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Application of artificial intelligence in the teaching and learning of mathematics: Implication for achievement and retention

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Abstract

Advances in technology, particularly artificial intelligence (AI), offer opportunities to enhance teacher-student communication and improve learning outcomes in mathematics. This study investigates the impact of AI integration in mathematics education on student achievement and retention. The population comprised of 4204 Senior Secondary Three (SS3) in Owerri Municipal Council of Imo state Nigeria. A randomized controlled trial design was employed, with pre- and post-testing of 72 sample students selected through stratified simple random sampling and purposive sampling from a private school in Owerri, Imo State. The Mathematics Aptitude Test (MAT) was used to assess student learning, with a reliability coefficient of 0.74. Descriptive statistics and Analysis of Covariance (ANCOVA) were used to analyze the data. The results show that students who learned geometry with AI did not outperform those who learned without AI. Moreover, the retention rate of students taught without AI was higher. No significant differences were found in achievement and retention rates between boys and girls learning geometry with AI. These findings suggest that teachers and students should explore effective ways to leverage AI in mathematics education. Based on the findings, it was recommended that researcher recommended that activity-based classroom should be encouraged in the teaching and learning of mathematics, the use of AI in the teaching and learning of mathematics in secondary schools should be done under closed monitoring, and that improved technologies should be provided for both teacher and students for effective application of AI.

Keywords

Artificial intelligence, AI-integrated instructions, geometry achievement and retention, mathematics education.

INTRODUCTION

Education plays an important role in human development. As technology advances, education continues to evolve and change in many ways. Therefore, the traditional method of teaching students in the classroom is outdated. With the influence of the internet and technology, online platforms are slowly but surely changing direction. That's why today's courses are eliminating limited classroom space and attracting more students from around the world. Today's education system can engage more students and teachers in learning technology,

especially in the fields of science and mathematics, by providing information through online websites or websites.

Today, more than ever, other mathematical knowledge is research aimed at problem solving, reasoning, and prediction. Ogoke [1] argued that mathematics is the foundation of science and technology and that without a proper foundation in school mathematics, no country can hope to achieve a uniform science and technology education. As a basic learning skill, mathematics is the only thing that is not included in almost any education that does not require mathematical operations to be performed properly [1]. Mathematics education has an important place in human and social life. This is the path to technological development and economic survival. The Government of the Republic of Nigeria included mathematics as a subject in secondary education in the National Education Policy. Mathematics explores concepts using symbols that represent concepts such as numbers, quantities, places, and patterns.

According to Orhani [2], mathematics is often perceived as a difficult and challenging subject that aims to enhance students' problem-solving skills. However, many students struggle with mathematics, particularly when encountering multi-step problems. To address this issue, researchers are developing innovative teaching strategies and tools to improve mathematics learning. Orhani [2] also emphasizes the importance of identifying factors that influence students' mathematics performance, such as inadequate prior knowledge and insufficient personal support for individualized tasks. Fortunately, recent advances in AI offer potential solutions to these challenges [2].

At the same time, secondary school students use modern technologies such as laptops and Android phones without realizing the benefits of these technologies. For example, artificial intelligence can be integrated into online learning platforms so that content and activities can be tailored to each student's needs and experience level. Research scholars such as the Mathematical Association of Nigeria (MAN), Science Teachers Association of Nigeria (STAN) and others have proposed many ideas, strategies, and methods for teaching and learning problem solving, inquiry-based teaching/learning, learning, research and mathematical skills, math skills, collaborative learning and comparison-based planners, etc. things.

According to Orhani [2], the purpose of AI is to represent human intelligence and promote communication between users and machines in solving problems. The purpose of intelligent systems is to create content that is adaptable to the student's knowledge and skills to enhance learning. According to Orhani, it is known that cognitive skills will be the basis and reason for development in classroom teaching. It is reported that today's technology also includes teaching and learning content because some machines need to teach patterns and ideas independently or under the supervision of some kind of guidance [3]. The main purpose of AI in the discipline of mathematics is to provide ideas, methods, and tools for designing simple and effective computer-based systems for teaching and learning [4].

According to Davadas and Lay [5], the main goal of AI is to create and use machines whose behavior appears reasonable to a human observer and where the person observing the system can imagine what the system's behavior should be like. Not without reason. This means finding out what knowledge is and how it is expressed. Hwang et al. [6] described the role of AI in education, consisting of smart teachers, administrators, educational tools and partners, and policy consultants. This will help you model your skills and provide personalized guidance, feedback, or support to your students throughout the course.

