helping them to develop critical thinking, collaboration, and practical problem-solving skills (Thomas, 2000; Hmelo-Silver, 2004).
By integrating these theoretical frameworks, AI technologies can create a robust and dynamic learning environment that supports various educational paradigms and enhances the overall learning experience.

3. Benefits and Challenges Associated with AI in Educational Context
3.1 Benefits:
Enhanced Engagement: Besides this, it also generates context-based and activity-based questions that are more fun for the students than just lecturing them and make them interested in what they are learning (Dünser et al., 2012). Thus, AI gives pathways and responses according to the requirement and competency of the learner so that learning could indeed be pertinent for any learners and learning disabled (Woolf, 2010).
Improved Understanding: AI can suggest a specific method and practice it.

3.2 Challenges:
Technical Issues: This paper has also identified one of the potential barriers to implementing AI in the learning environment to be technical including matters concerning the compatibility of used software, hardware, and availability of software support.
Cost and Accessibility: AI technologies are fixed assets and this is very capital-demanding on organizations, especially those that are financially strapped like the school (Bower et al., 2014). Moreover, some scholars are concerned with issues to do with equality alongside the delivery of these technologies for each student (Eynon & Malmberg, 2011).

Augmented Reality in Mathematics Instruction
4. AI in Teaching Mathematics
The adoption of Artificial Intelligence (AI) continues to rise in learning instituting, providing enriched strategies for learning mathematics. Intelligent technologies are used for learning and tutorial supports, which produce individually tailored feedback, and have been reported in many studies and double-blind, especially for ameliorating mathematical skills and learning gaps.
Technology-aided education can also gather learning information from students; it can then proceed to deliver lessons based on the student's style of learning and speed. They employ the use of certain algorithms to determine a student's strong points and areas of improvement as well as modify a curriculum. This pushes AI systems to immediately provide feedback based on the student's performance and in a way guides an individual in making corrections and bettering understanding of the content.
For instance, DreamBox and ALEKS, learning management and analysis systems implemented with AI's help, design individual pathways where it adapts the difficulty and variety of the problems to the current performance of students (Kulik et al., 2016). Adaptive learning thus guarantees the students continue to learn but do not get overstressed or conversely feel too lazy to learn.

4.1 Employing Artificial Intelligence Techniques in the Instruction of Mathematics with Case Studies and Experimentations
One more condition of usefulness has been added based on several works that suggest that AI is useful in Mathematics education. Ma et al. (2014) carried out a study to establish the extent of the integration of an AI-tutoring system in the context of one middle school mathematics class. According to the information, the student, using the specified system, received tremendous augmentation in the assessments compared to the more traditional approaches to transferring the knowledge and skills; owing to the precise setting of the problems and the possibility of the feedback for each specific error. Also, in another study by Holmes et al. (2019), the authors wanted to know the impact that AI learning analytics could have in addressing student learning in a high school algebra class; the study revealed that students who engaged in the AI-integrated learning, their scores in tests were higher and gained in concepts.

Another splendid example is the use of ITs, for instance, when the student is having a difficult time solving a math question, and an ITS is useful in giving the particulars of a detailed solution. Of such systems, for instance, Carnegie Learning's Cognitive Tutor it has been established that it improves the student learning by making them more self-reliant and by fading (Koedinger et al., 1997).

Evaluation of possibilities of applying AI to enhance mathematical accomplishments and accepting learners' peculiarities into consideration.

Table 1: AI Technologies and Their Applications in Education

AI Technology	Description	Applications	Benefits
Intelligent Tutoring Systems	Provides personalized tutoring and feedback	Math tutors, homework assistants	Personalized learning, targeted support
Adaptive Learning Platforms	Adjusts content based on student performance	Online math courses, e-learning platforms	Customizes learning paths, tracks progress
Automated Assessment Tools	Assesses and grades student work automatically	Online quizzes, assignments	Instant feedback, reduces grading time

In regards to Mathematics competence, it has been shown that AI is quite effective in delivering targeted learning that is contingent on one's ability and makers. AI can show, which field a student or a learner needs to improve, and it can present information/review and materials as well as exercises that require a student or a learner to close the gap in understanding. This is especially the case with groups of students such as Learning-Disabled students, or students those who need exercise challenges at a higher level.

