Educational Technology Quarterly, Vol. **2026**, Iss. 1, pp. 60–80 10.55056/etq.1089

From algorithms to innovation: pre-service mathematics teachers' perceptions of robotics-enhanced problem-solving instruction

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Abstract. Educational robotics has gained substantial attention for its capacity to transform the way students learn. Conversely, over-reliance on traditional teaching techniques, which prioritise memorisation over critical thinking and problem-solving, still prevails in mathematics classrooms. Different perceptions exist regarding the potential for educational robotics to enhance problem-solving skills. The study, therefore, surveyed demographic differences in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance problem-solving skills among 242 undergraduates randomly selected from three prominent campuses in Ekiti State. Data were analysed through descriptive statistics, independent t-tests, and ANOVA. The findings reveal a broad consensus that educational robotics enhances conceptual understanding and fosters problem-solving skills. However, the findings reveal significant differences in perceptions based on gender, age, and level. Educational robotics should not be an afterthought, but a core component of pedagogical preparation. The study recommends that the National Universities Commission include robotics integration as a criterion for accrediting teacher-education programs.

Keywords: educational robotics, problem-solving, pre-service teachers, STEM, mathematics education, Nigeria

1. Introduction

Mathematics is fundamental to education and plays a central role in shaping human analytical and problem-solving skills, which are essential in everyday life and the workplace [11]. Our lives are made more orderly and stable by mathematics, which keeps confusion and anarchy at bay. Mathematics develops a wide range of abilities, such as critical thinking, reasoning, creativity, problem-solving, and communication [10, 33].

Mathematics failure rates in both internal and external examinations have been persistently high, particularly in tertiary institutions [18]. Many students struggle with abstract mathematical concepts, resulting in low pass rates and disengagement [39]. For instance, Mullis et al. [37] revealed that many students failed to meet basic mathematical proficiency standards, with tertiary-level students often underprepared [53]. The inability of traditional teaching methods to engage students effectively, alongside poor foundational skills, has exacerbated this issue [28].

Mathematics education in Nigeria faces several challenges, including outdated teaching methods,

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Received	Accepted	Published	Version of record
2025-08-04	2025-12-02	2026-01-05	2026-03-20

lack of proper instructional materials, and inadequate teacher training [10, 18]. These issues are particularly pronounced in the training of pre-service teachers, who often lack exposure to modern pedagogical tools, including educational technologies [12].

The over-reliance on traditional teaching techniques, which prioritise memorisation over critical thinking and problem-solving, is one of the numerous issues plaguing mathematics education in Nigeria and many other developing nations [21, 33]. Pre-service teachers often lack the pedagogical resources and problem-solving skills necessary to effectively teach mathematics using educational technologies, despite their significant impact on how future students are taught [17]. Educational technology, particularly educational robotics, has gained substantial attention for its potential to revolutionise the way students learn, particularly in the context of STEM education [34, 39, 47].

Both teachers and students need to be able to solve mathematical problems. According to Jaipal-Jamani [29], problem-solving involves understanding the problem, devising a strategy, carrying out the plan, and evaluating the solution [42]. For pre-service teachers, these skills are essential as they directly affect their ability to teach mathematics effectively [13]. However, numerous studies indicate that pre-service teachers in Nigeria often exhibit limited proficiency in these areas, a situation compounded by traditional pedagogical approaches that emphasise rote learning over critical thinking [26]. In Nigeria, pre-service teachers often struggle with problem-solving tasks, which hinders their ability to teach these concepts to their students [49].

The rapid integration of technology into education has revolutionised traditional teaching and learning paradigms, creating opportunities for innovative instructional strategies [10, 35]. Educational robotics, a subset of educational technology, has gained global recognition for its potential to transform learning experiences, particularly in mathematics education [29]. Educational robotics has been shown to enhance students' cognitive development, particularly in problem-solving and critical thinking [23].

While studies show that integration of technology (especially robotics) into education can enhance learning and support mathematical problem-solving skills [2, 15, 36], different perceptions exist regarding the potential of educational robotics to enhance mathematical problem-solving skills, especially among pre-service mathematics teachers, predisposing the adoption of these tools, especially in developing nations like Nigeria. Continued research is needed to investigate pre-service mathematics teachers' perception of the abilities of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction. This paper investigates pre-service mathematics teachers' perception of the capacities of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.

This study examines whether there exist disparities in perception based on gender, age, and level. Studies in the literature focus on the impact of using educational robotics to enhance achievement, but gaps exist in certain areas. One significant gap is that very few studies have been conducted on pre-service mathematics teachers' perception of the possibilities of educational robotics to enhance mathematical problem-solving skills, especially in developing nations like Nigeria. Another area that has not been well researched is addressing the demographic disparities surrounding the pre-service mathematics teachers' perception of the capabilities of educational robotics to enhance mathematical problem-solving skills.

