



Mathematics Teachers' Self-Efficacy in Utilizing Artificial Intelligence (AI) Tools as Correlate of their Professional Development in Mathematics

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Abstract

This study examined the Mathematics teachers' self-efficacy in utilizing Artificial Intelligence (AI) tools as correlate of their professional development in Mathematics in Boki Local Government Area of Cross River State, Nigeria. Two research questions and null hypotheses guided the study. A correlation survey research design was adopted for the study. All the 46 Mathematics teachers in the population were used. Teachers' Self-Efficacy in AI Questionnaire (TSEQ-AI) and the Teachers' Professional Development Questionnaire (TPDQ) were used. Cronbach's Alpha reliability estimates of 0.85 for TSEQ-AI and 0.75 for TPDQ were obtained. Linear regression analysis was used to answer research questions, while regression ANOVA tested null hypotheses at the 0.05 significance level. Findings revealed a significant relationship between Mathematics teachers' self-efficacy in AI use and their professional development. However, teachers' teaching experience did not significantly moderate this relationship. Based on these findings, it was recommended, among others, that educators and policymakers should focus on strengthening the relationship between Mathematics teachers' self-efficacy in AI and professional development by providing targeted support.

Key Words: Mathematics Teachers, Self-Efficacy, AI Tools, Teaching Experience, Professional Development

Introduction

The integration of Artificial Intelligence (AI) in Mathematics education has sparked a paradigm shift, where teachers' self-efficacy in utilizing AI tools emerges as a crucial factor in determining their professional growth and student learning outcomes. As AI technology continues to reshape the educational landscape, Mathematics teachers' self-efficacy in leveraging these tools becomes a vital component of their professional development, influencing their instructional practices and student achievement. In the era of digital transformation, Mathematics teachers' self-efficacy and competence in utilizing AI tools pay a pivotal role in shaping their professional identity, pedagogical approaches and ultimately, students learning experiences.

The role of Mathematics education in the socioeconomic, scientific and technological development of any nation cannot be overemphasized. Nevertheless, Adeniyi (2014) posited that Mathematics is considered the vehicle that drives and brings about scientific and technological development of any nation, which demands that her citizens in formal schools should be competent in manipulating Mathematics.

Rosen (2020) further stated that Mathematics translates to be a subject that enables a learner to have adequate understanding and interpretation of concepts in science and technology. The author continued that, Mathematics is a tool use in science, technology and industry for the realization of the nation's scientific and technological aspirations. This to say that, some technological developments in the field of education are influenced by Mathematics, as Alpaydin (2020) stated that Mathematics is foundational to the development of algorithms used in machine learning, a core component of modern technology. Algorithms are based on mathematical principles and are essential for tasks such as data analysis, pattern recognition, and decision-making in education. Encryption, digital signatures, and secure communication protocols rely on mathematical concepts such as number theory and discrete logarithms to safeguard sensitive information (Stinson, 2005). Therefore, the advancement of technology, emergent and use of Artificial Intelligence (AI) are rapidly changing the landscape of education which has brought unprecedented changes and opportunities to various fields, including Mathematics education.



AI technology has significantly transformed and revolutionized teaching and learning experiences, making them more personalized, interactive, and engaging. However, Russell & Norvig (2021) stated that AI is the branch of computer science concerned with creating intelligent agents, which are systems that perceive their environment, learn, reason, and act autonomously. As the importance of Mathematics education continues to grow, according to Rosen (2020), educators are seeking innovative approaches to engage students and enhance learning outcomes. Olsher & Thurm (2021) asserted that the utilization of AI in Mathematics education provides personalized and adaptive learning experiences, automating administrative tasks, and enabling intelligent data analysis for personalized feedback and assessment. In recent years, AI technologies such as intelligent tutoring systems, virtual teaching assistants, and automated grading systems have gained prominence in Mathematics education. These technologies can provide students with personalized feedback, adapt to their individual learning needs, and support their problem-solving abilities (Blikstein, 2020). A great number of research found that teaching Mathematics with AI technologies or tools can enhance students' learning (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020; Olsher & Thurm, 2021). Students need to feel comfortable using AI technologies or tools and understand their potential benefits for their mathematical learning while teachers need to be trained in how to effectively incorporate AI tools into their teaching practices, develop their pedagogical strategies, and understand how to interpret and utilize AI-generated data effectively.

Various tools are designed specifically to help in teaching and learning of Mathematics. These designs utilize artificial intelligence technologies to enhance the learning experience, provide personalized instruction, and support problem solving. Specifically, research findings have also highlighted some of the AI based designs for effective teaching and learning of Mathematics such as GeoGebra, Wolfram Alpha, Desmos, Photomath, Symbolab, and others.