Single studies illustrate that with the use of upcoming AI-based adaptive learning, it is possible to obtain a significant rise in the level of basic skills in mathematics. For instance, the work of Kulik et al (2018) revealed that students enrolled in adaptive learning technologies yielded a higher normative score on standardized Math than those enrolled in conventional course media. Moreover, regarding additions and subtractions, the kind of real-time feedback offered by these AI systems cuts down the time spent on it, so that the student can progress in the understanding of the concept as well as develop problem-solving skills (Holmes et al., 2019).

4.2 The effectiveness of using AR and AI in the Classroom.

The use of Augmented Reality (AR) and Artificial Intelligence (AI) in teaching and learning continues to reap huge benefits, especially in the area of mathematics teaching and learning. AR in scanning the physical environment provides an interactively enriched experience of placing information details over the real environment by mapping related digital information to the students' learning area, making easier and more effective teaching of complex concepts such as mathematics (Azuma, 1997). On the other hand, AI improves the learning environment, its feedback, and ITS leading to efficient learning and catering to the needs of individual students (Woolf, 2010).

The effects of use of AI Technologies in Mathematics Learning: Joint or Interactions

The integration of AI keeps the students interested in mathematics and offers them benefits in the following manners. AI algorithms are used to monitor how the students are interacting with the made AR visualizations. This not only assists in conceptual understanding but also in accelerating the method of teaching as per the learning abilities of every learner.

For example, Geometric shapes and three-dimensional graphs can be explained using AR as if they are real-life objects. When these AR tools are connected to AI, they can also evaluate a student's progress, determine his or her difficulties, and recommend the best activities to complete to overcome these difficulties. This integration creates a highly effective learning atmosphere, which in the case of such subjects as mathematics is of paramount importance since a learner requires profound conceptual knowledge (Chen et al., 2020).

4.3 Integrated Solutions for AR and AI and their Effect on student performance

Several combined AR and AI applications have revealed enhanced positive effects on learners' performance in mathematics. One of the examples is the AI-enhanced AR app for education "GeoGebra AR" which lets students manipulate geometric shapes that are placed in a three-dimensional space. The app incorporates features that include intelligent tracking of student's progress; the students are immediately made to appreciate results and correct mistakes as well as get a better understanding of geometric ideas.

Another example is an application called MathAR supports students in learning algebra with the help of augmented reality which is accompanied by instructions from an artificial intelligence tutor. Research has also demonstrated that students who use MathAR have higher levels of engagement and better problem-solving abilities than those who do not (Johnson et al., 2016).

Advantages that can be obtained due to the integration of AI for a more inclusive and productive learning experience. Several advantages can stem from the integration of AI to enhance the delivery of an improved learning environment in mathematics. AR can turn concepts into objects that the students can see and interact with, whereas AI can make the process individualized; therefore, the integration of AI can create a very useful educational tool. Just as importantly, learning is more fun and learned effectively, not forgetting the fact that students will receive the right support that they require to pass their courses.

AI helps make this exploration purposeful and effective by respecting and cohering to different customers' learning patterns while offering timely feedback (Billinghurst & Duenser, 2012). Thus, students can recall concepts being studied and enhance their understanding of the subject matter being taught.

All in all, suggestions for using AI in mathematics instruction reveal the high potential to lead to better educational outcomes. It means that educators can develop the best and most effective learning environment with the help of technologies based on the integration of learning management systems and other elements.

5. Experimental Research and Findings

A brief description of several essential experimental researches conducted on the topic and the approaches used by the authors.