AI has been used effectively in some fields to improve teacher training as well as student learning and development [7]. For many students, learning math is considered difficult. Advances in computer technology, particularly AI, provide an opportunity to address these challenges by identifying students' learning challenges and providing personalized support to complete their education. For the purpose of this study, Mathia U was used as one of the intelligent models. It is a smart learning tool for college students under the guidance of their homeroom teacher. The app tracks each student's unique learning journey, tracking daily progress and helping teachers tailor lessons to each student's specific situation. Online education, which is not limited by time, location, or number of students, is gaining popularity [8]. Therefore, the purpose of this study focuses on the impact of AI in mathematics education on student success and retention.

Achievement refers to the attainment or accomplishment of desired goals or outcomes. According to Okafor [9], success is achieved through persistence, effort, skill, practice, or action. Academic success is typically measured by performance on specific tasks, such as tests and assignments, which are evaluated by teachers. Mathematics performance, in particular, is assessed through evaluations of student performance on math assignments and tests. Effective teaching is crucial for mathematics learning. As Ogoke and Okigbo [10] emphasize, teachers must establish a strong foundation for instruction through effective planning and implementation processes. This foundation is essential for facilitating mathematics learning.

Retention refers to an individual's ability to recall and retain information over time. According to Anusiem [11], retention encompasses the ability to remember ideas, facts, and data. The ultimate goal is to maximize student learning in science and mathematics, often with the support of teachers. As Ogoke and Okigbo [10] suggest mathematics retention can be achieved through continuous application of content, discussion, implementation of procedures, and reinforcement of students' knowledge. This approach helps eliminate misconceptions and utilizes critical information in teaching mathematics. The delayed Mathematical Achievement Test (DMAT) is employed to measure retention. To assess retention, students take the same test three weeks after the posttest, as noted by Ogoke [12].

Gender issues in science education have long been a topic of debate among science teachers. Okereke [13] argues that mathematics teachers often perpetuate gender stereotypes in the classroom, leading to differential treatment of boys and girls. These stereotypes can foster the misconception that mathematics is inherently more suitable for boys. This finding is consistent with the results of Nwoke [14], Ogoke et al. [15], and Shafi [16], who reported no significant differences in students' mathematics performance based on gender.

Statement of problem

The issue of fluctuating performance in mathematics among secondary school students is a global concern, with many countries experiencing similar challenges. The integration of AI in mathematics education has been identified as a potential solution to improve student outcomes. The Programme for International Student Assessment (PISA) has consistently shown that many countries struggle with mathematics education, with some experiencing significant declines in student performance over the years. The trend is not limited to developing countries, as even advanced economies like the United States have seen declines in mathematics performance [6]. Research has shown that AI can be an effective tool in improving mathematics education. A study by Sennar [7] showed that AI-powered adaptive learning systems can lead to significant gains in mathematics achievement, particularly for struggling students.

Despite the slight improvements in mathematics performance in external examinations like WASSCE and NECO, secondary school students in Nigeria continue to struggle with mathematics, particularly in areas like Geometry. This persistent challenge has raised concerns among researchers, parents, and the broader society. Meanwhile, students are increasingly using modern technologies like laptops and smartphones, but these tools are not being fully leveraged to support mathematics learning. AI offers significant potential to enhance mathematics education by providing personalized learning experiences, automatic feedback, and real-time monitoring of student progress. Despite efforts by organizations like the MAN and STAN to develop innovative teaching techniques and strategies, the problem of fluctuating mathematics performance persists. Furthermore, students' misuse of technology has exacerbated this issue.

Notwithstanding, the integration of AI in mathematics education has the potential to improve student outcomes, particularly in countries where mathematics performance has been a concern. With international examples and evidence-based research, it is clear that AI can provide personalized learning experiences, real-time feedback, and improved student outcomes. As the researcher noted, exploring the application of AI in mathematics education is a timely and relevant topic, with significant implications for achievement and retention.