Wolfram Alpha is a computational knowledge engine providing direct answers and data-driven insights for mathematical queries. It's a powerful tool for mathematical computations, including solving equations, graphing functions and visualizes concepts such as curves, surfaces, 2D and 3D plots, symbolic calculations and generating step-by-step solutions (Wolfram Alpha, 2024). On the other hand, GeoGebra

is dynamic Mathematics software focusing on visualization and exploration. It is ideal for teaching and learning geometry such as angles, triangles, and circles, algebra, calculus, and statistics. It features interactive tools for visualization, exploration, and problem-solving, making it suitable for teaching and learning mathematics at various levels (GeoGebra, 2021). Desmos is a graphing calculator emphasizing interactive visualization and exploration of mathematical functions. It allows users to graph mathematical functions and explore concepts such as linear equations, quadratic functions, and trigonometric graphs. It is well-suited for teaching and learning graphing concepts, interactive demonstrations, animations, visualize mathematical concepts, demonstrate problem-solving techniques, and engage students in interactive explorations (Desmos, 2024). Photomath is a mobile app using AI to provide step-by-step solutions to Mathematics problems through image recognition. It is a helpful tool for students to check answers and understand problem-solving processes. Students can scan handwritten or printed Mathematics problems using their smart phone camera, and the app will recognize and solve them in real-time. Photomath can reinforce mathematical concepts learned in the classroom by providing additional practice and explanations in a convenient and accessible format. The mobile app allows users to access mathematical help and resources anytime, anywhere, making it suitable for self-paced learning and study (Photomath, 2022).

Finally, Symbolab is an online tool offering step-by-step solutions, interactive graphs, and practice exercises for various Mathematics topics. It utilizes AI algorithms to interpret and solve mathematical expressions and equations, offering detailed explanations and visualizations. Students can use Symbolab to solve mathematical problems, verify their answers, and learn problem-solving techniques for various topics such as algebra, calculus, and trigonometry. It is designed to assist students in learning and mastering mathematical concepts (Symbolab, 2023).

These AI tools offer innovative solutions for teaching and learning Mathematics, leveraging advanced technologies to enhance understanding, engagement, and problem-solving skills in Mathematics education. Overall, these tools demonstrate the potential of AI to enhance education and research by providing intelligent support, personalized learning experiences, and efficient problem-solving solutions. Perhaps, the effective

utilization of AI tools and technologies in the classroom depends on teachers' self-efficacy,

Self-efficacy is an important construct in education as it has been found to positively impact teaching effectiveness and student outcomes. Ormrod (2006) refers to self-efficacy as the belief that one is capable of performing tasks in certain ways to attain certain goals. Askar & Davenport (2009) submit that self-efficacy has emerged as an important means of understanding and predicting a person's performance. Mathematics self-efficacy is a person's belief in his ability to successfully perform well in Mathematics (Burnham, 2011). Tschannen-Moran & Hoy (2001) defines Mathematics teacher's self-efficacy as teacher's capability to organize and execute courses of action during classroom Mathematics instruction to accomplish specific teaching tasks within a particular context. Mathematics teachers who possess high levels of self-efficacy in using AI are more likely to engage with and effectively utilize AI tools and resources in their teaching practices and professional development opportunities.

Mathematics teacher professional development plays a crucial role in equipping them with the necessary skills and knowledge to effectively integrate new technologies into their teaching practices. Mathematics teachers' professional development refers to activities and programs designed to improve teachers' knowledge, skills, and practices in Mathematics education (Reeves, 2010). It encompasses both formal and informal learning opportunities, such as workshops, conferences, online courses, coaching, and collaborative learning communities. For teachers to successfully integrate AI into their teaching practices, it is crucial to provide them with appropriate professional development opportunities. These opportunities should address both the technical skills required to use AI technologies and the pedagogical knowledge needed to effectively incorporate them into Mathematics instruction (Wong, 2021). The author continued that access to high-quality training and professional development opportunities is essential for improving teachers' self-efficacy in using AI technological tools. When educators perceive AI tools as valuable assets for enhancing students' mathematical proficiency, they are more likely to develop confidence in their ability to integrate these tools effectively. Teachers with strong pedagogical content knowledge along with technological fluency are more likely to feel confident in integrating AI tools effectively in their teaching practices (Kasim, 2021). Although, there are many

factors that influence teachers' confidence and self-efficacy in integrating AI technologies and tools into their instructional practices notably, teachers' qualification, gender differentiation and teachers' experiences in both pedagogical knowledge and technological skills when utilizing AI tools in Mathematics instruction.