Ibáñez et al. (2014) recently experimented with an AR learning environment in High school with 62 students to evaluate the degree and effectiveness of such a learning environment for teaching geometrical concepts. The technique used a control group that went through normal lessons and an experimental group that included an AR application. In assessing the extent of the student's learning and mastery of concepts that are geometric in nature, pre-tests and post-tests were utilized.

About the effects of AR on primary school learners' learning achievement of Mathematics in China, Cai et al. (2017). The sample entails 120 students and they were grouped into an experimental group and a control group. One set of students employed AR tools in solving mathematical problems and on the other end, a ''control group'', the regular approach was employed. This qualitative data was obtained through tests, observations, and interviews to measure the students' performance and their perceptions of mathematics.

The study that was conducted by Chang et al. (2013) sought to understand the effectiveness of AR in teaching algebra to students in middle school. The study involved 45 students who were divided into two groups: on AR-based instructional materials and another group using conventional textbooks. The students' problem-solving abilities in addition to their level of participation were determined by the use of tests and self-administered questionnaires.

5.1 Comparative Analysis of Traditional vs. Innovative Approaches in Mathematics Instruction

The textbook method is characterized by lecture, textbook, and non-interactive methods including the use of objects that do not change with time. On the other hand, AR applications give the learners an engaging and responsive experience which if used properly, can help elaborate otherwise abstract concepts in mathematics (Bujak et al., 2013). As the research work of Ibáñez et al. (2014), revealed that the level of learning and retention of geometric concepts, among the students using Augmented Reality was significantly higher as compared to other students taught geometrically.

Similar research conducted by Cai et al. (2017) obtained similar results whereby the use of AR tools enabled the stakeholders to manipulate and understand mathematical problems and relations thereto, translating into enhanced problem-solving skills and attitude toward mathematics. In the same vein, Chang et al. (2013) confirmed that the use of AR-based instruction in teaching and learning made the students more engaged and motivated leading to better performance in algebraic problem-solving tasks.

5.2 Evidence of Effectiveness

From these studies, there is an indication that AR can be very useful in supporting and improving the coaching of mathematics. Qualitative research has recorded that students influenced by augmented reality outperform the students who do not use augmented reality as per the survey and test results. For example, Ibáñez et al. (2014) found a percentage increase in the experimental group performing s plus net test scores of 15%.

Similar to the quantitative findings, qualitative results, gathered by conducting surveys and observation, indicate an enhanced student engagement due to AR. This positive disposition may be due to using AR learning experience; students had more fun proposing that using AR makes learning mathematics less boring and less stressful (Cai et al., 2017; Chang et al., 2013).

6. Challenges and Limitations that can be encountered when using AR and AI in Classrooms

The core challenges of applying artificial intelligence (AI) in classrooms are technical and logistical. Of the difficulties that are connected with the application of AI in education, one of the most important ones is their rather high price which may pose a problem for lots of schools and universities (Wu et al., 2013). Purchasing the necessary hardware equipment including AR headsets or smart devices and the necessary software licenses and updates is always a burden on the finances of any institution more so those schools which are not well endowed financially. Also, the reinforcement of these technologies in school programs entails enormous preparation. averting disruption with current educational paradigms

and concerns related to addressing today's educational contexts and curriculum are essential issues that should be taken into consideration (Bacca Acosta et al., 2014).

Furthermore, sometimes the schools' facilities will require enhancement to enable the proper functioning of AR and AI solutions. This work entails seeing to it that the internet connection is resilient, availability of bandwidth and dependable electric power for handling the faze (Cheng & Tsai, 2013). In the absence of such enhancements, the operations of AR and AI applications can be hindered, and this causes dissatisfaction among teachers and learners.