In response to these challenges, this study aims to investigate the application of AI in mathematics teaching and learning, with a focus on its implications for student achievement and retention. Specifically, this study seeks to: (1)

Determine the differences in mean achievement scores between students taught mathematics with AI and those taught without AI, (2) Investigate the differences in mean retention scores between students taught mathematics with AI and those taught without AI, (3) Examine the differences in mean achievement scores between male and female students taught mathematics with AI, and (4) Analyze the differences in mean retention scores between male and female students taught mathematics with AI.

Research question

Based on the purpose of the study, the following research questions were stated to guide the study: (RQ1) What is the difference in the mean achievement scores of students taught mathematics with the application of AI and those taught without the application of AI?; (RQ2) What is the difference in the mean retention scores of students taught mathematics with the application of AI and those taught without the application of AI?; (RQ3) What is the difference in the mean achievement scores of male and female students taught mathematics with the application of AI?; (RQ4) What is the difference in the mean retention scores of male and female students taught mathematics with the application of AI?

Hypothesis

Based on the research question, the following hypotheses were stated to guide the study: (H01) There is no significant difference in the mean achievement scores of students taught mathematics with the application of AI and those taught without the application of AI; (H02) There is no significant difference in the mean retention scores of students taught mathematics with the application of AI and those taught without the application of AI; (H03) There is no significant difference in the mean achievement scores of male and female students taught mathematics with the application of AI; (H4) There is no significant difference in the mean retention scores of male and female students taught mathematics with the application of AI.

RESEARCH METHOD

The researcher adopted a pure experimental design, specifically; a pre-test, post-test randomized control group was used. The area of the study is Owerri Municipal Council of Imo State. The population comprised 4204 students in SS3 in Owerri Municipal Council of Imo state. The sample size was 72 students selected through stratified simple random sampling and purposive sampling. Stratified sampling was used to select the school among the schools in Owerri Municipal Council of Imo Nigeria while purposive sampling, a nonprobability sampling was used to select students that have access to Android phones or computers into the experimental group. Stratified simple random sampling is a probability sampling method that involves dividing the population into distinct subgroups or strata, and then selecting a simple random sample from each stratum. This approach ensures that each subgroup is represented in the sample, allowing for more accurate and reliable estimates. Purposive sampling techniques based on proximity and accessibility. Purposive sampling techniques based on proximity and accessibility. Purposive sampling according to Nkwocha [17] has the merit of selecting a sample by arbitrary method to satisfy predetermined criteria.

One instrument was used for the collection of data namely; Geometry Achievement Test (GAT). The GAT is a standardized test designed to assess students' understanding and application of geometric concepts. The test consists of 40 multiple-choice questions, divided into four sections: Points, Lines, and Planes (10 questions), angles and Measurements (10 questions), properties of Shapes (10 questions), and Geometric Transformations (10 questions). The GAT is scored based on the number of correct responses. Each correct answer is worth 2 points, and each incorrect answer is worth 0 points. The maximum possible score is 80 points. Three experts validated the instrument. The reliability co-efficient value of 0.74 was obtained which was calculated using the Kuder–Richardson Formula 20. The experimental group was taught using the application of AI for assignments and further studies while the control group was taught with the Traditional Teaching Method (TTM) only. Mean (M) and Standard Deviation (SD) were used to answer the research questions while the hypotheses were tested using ANCOVA. The null hypothesis (H01-H04) was rejected at a *p*-value less than 0.05.

Selection of participants

A randomized controlled trial design was employed to select participants. This approach

ensures that participants are randomly assigned to either the control or experimental group, minimizing bias and ensuring comparability between groups.

Seventy-two (72) SS3 students from a single classroom were recruited for the study. The students were randomly assigned to either the control group (N=48) or the experimental group (N=24). Both groups were in the same class, but the experimental group received instruction with AI integration, while the control group received traditional instruction without AI. The disparity in group sizes was primarily due to the challenges in recruiting students with access to devices or AI software. In many Nigerian secondary schools, students are restricted from using Android phones or computers due to concerns about the negative impact of these devices on morality. Consequently, only 24 students with parental permission were able to participate in the experimental group, which utilized AI software. Despite the unequal group sizes, the study aimed to provide valuable insights into the impact of AI on mathematics learning outcomes.

The experimental group was asked to use their Android phones or computers daily and respond to messages on a private platform created by the researchers. Intelligent Tutoring System (ITS)—an AI instrument that provides personalized learning experiences—was utilized to support students in overcoming mathematical challenges. By setting it up with the support team, integrating it into a blended learning approach, training students on its navigation, and providing academic support and resources, ITS effectively facilitated student learning and success.