2. Literature review

Agnoletti et al. [3] argued that today's world is facing more rapid technological progress than ever, and adaptation and the development of new competences and skills are essential. Studies have shown that integrating programmable robots into the curriculum exposes learners to hands-on activities that encourage exploration, collaboration, and the real-world application of mathematical concepts [24, 35]. Research indicates that robotics fosters computational thinking, critical reasoning, and creativity, which are essential for effective problem-solving [28].

According to Papadakis [43], computational thinking and coding, aspects of robotic engineering, were traditionally seen as components of secondary education programs that focused on programming and algorithm development at the start of the twenty-first century, as researchers around the world were calling for computational thinking and coding to become a new imperative for Western societies.

According to Arocena, Huegun-Burgos and Rekalde-Rodriguez [9], a robot is a programmable machine that can manipulate objects and perform operations that only humans could previously perform. In addition, robots provide a capacity, thought, or resolution feeling, although they are mostly limited to executing orders. Agnoletti et al. [3] remarked that the inclusion of ER in education can favour the learning process, as ludic activities can stimulate computational thinking, contributing to increased student engagement in STEM and, consequently, improving their problem-solving skills.

With its capacity to apply knowledge of instructional strategies and students' active production of meaning, educational robotics is becoming a significant instrument in the teaching-learning process [52]. The phrase "educational robotics", sometimes known as "pedagogical robotics", is used in robot teaching to provide curriculum and classroom training [25, 52]. According to Valsamidis et al. [52] and Gümüş et al. [25], educational robots often fit into one of the following categories: Robo Wunderkind, a modular system with blocks that snap together to create various robots with distinct functions; LEGO Mindstorms and VEX are kit-based systems that enable the construction and programming of more complex robots; Blue-Bot is a basic robot for teaching early programming concepts like sequencing and spatial reasoning; and mBot and Edison are programmable robots that teach students coding and electronics. Android, Zoomorphic, Mobile, Poliarticulated, Hybrid, Kidoboto, Lego EV3, MBot, Lego Spike, Lego Wedo, Matatalab, and Lego Boost are a few more examples. Souza, Andrade and Sampaio [48] describe educational tobotics as a multidisciplinary approach that considers design, assembly, and use of robots based on principles of engineering, computing, mathematics, and physics.

Studies have highlighted the impact of educational robotics in education; Mangina et al. [36] reiterated that robotics allows students to engage with abstract concepts tangibly and interactively, fostering a deeper understanding. Robotics programs, such as LEGO Mindstorms, have been widely used in schools to enhance problem-solving skills by encouraging students to engage in hands-on tasks that require mathematical reasoning [2, 15]. Robotics has long been regarded as an effective tool for promoting problem-solving skills, particularly in STEM fields, regardless of gender affinity [23].

Güven Demir and Gümüş [27] developed the concept of constructionism, which suggests that students learn best when they build or create something meaningful. Educational robotics provides an excellent platform for students to apply abstract mathematical concepts to tangible objects, fostering both engagement and deeper understanding. Robotics promotes critical thinking and problem-solving skills, which are essential in mathematics education [7].

Research has shown that educational robotics can enhance students' mathematical problem-solving abilities by providing hands-on learning opportunities [34]. For instance, using programmable robots in the classroom allows students to engage with mathematics in a practical, problem-solving context, as they learn how to design algorithms, manipulate variables, and solve complex mathematical problems [22, 47].

Robotics can also enhance computational thinking, a skill closely related to problem-solving. According to Kyriazopoulos et al. [34] and Angeli [7], computational thinking involves breaking down complex problems into manageable steps and devising algorithms to solve them, a process central to both robotics and mathematics.

The integration of robotics into teacher education has been widely studied in countries such as Finland, South Korea, and the United States, where robotics is utilised as a tool for enhancing both teaching and learning in mathematics [38, 41, 44]. These studies have shown that pre-service teachers exposed to robotics-based instruction develop better problem-solving skills, higher engagement in their learning, and a more positive attitude toward teaching STEM subjects [47].

Educational robotics is transforming the way students engage with learning by making complex concepts more interactive and accessible. Robotics-based education is particularly effective in STEM subjects, where hands-on problem-solving skills are essential [51]. The use of robotics in teacher education is relatively new in Nigeria, but it has shown promising results in other countries. In Finland, robotics-based teacher training programs have led to improved problem-solving skills among pre-service teachers, enabling them to incorporate innovative teaching strategies in their classrooms [46]. Similarly, in South Korea, robotics has been integrated into pre-service teacher education programs, resulting in better student engagement and enhanced teaching practices [31, 54].