Table 2: Challenges and Limitations of AI in Education

Challenge/ Limitation	AI	Mitigation Strategies
Technical Issues	Dependence on data quality	Invest in reliable technology and training
Teacher Training	Need for AI understanding	Professional development programs
Accessibility and Equity	Unequal access to devices	Provide subsidies, improve access

6.1 Effects of Training on Teachers and the Importance of Training Resources

Another great difficulty is that of the overall training of teachers and the question of the availability of resources appropriate to the level of education of the pupils in the respective classes. They have to know how to use AR and AI tools, to incorporate them into education processes. However, lots of teachers are not trained on how to use these sophisticated applications and do not feel sufficiently self-assured to attempt their implementation (Ibáñez & Delgado-Kloos, 2018). Continuing education schemes are indispensable to prepare educators and enhance their qualifications necessary for the integration of AR and AI. These programs should also include not only the technical aspect of the utilization of these technologies but also the ways and strategies of how best to utilize them.

Moreover, quality resources of educational materials, support, and technical help are equally important to achieve the effectiveness of AR and AI in education. If not properly supported, the teachers may not be able to incorporate these technologies in their teaching and hence the benefits cannot be realized among the learners.

6.2 Issues Associated with Access and Inclusion of Technology

When using AR and AI in education it is crucial to take into consideration accessibility as well as equity. It remains a possibility that these technologies are going to increase the gap between the rich and the poor, hence disadvantaging low-income students who are unable to afford the devices or even a good internet connection at home (Dolan, 2016). The next condition to be considered by the school is to guarantee ROI without deepening the learning inequalities by denying all students fair access to AR or AI tools and resources.

However, the incorporation of AR and AI applications has to ensure that all the needful students including the disabled are taken into consideration. It is recommended that a universal design be followed to develop a meaningful learning architecture. Some of these requirements are offering other ways for people with disabilities to control devices, for example, by voice commands or hand gestures, and checking whether the product is accessible to people with disabilities.

7. Future Directions
7.1 Emerging Trends and Technologies in AI for Education

Current usage of AI technologies is fairly limited in the field of education; nonetheless, both technologies are innately married to a great extent with the prospect of enhancing the learning of mathematics. Such trends will continue to rise in the use of AI which will lead to improvement of the learning experiences.

Regarding the ITSs, one present evolution is leveraging AI agents that will be able to assist learners and provide them with academic help. Such systems can always evaluate various performances, especially of the students, and adapt the conveyed information to that particular student. For instance, GeoGebra AR and Math VR are open-source application that incorporates the AI algorithm to offer feedback and problem-solving activities aligned to the student's capacity to understand Mathematics conceptual content and meaning (Chen et al., 2022).

The next major trend is related to employing such approaches as machine learning algorithms for enhancing the interaction as well as the realism of augmented reality applications. Machine learning could help the object tracking and object identification stages be more efficient and could help accomplish the merging of the real and virtual environments in a manner that would be natural for the user. This reformation is especially useful in mathematics learning as it is easier to have the concepts taught in a manner that will facilitate its easy understanding or possibly observation.

7.2 Implications for the Future Research and Experimental Studies

Therefore, the following research directions can be identified concerning the further improvement and implementation of AI in mathematics instruction. First, there is a necessity to carry out a set of time-related investigations aimed at the identification of trends limiting the application of AR and AI for enhanced student performance. Thus, it is crucial to ascertain the medium to extended effects of such technologies even though most of the research studies the brief interventions since it seems decisive to apply such findings to the learning environment properly (Smith et al., 2021).

Second, future research can look at the directions of the possible further application of AR and the relation between it and other AI solutions. Therefore, the conclusions that can be made based on pilot studies and early works on small samples should address the realities of the technologies' scalability and the possibilities they can bring to an increasing number of students and institutions. It involves analyzing the questions of application concerning technology, the educational function of connected learning, and such problems of mass application.

Furthermore, when having research from the field of education and computer science and cognitive psychological science it will allow getting a better understanding of how teaching mathematics can be enhanced through the use of augmentation of reality and applications of artificial intelligence. Interactions between these fields can lead to the development of new improved and more effective learning technologies (Miller et al., 2022).