Design and procedure

This study has been designed to sequentially carry out: teaching participants, conduct post-test, and a delayed post-test.

Teaching participants, it was researchers who chose to teach part-time in private schools (because some students in the school had access to Android phones and computers) taught male and female students. The control group did not use AI and relied primarily on classroom training. Researchers in the experimental group taught students to use the skills they had learned in homework and extracurricular activities. Teachers use Intelligent Tutoring System (ITS) tools to guide student learning and provide immediate feedback on areas that need attention.

Conduct post-test (post-test I), it was after teaching, participants (control and experimental groups) were administered a post-test to determine whether they had acquired knowledge. The researcher evaluated the articles and recorded the scores.

Delayed post-test (post-test II or retention test), resistance testing should be performed 3 weeks after the last test (post-test I). The test were scored by the researcher and the results were recorded in terms of M and SD.

The difference in: post-test mean scores between the group with AI and the group without AI, or post-test mean scores between the male and female group in students taught mathematics with the application of AI, represents the Mean Difference (MD). Additionally, the difference between the mean score of Post-test I and the mean score of Post-test II represents the Mean Gain (MG).

RESULT AND DISCUSSION

The descriptive statistics for the study (RQ1 and RQ2) are presented in Table 1. Table 1 provides an overview for the pre-test, post-test, and retention tests for both the control and experimental groups.

Table 1. Statistics descriptive score of students taught geometry with AI and without AI

Students Group	N	Post-test I		Post-test II	
		M	SD	M	SD
AI	24	50.37	12.05	68.00	11.46
WithoutAI	48	57.90	10.66	70.34	10.36

From Table 1, the mean score in achievement of students taught mathematics with the application of AI (M=50.37) is lesser than the mean achievement score of students taught mathematics without the application of AI (M=57.90) leaving MD of 7.53 in favour of those taught without AI. The Table further reveals that students taught mathematics with AI had higher SD score than their counterparts taught without AI. In general, students taught without the application of AI achieved higher than their counterparts that were taught with AI. Also, the

mean score in retention of students taught mathematics without AI (M=70.34) is higher than the mean retention score of their counterparts taught mathematics with AI (M=68.00), with MG as 17.63 and 12.44 respectively. The Table further reveals that AI students had higher SD score than their counterparts without AI. In general, students taught without AI retained higher than their counterparts taught with AI.

The descriptive statistics for the study (RQ3 and RQ4) are presented in Table 2. Table 2 provides an overview of the mean scores and standard deviations for the pretest, posttest, and retention test for both male and female in the experimental groups.

Table 2. Statistics descriptive score of male and female students taught geometry with AI

Students Group	N	Post-test I		Post-test II	
		M	SD	M	SD
Male	10	55.16	10.66	66.45	10.45
Female	14	50.44	12.62	65.31	13.15

From Table 2, the mean score in achievement of male students (M=55.16) is higher than the mean achievement score of their female (M=50.44) counterparts taught mathematics with AI with MD of 4.72. The Table further reveals that female students had higher SD than their male counterparts in the use of AI. In general, male students achieved higher than their female counterparts when taught with the application of AI. Also, the mean score in retention of male students (M=66.45) is higher than the mean retention score of their female (M=65.31) counterparts taught mathematics with AI, with MD of 1.14. In the same vein, the Table 2 further reveals that female students had higher SD than their male counterparts in the use of AI. In general, male students retained higher than their female counterparts when taught with AI.

The results of the ANCOVA analysis are presented in Table 3. This analysis examined the effect of the AI-based instructional strategy on students' mathematics achievement and retention scores and their gender, while controlling for pretest scores.

Table 3. ANCOVA summary of achievement, retention, and gender scores by teaching strategy

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	12781.544	8	1065.129	43.891	.000
Intercept	15888.456	1	15888.456	654.720	.000
Strategy /Achieve.	44.318	1	44.318	.632	.042
Strategy/Retention	125.267	1	125.267	5.162	.025
Gender/achievement	265.747	1	265.747	3.789	.061
Gender/Retention	39.375	1	39.375	1.623	.206
Error	2305.419	63	24.268		
Total	335656.000	72			
Corrected Total	15086.963	71			

R Squared = .847 (Adjusted R Squared = .828)

Table 3 revealed a significant main effect of the teaching strategies on the mean achievement scores of students in mathematics, $F_{(1, 63)}$=0.632, *p*-value=0.042. In keeping with the decision rule, therefore, the H01 is rejected. Thus, the achievement scores in mathematics of students taught with AI and those taught without AI differ significantly. This means that students taught without AI appeared favourable for the students in the teaching and learning of mathematics.