Teachers' experience as aforementioned is also a prevalent factor impacting the integration of AI in education. According to Ekmekci and Serrano (2022), an experienced teacher is one who have taught for many years (five year and above) and are able to motivate students and hold their attention, know how they manage their lesson and classroom effectively. This implies that teachers' experienced in AI integration in education is defined by the duration of the teacher using the technology. Therefore, examining the impacts of teachers' experiences with AI in teaching is very crucial as to gain deeper insights into the opportunities and challenges associated with AI-driven pedagogical interventions. One of the primary impacts of teachers' experience with AI in teaching is the enhancement of instructional efficiency and effectiveness (Yi, Jia, & Wang, 2020).

Although the AI tools and technology integration into their instructional practices has been gaining attention, but its impact in professional development especially for Mathematics teachers, remains a question mark. To this end, it is therefore imperative to determine the moderating roles of Mathematics teachers teaching experience and relationship with self-efficacy in utilizing AI tools and professional development in education in Boki Local Government Area of Cross River State Nigeria. Specifically, the study sought to determine:

1. The relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development.
2. The relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development as moderated by years of teaching experience.

Methods

The study adopted a correlation survey research design. According to Nworgu (2015) the design seeks to establish what relationship exists between two or more variables. The participants of the study comprised of 46 Mathematics teachers (34 males and 12 females) drawn from all the 30 public secondary schools in Boki Local Government Area of Cross River State. A census

sampling approach was employed, involving all 46 Mathematics teachers in the population. The instruments for data collection for this study were two structured questionnaires adapted by the researcher. These are Teachers' Self-Efficacy Questionnaire in AI (TSEQ-AI) and the Teachers' professional development questionnaire (TPDQ). They were subjected to face validation by three experts: two from the Mathematics unit while one from Measurement and Evaluation unit all in the department of Science Education, Faculty of Education University of Nigeria Nsukka. Their internal consistency was determined

using Cronbach Alpha method and coefficients 0.85 and 0.75 were gotten. Data were collected with the help of research assistants through direct delivery method in the administration and retrieval of the questionnaires from the respondents, who were the Mathematics teachers across the public secondary schools in the study area. Linear regression analysis was used to answer research questions. All formulated null hypotheses were tested using regression ANOVA at 0.05 level of significance. Reject $p \leq 0.05$ level of significance otherwise accept.

Results

Table 1: Regression analysis of the relationship between Mathematics teachers' self-efficacy in Utilizing AI Tools and their professional development

Model Summary

Model	N	R	R Square	Adjusted R Square
1	41	0.052 ^a	0.003	-0.023

Table 1 shows regression analysis of the relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development. It reveals an R value of 0.052 and an R square of 0.003. This implies that there was positive but weak relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional

development. The coefficient of determination (R square) indicates that 0.3% variance in teacher's professional development is accounted for by the Mathematics teachers' self-efficacy in the use of AI. While the remaining 99.7 could be attributed to other factors this study did not consider.

Table 2: Regression ANOVA for the relationship between Mathematics teachers' self-efficacy in the use of AI and their professional development

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	6.010	1	6.010	0.105	0.748 ^b
	Residual	2236.965	39	57.358		
	Total	2242.976	40			

Table 2 shows regression ANOVA for the relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development. It reveals an F (1, 39) value of 0.105 and an associated p-value of 0.03. The associated p-value is greater than the level of significance p-value (0.05). Therefore, the null hypothesis that no significant

relationship exists between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development is not rejected. In other words, there is no significant relationship between Mathematics teachers self-efficacy in the use of AI and teachers professional development.

Table 3: Regression Model Summary of the Relationships among the Dependent Independent and Moderating (experience) Variables

Model Summary				
Model	N	R	R Square	Adjusted R Square
1	41	0.140 ^a	0.019	-0.062

Table 3: shows the combined contribution of Mathematics teachers' self-efficacy in the utilizing AI tools, experience and the interaction of Mathematics teachers' self-efficacy and experience in prediction of teachers' professional development. The model summary indicates a multiple correlation value

($R=0.140$), R-Square value of 0.019, and Adjusted R-Square value of -0.062. It implies that 0.140 percent variance in low teachers' professional development is accounted for by the Mathematics teachers' self-efficacy, experience and interaction of Mathematics teachers' self-efficacy and experience.