7.3 Potential Developments in AR and AI that Could Further Enhance Mathematics Instruction

The following possibilities within the framework of further development of AR and AI can be expected for the subsequent enhancement of the teaching of mathematics: One such development is in the development of AR glasses and headsets that are now becoming cheaper as well as more portable. They can also allow students to learn in a Virtual Math environment; interactively and without having to use some limbs manually (Anwar et al., 2023).

Natural language processing which is one of the possible future evolutions of AI will foster the conversational processes. To me, the possibility of the NLP idea is that it can help in making the communication between the students and the educational technologies free from the rigid and unnatural structure of dialog, so the concluding fee complete back can be enhanced. For instance, students can use voice interaction with AR applications, this will boost the learning activity of students and provide them with positive learning sessions.

Besides, the application of artificial intelligence in the acquisition of data can assist education stakeholders in considering students' performance as well as learning processes. Maybe, with the usage of collected data from distinct AR applications, it is possible to identify the main problems that students have and provide the necessary support in their solving. An approach of this nature can go a long way in enhancing the quality of learning and teaching of mathematics; Thus, leading to the pro-development of customized learning.

In other words, it is possible to state that the collaboration with AI in the scope of Math classes reveals multiple trends and ideas at the intensiveness of their ongoing innovations. Further studies and innovations have been required to use the technology effectively and finally improve the achievement of mathematics of learners worldwide.

8. Conclusion

AI integration in learning mathematics opines rich potential in transforming the way the learner comprehends as well as perform. This research focuses at the historical background and current uses of AI and the possibility of integrating them in today's learning environments. It is possible to apply AI technology learning solutions, it gives student controlled learning paths, prompt feedback, and smart learning systems that encompasses the individual needs of the student thereby enhancing aspects like critical thinking and problem solving. The theories of constructivism, cognitivism, behaviourism and Project based learning justify the utilisation of AI in learning. These frameworks demonstrate that learning can be context-based, collaborative, and emerged which can be easily supported by the use of AI. However, adopting these technologies is not without some few difficulties as explained in this paper. Technical problems, cost, access, and the requirement for teachers' professional development are remarkable challenges that need to be overcome in order to provide equal opportunities and appropriate application of AI in schools. In AI, experimental research coupled with case studies highlight on how it can enhance the learning of mathematics. Research findings reveal that students under the use of AI learn better, solve problems better, perform better compared to when under traditional methods of learning. Thus, the next studies should be directed to examine the long-term effects of using AI applications, expand the demonstration of effectiveness to other classrooms and educational systems, and investigate how AI integration with other technologies can enhance the educational process. Thus, AI are given the capacity to positively impact the process of mathematics education significantly. These technologies when approached with the current problems and further development will help educators to create useful learning spaces that are more engaging, open, and functional.

References

1. Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, *6*(4), 355-385.
2. Billinghurst, M., & Duenser, A. (2012). Augmented reality in the classroom. *Computer*, *45*(7), 56-63.
3. Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.
4. Luckin, R., & Holmes, W. (2016). Intelligence Unleashed: An argument for AI in education.
5. Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. Pearson.

6. Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Mathematics teaching*, *77*(1), 20-26.
7. Klopfer, E., Perry, J., Squire, K., & Jan, M. F. (2017). Collaborative learning through augmented reality role-playing. In *Computer Supported Collaborative Learning 2005* (pp. 311-315). Routledge.
8. Jonassen, D. H. (2000). Computers as mindtools for schools: Engaging critical thinking. *(No Title)*.
9. Baker, D. L., Ma, H., Polanco, P., Conry, J. M., Kamata, A., Al Otaiba, S., ... & Cole, R. (2021). Development and promise of a vocabulary intelligent tutoring system for Second-Grade Latinx English learners. *Journal of Research on Technology in Education*, *53*(2), 223-247.
10. VanLehn, K. (2006). The behavior of tutoring systems. *International journal of artificial intelligence in education*, *16*(3), 227-265.
11. Newell, A., & Simon, H. (1956). The logic theory machine--A complex information processing system. *IRE Transactions on information theory*, *2*(3), 61-79.
12. Ashley, M. I. K. D., & Chan, T. W. (1982). Intelligent tutoring systems.
13. Mayer, R. E. (2002). Multimedia learning. In *Psychology of learning and motivation* (Vol. 41, pp. 85-139). Academic Press.
14. Schunk, D. H. (2012). *Learning theories an educational perspective*. Pearson Education, Inc.
15. Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: a modern approach*. Pearson.
16. Skinner, B. F. (1961). The science of learning and the art of teaching.
17. Piaget, J. (1973). To understand is to invent: The future of education.
18. Woolf, B. P. (2010). *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning*. Morgan Kaufmann.
19. Bacca Acosta, J. L., Baldiris Navarro, S. M., Fabregat Gesa, R., & Graf, S. (2014). Augmented reality trends in education: a systematic review of research and applications. *Journal of Educational Technology and Society, 2014, vol. 17, núm. 4, p. 133-149*.
20. Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education–cases, places and potentials. *Educational Media International*, *51*(1), 1-15.
21. Thomas, P. C., & David, W. M. (1992, January). Augmented reality: An application of heads-up display technology to manual manufacturing processes. In *Hawaii international conference on system sciences* (Vol. 2, pp. 659-669). ACM SIGCHI Bulletin.
22. Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2020). Horizon report: 2020 higher education edition. Austin, Texas: The New Media Consortium.
23. Pérez, Á., & Gómez, J. (2019). Augmented reality in education: Uses and applications. International Journal of Educational Technology, 9(2), 101-115.
24. Dünser, A., Billinghurst, M., Wen, J., Lehtinen, V., & Nurminen, A. (2012). Exploring the use of handheld AR for outdoor navigation. *Computers & Graphics*, *36*(8), 1084-1095.
25. Eynon, R., & Malmberg, L. E. (2011). A typology of young people's Internet use: Implications for education. *Computers & Education*, *56*(3), 585-595.
26. Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.
27. Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education*, *68*, 536-544.
28. Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778-791.
29. Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & education*, *71*, 1-13.
30. Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using Augmented Reality in Education from 2011 to 2016. *Innovations in smart learning*, 13-18.
31. Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of science education and technology*, *22*, 449-462.
32. Kaufmann, H., & Schmalstieg, D. (2002, July). Mathematics and geometry education with collaborative augmented reality. In *ACM SIGGRAPH 2002 conference abstracts and applications* (pp. 37-41).
33. Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education promises and implications for teaching and learning*. Center for Curriculum Redesign.
34. Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, *8*, 30-43.
35. Kulik, J. A., & Fletcher, J. D. (2016). Effectiveness of intelligent tutoring systems: a meta-analytic review. *Review of educational research*, *86*(1), 42-78.
36. Ma, W., Adesope, O. O., Nesbit, J. C., & Liu, Q. (2014). Intelligent tutoring systems and learning outcomes: A meta-analysis. *Journal of educational psychology*, *106*(4), 901.

37. Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, *6*(4), 355-385.
38. Chen, G., Zou, D., Cheng, G., & Xie, H. (2020). Trends in augmented reality-based mathematics education: A systematic review. *Computers & Education, 144*, 103666.
39. Johnson, L., Becker, S. A., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *NMC horizon report: 2016 higher education edition* (pp. 1-50). The New Media Consortium.
40. Ibáñez, M. B., Di-Serio, Á., Villarán-Molina, D., & Delgado-Kloos, C. (2014). Augmented reality-based simulators as discovery learning tools: An empirical study. *IEEE Transactions on Education*, *58*(3), 208-213.
41. Cai, S., Chiang, F. K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778-791.
42. Chang, H. Y., Wu, H. K., & Hsu, Y. S. (2013). Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue. *British Journal of Educational Technology*, *44*(3).
43. Dolan, J. E. (2016). Splicing the divide: A review of research on the evolving digital divide among K–12 students. *Journal of Research on Technology in Education*, *48*(1), 16-37.
44. Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.
45. Anwar, M. S., Ullah, I., Ahmad, S., Choi, A., Ahmad, S., Wang, J., & Aurangzeb, K. (2023). Immersive learning and AR/VR-based education: cybersecurity measures and risk management. In *Cybersecurity Management in Education Technologies* (pp. 1-22). CRC Press.
46. Bodnar, C. A. , Anastasio, D. , Enszer, J. A. , & Burkey, D. D. Engineers at play: A synthesis of games as educational aids to teach undergraduate engineering students. EduCause Review. https://er. educause. edu/articles/2019/10/engineers-at-play-games-as-teaching-tools-for-undergraduate-engineering-students
47. Copeland, B. J. (2021). Artificial intelligence. Encyclopedia Britannica. https://www. britannica. com/technology/artificial-intelligence
48. T, Hallinen, N R & Schwartz, D L 2021, Modeling dynamic learning with artificial intelligence: The main idea here is that there are great promises and great pitfalls, and I think this is something that most people can really relate to. Educational Psychologist, 56(4), 248-257. https://doi. org/10. 1080/00461520. 2021. 1919289
49. Latham, A. M. , Crockett, K. , McLean, D. , & Edmonds, B. (2012). An ITS-ISA model for automatically identifying learning styles in a conversational ITS. Computers & Education vol. 59, no. 1, pp. 95-109. https://doi. org/10. 1016/j. compedu. 2011. 11. 001
50. Luckin, R. , Holmes, W. , Griffiths, M. , & Forcier, L. B. (2016). Intelligence Unleashed: AI can be used to enhance education by improving the delivery of instruction and content. Pearson.
51. Of, M. W. , & Adesope, O. O. (2014). Intelligent tutoring systems and learning outcomes: An analysis of analyses. Journal of Educational Psychology, 106(4), 901-918. https://doi. org/10. 1037/a0037123
52. Mavrikis, M. , Gutierrez-Santos, S. , Geraniou, E. , & Noss, R. (2020). The design requirements of ILE, the indicators of student perception and the validation of metrics for learning within intelligent exploratory learning environments. In this paper, the authors look at personal and ubiquitous computing by analyzing a couple of scenarios in depth and considering the implications for interface design. http://dx. doi. org/10. 1007/s00779-019-01293-8
53. Y. Ozuru, S. Briner, R. Best & D. S. McNamara, (2020). Self explanations as a factor in the interaction between high and low knowledge students and an intelligent tutor. Discourse Processes, 57(2), 99-114. https://doi. org/10. 1080/0163853X. 2019. 1570824
54. Richardson, A. , Delaney, H. , & McLean, D. (2020). Covid-19: Our role in the search for solutions. MetaTutor VR: Exploring the effectiveness of using virtual environment to facilitate and mentor self-regulated learning processes [Paper presentation]. ICLS 2012-Int Conf of the Learn Sci, Nashville, TN, United States.
55. Ritter S. , Anderson J. R. , Koedinger, K. R. , and Corbett, A. , 2007 Cognitive tutor: Mathematics education: the secondary level & applied research. Psychonomic Bulletin & Review, 14, 249–255. https://doi. org/10. 3758/bf03194060
56. S. Ruan, S. Münzer, K. Möller, H. D. Zimmer, L. Jing, & L. Bucher (2019). Teacher and artificial intelligent peer feedback: The perception and word retention of German among learners. Language Learning and Technology, 23(1), pp. 131–148. https://doi. org/10125/44683
57. In Steenbergen-Hu & Cooper (2014), An evaluation of the impact of the intelligent tutoring system on students' academic performance in the college population: A meta-analysis. Journal of Educational Psychology, 106(2), 331–347. https://doi. org/10. 1037/a0034752