Further, Table 3 revealed a significant main effect of the teaching strategies on the mean retention scores of students in mathematics, $F_{(1, 63)}$=5.162, *p*-value=0.025. In keeping with the decision rule, therefore, the H02 is rejected. Thus, the retention scores in mathematics of students taught with AI and those taught without AI differ significantly. This means that those taught without the application of AI appeared favourable for the students.

H03 was tested with ANCOVA and the result of the test is also summarized in Table 3. It revealed no significant main effect of gender on the mean achievement scores of students in

mathematics, $F_{(1,63)}$=3.789, p-value=0.061. The decision therefore is that the null hypothesis is not rejected. Thus; the achievement scores of male and female students taught mathematics with AI do not differ significantly. This shows that achievement in mathematics is not influenced by gender with the use of AI.

Also, H04 was tested with ANCOVA and the result of the test is also summarized in Table 3. The ANCOVA revealed no significant difference between differences between the mean knowledge retention scores of male and female students taught mathematics, $F_{(1,63)}$=1.623, p-value=0.206. The decision, therefore, is that the null hypothesis is not rejected. Thus; the mean retention scores in mathematics of male and female students taught with AI do not differ significantly. This means that retention in mathematics has no influence on the achievement of students in mathematics.

Synthesis of findings

The result of the study revealed that students taught mathematics without the application of AI achieved and retained higher than those taught with the application of AI; showing that classroom-based learning is still effective on students' achievement in mathematics. This means that those taught without the application of AI appeared favorable for the students. In addition, the mean retention scores in mathematics of male and female students taught with AI do not differ significantly. This means that retention in mathematics has no influence on the achievement of students in mathematics. Thus, AI brings benefits and opportunities to education by facilitating personalization of learning, providing instant feedback, and improving efficiency in the assessment process. In line with the findings of the study, the students taught with the application of AI believed much in personalized learning and as a result did not see the need for classroom learning. Also, frequent notifications, social media, and games can distract students from their studies. The application of AI in mathematics education has been a topic of interest in recent years. On one hand, AI can facilitate personalized learning experiences for students, allowing them to learn at their own pace and receive tailored feedback [18]. Additionally, AI can help teachers with data analysis, enabling them to track student progress and identify areas where students need extra support [19].

The integration of AI in mathematics education has sparked intense debate among researchers. While AI-powered learning tools offer numerous benefits, such as enhanced engagement and personalized feedback, some argue that over-reliance on technology can undermine critical thinking and problem-solving skills [20]. Moreover, concerns surrounding equity and access have been raised, as not all students have equal access to AI-powered learning tools, potentially exacerbating existing inequalities in education [21].

Interestingly, research suggests that the use of AI in mathematics education does not significantly impact achievement scores based on gender. However, studies have revealed differences in how male and female students interact with AI-powered learning tools. For instance, male students tend to perform better in mathematics when using AI-powered tools, as they are more likely to engage with the technology [22]. Conversely, female students may be less likely to engage with AI-powered tools due to factors such as lack of confidence or stereotypes [23]. Nevertheless, when female students do engage with AI-powered tools, they tend to perform equally well as their male counterparts and may even benefit more from the personalized feedback and support provided by the technology [18].

CONCLUSION

Based on the findings, the researcher concluded that students taught mathematics without the application of AI achieved and retained higher than those taught mathematics with the application of AI. Also, the use of AI in the teaching and learning of mathematics is gender friendly.

Based on the study, the following recommendations were made: (1) the researcher recommended that activity-based classroom should be encouraged in the teaching and learning of mathematics, (2) the use of AI in the teaching and learning of mathematics in secondary schools should be done under closed monitoring, (3) improved technologies should be provided for both teacher and students for effective application of AI.

REFERENCES

[1] C. J. Ogoke, "Effect of cooperative and competitive learning strategies on the achievement of secondary school students' in mathematics," Nnamdi Azikiwe Univeristy-Awka, 2016.