Table 4: Un-standardized and Standardized Coefficients for Estimating the Moderation Effect of Teaching Experience Relationship between Mathematics Teachers' Self-efficacy and Teachers' Professional Development

Model		Un-standardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	44.29	13.79		3.21	0.00
	Mathematics teachers' self-efficacy	0.10	0.20	0.15	0.50	0.02
	Experience	0.01	0.10	0.02	0.53	0.96
	Interaction	0.02	0.26	0.05	0.11	0.85
a Dependent Variable: teachers professional development						

Table 4 shows that the standardized coefficient for the contribution of Mathematics teachers' self-efficacy, experience and interaction of teaching experience and Mathematics teachers' self-efficacy in prediction of teachers' professional development. The results show that Mathematics teachers' self-efficacy significantly contributed in prediction of teachers professional development ($Beta=0.15$, $t=0.50$, $p=0.02$), whereas experience was not a significant contributor to teachers professional development in Mathematics ($Beta= 0.02$, $t=0.53$, $p=0.96$). Therefore, experience has no significant moderation effect on the relationship between teachers' self-efficacy and teachers professional development in Mathematics ($Beta=0.05$, $t=0.11$, $p=0.85$). Hence, the null hypothesis which stated that there is no significant relationship between Mathematics teachers' self-efficacy in the utilizing AI tools and teachers professional development as moderated by teaching experience is not rejected.

Discussion

The discussion of the findings of this study was presented according to the research purposes that guided the study.

Relationship between Mathematics teachers' self-efficacy in utilizing AI tools and their professional development

The result of the study presented in table 1 reveals an R value of 0.052 and an R square of 0.003. This implies that there was positive and weak relationship between Mathematics teachers self-efficacy in the use of AI and teachers professional development. The findings of this study agree with the findings of Smith & Jones (2019) who explored the complexities of teachers' self-efficacy in AI use and their professional development, and found a more complex relationship between teachers' self-efficacy in using AI and their professional development. This may be attributed to the interconnection of various contextual, psychological and environmental factors.

However, the study disagree with the Charlotte, Josef, Anna-Lena, & Stefanie (2023) study which they found out that there is positive teachers' self efficacy to integrate digital media in teaching as well as enhances students' motivation to learning.

Relationship between mathematics teachers' self-efficacy in the use of AI and teachers professional development as moderated by years of teaching experience

The results show that Mathematics teachers self-efficacy significantly contributed in prediction of teachers professional development (Beta=0.15, $t=0.50$, $p=0.02$), also experience was significant contributor to teachers professional development in Mathematics (Beta= 0.02, $t=0.53$, $p=0.96$). Experience has significant moderation effect on the relationship between teachers self-efficacy and teachers professional development in Mathematics (Beta=0.05, $t=0.11$, $p=0.85$). Hence, the null hypothesis which stated that there is no significant relationship between Mathematics teachers self-efficacy in the use of AI and teachers professional development as moderated by experience is not rejected.

Hence, a research carried out by Wang and Chen (2022) agreed that experienced mathematics teachers tended to approach AI integration with caution, citing concerns about its impact on traditional teaching practices and student learning outcomes. Chen and Patel (2024) disagreed with these findings which revealed that there is a significant relationship between teachers' self-efficacy in the use of AI and teachers' professional development as experienced mathematics teachers were more likely to adapt AI-assisted instruction to align with their existing teaching practices and pedagogical preferences. Their finding equally stated that professional development initiatives tailored to address the needs and concerns of experienced educators were essential for fostering successful AI integration. This was equally supported by Garcia and Kim (2023) as the result of their comparative analysis examining the impact of professional development on teachers' professional growth in AI integration across different levels of teaching experience indicated that, while all teachers showed improvements in self-efficacy, those with fewer years of teaching experience displayed greater receptiveness to innovative pedagogical approaches facilitated by AI. Also,

Conclusion

From the discussion of the findings of the study, it is therefore concluded that, there is a low self efficacy of Mathematics teachers in the use or integration of AI tools in their teaching practices. There is a good chance that participating in professional development activities increases a teacher's confidence (self-efficacy) in using AI in their teaching. Therefore, Mathematics teachers should be encouraged to engage in professional development as it is a good factor to boast their self efficacy in the use of artificial intelligence (AI). In line with the findings also, experience has no significant moderation effect on the relationship between teachers' self-efficacy and their professional development in Mathematics. Whereby, experienced teachers should be encouraged to mentor and coach newer teachers.

Recommendations

Based on the conclusion of this study, the following recommendations were made;

1. Educators and policymakers should focus on strengthening the relationship between Mathematics teachers' self-efficacy in utilizing AI tools and professional development by providing targeted support, training, and resources to enhance AI integration, innovation, and equitable access to quality Mathematics education.
2. Experienced teachers are encouraged by school administrators to mentor and coach newer teachers by providing opportunities for collaboration and feedback. Again, encouraging experienced teachers to take on leadership roles and share their expertise with colleagues.

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