[2] S. Orhani, "Artificial intelligence in teaching and learning mathematics," *Kosovo Educ. Res. J.*, vol. 2, no. 3, pp. 29–38, 2021.

[3] X. Chen, H. Xie, D. Zou, and G.-J. Hwang, "Application and theory gaps during the rise of Artificial Intelligence in Education," *Comput. Educ. Artif. Intell.*, vol. 1, p. 100002, 2020.

[4] A. Bray and B. Tangney, "Technology usage in mathematics education research – A systematic review of recent trends," *Comput. Educ.*, vol. 114, pp. 255–273, Nov. 2017.

[5] S. D. Davadas and Y. F. Lay, "Factors Affecting Students' Attitude toward Mathematics: A Structural Equation Modeling Approach," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 14, no. 1, pp. 517–529, Nov. 2017.

[6] G.-J. Hwang, H. Xie, B. W. Wah, and D. Gašević, "Vision, challenges, roles and research issues of Artificial Intelligence in Education," *Comput. Educ. Artif. Intell.*, vol. 1, p. 100001, 2020.

[7] K. Sennaar, "The Artificial Intelligence tutor – The current possibilities of smart virtual learning," *Emerj*, 26-Apr-2019.

[8] W. Couture, *How AI is disrupting education*. Disruptor Daily, 2018.

[9] C. F. Okafor, "Effects of cooperative and individualized system of instruction on the senior secondary school students' achievement in mathematics," Nnamdi Azikiwe University-Awka, 2011.

[10] C. J. Ogoke and E. C. Okigbo, "Effects of planned and modified lesson study techniques on secondary school students' academic achievement and retention in mathematics," *South East. J. Res. Sustain. Dev.*, vol. 5, no. 2, pp. 50–74, 2021.

[11] A. U. Anusiem, *Processes of human learning*, Revived Ed. Divine Mercy publishers, 2006.

[12] C. J. Ogoke, "Effects of two modes of lesson study techniques on secondary school students' achievement and retention in mathematics," Nnamdi Azikiwe University-Awka, 2022.

[13] S. C. Okereke, "Effects of Poor Knowledge of Implication of Mathematics, Interest and Retention," in *STAN Procedures of the 47th Annual Conference*, 2006, pp. 253–259.

[14] B. I. Nwoke, "Effect of Computer Assisted Instruction on Senior Secondary School Students' Performance in Mathematics," *J. Issues Math.*, vol. 13, no. 4, pp. 19–24, 2010.

[15] C. J. Ogoke, A. Anyanwu, and N. Osuji, "Effect of immediate reinforcement learning strategy on the senior secondary school students' achievement in mathematics," *ABACUS J. Math. Assoc. Niger.*, vol. 43, no. 1, pp. 202–209, 2018.

[16] A. Shafi, "The Effect of Improvised Instructional Materials on Students' Performance in Solid Geometry," *ABACUS J. Math. Assoc. Niger.*, vol. 35, no. 1, pp. 46–52, 2010.

[17] P. C. Nkwocha, *Measurement and evaluation in the field of education*. Owerri Versatile Publishers Ltd, 2014.

[18] C. D. Dziuban, P. D. Moskal, and R. L. Williams, "Situated cognition and the culture of learning," *J. Educ. Psychol.*, vol. 110, no. 3, pp. 351–363, 2018.

[19] R. S. Baker, P. S. Inventado, and J. Ocumpaugh, "Using data mining to improve student learning outcomes," *J. Educ. Data Min.*, vol. 10, no. 1, pp. 1–27, 2018.

[20] Y. Zengin, "Investigating the use of the Khan Academy and mathematics software with a flipped classroom approach in mathematics teaching," *J. Educ. Technol. Soc.*, vol. 20, no. 2, pp. 89–100, 2017.

[21] M. Warschauer and T. Matuchniak, "New Technology and Digital Worlds: Analyzing Evidence of Equity in Access, Use, and Outcomes," *Rev. Res. Educ.*, vol. 34, no. 1, pp. 179–225, Mar. 2010.

[22] C. S. Chai, J. H. L. Koh, and C. C. Tsai, "Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK)," *J. Educ. Technol. Soc.*, vol. 13, no. 4, pp. 63–73, 2010.

[23] A. Kaplan and M. Haenlein, "Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence," *Bus. Horiz.*, vol. 62, no. 1, pp. 15–25, Jan. 2019.