A growing number of people are utilising educational robots to enhance student engagement, particularly in STEM courses [4]. Robots, as interactive, tangible learning tools, offer learners the opportunity to engage with complex concepts in a hands-on manner [45, 47]. The use of robotics in education is gaining popularity worldwide, particularly in countries such as the US, Finland, and South Korea, where it has been successfully integrated into teacher preparation programs [31, 54]. Particularly in STEM subjects, educational robotics is gaining more widespread recognition as a technology that promotes active, hands-on learning [29, 39, 55]. Students have the chance to apply mathematical ideas to address real-world problems using educational robotics. Robotics improves computational thinking, logical reasoning, and problem-solving abilities, all of which are critical in mathematics education, according to research by Chan et al. [16]. The hands-on aspect of educational robots creates an engaging learning environment, according to Suseelan, Chew and Chin [49], who also stresses the potential of educational robotics in developing problem-solving and critical thinking abilities. This is in line with research by Zhuang et al. [57] and Swenson [50], who highlight how educational robotics enable interactive learning and real-time feedback, which are essential for solving mathematical problems.

According to Swenson [50], project-based learning using educational robotics increases students' interest in mathematics. Nigerian pre-service teachers could see this as a means of making mathematics less abstract and more relevant. In a similar vein, Trapero-González et al. [51] noted that educational robots promote better learning by aiding in the visualisation of mathematical concepts. These studies provide strong evidence for the use of educational robots. According to Chinaka, Agbede and Olugasa [17], Nigerian pre-service teachers list limited training opportunities, high expenses, and a lack of resources as obstacles to implementing educational robots. Similar obstacles are reported globally by Silva et al. [47], who also note that collaborations with technology suppliers can help mitigate these difficulties. Egbai and Eke [18] assumes that there are insufficient resources and access to educational robotics kits in Nigerian schools, and the viability of this strategy may be limited by the high cost of these kits and the lack of financial resources in Nigerian schools. Besides, medical students view educational robots as creative, yet they feel unprepared to incorporate them into their lessons, according to Aljefiri et al. [5]. Similar opinions were reported by Nigerian pre-service teachers, who expressed excitement but identified inadequate facilities and training as obstacles [14, 20].

Moreover, by fostering an inclusive learning environment, educational robotics can help close the gender gap in STEM, according to Mangina et al. [36] and Aljefiri et al. [5]. However, according to Bali et al. [14], pre-service teachers in Nigeria think that biases and societal norms may prevent girls from participating in robotics-based mathematics education. Although these studies recognise the importance of gender, they do not offer practical solutions for getting past Nigerian-specific systemic and cultural obstacles. Additionally, pre-service teachers from rural and urban Nigerian schools held differing opinions about integrating educational robots, according to Essien and Ntui [20]. Urban instructors were more positive about the integration. This supports the findings of Seppinen [46], who found that improved infrastructure in urban schools increases the likelihood of adopting educational robotics. Although these results draw attention to disparities, they overlook how rural schools may still adopt robotics despite limited funding.

When examining demographic differences, including students' age, gender, and year of study, Almasi et al. [6] found no gender differences in the use of electronic or technological systems. Their results demonstrated that men and women use electronic or technological systems at the same rate. Additionally, Eshun Yawson and Amofa Yamoah [19] found no gender disparities in the use of technology or electronic systems for educational purposes. Their results demonstrated that men and women use electronic or technological systems at the same rate; however, according to the studies by Aristovnik et al. [8], Adams et al. [1], and Zhang, Chen and Wang [56], male students were more eager than female students to adopt and use electronic or technological systems for learning.

Furthermore, the Almasi et al. [6] study indicated a valuable variation between the age groups by identifying substantial differences in the year of study in terms of employing electronic or technological systems for learning reasons. According to their study, there are notable differences in how first-, second-, and third-year students use technical or electronic systems for learning. In particular, they discovered that third-year students used technology and electronic devices for learning more than first- and second-year students.

In his study, Ngoasong [40] also asserted that it was challenging for students with little to no prior experience using ICT or technological systems for learning to adapt to the learning process initially. Similarly, according to Adams et al. [1], postgraduate students are more motivated and use electronic or technological systems for learning than undergraduate students. As a result, more seasoned students find it easier to use technological or electronic learning systems than less seasoned ones. According to Johannsen et al. [30], learning outcomes improve the sooner students start using electronic or technical systems for learning reasons.

The examined literature highlights how educational robots can improve students' ability to solve mathematical problems by encouraging critical thinking, participation, and teamwork. Nonetheless, several significant obstacles exist, including inadequate infrastructure, insufficient teacher training, societal biases, and curricular limitations. Although they are excited about instructional robotics, Nigerian pre-service teachers believe they are not ready to incorporate it successfully. Systemic changes are necessary to address these issues, including curricular integration, training in digital literacy, and targeted professional development initiatives. Given that Nigerian pre-service mathematics teachers will be teaching this important subject in the future, this study investigated how pre-service teachers perceive the potential of educational robotics to improve mathematical problem-solving abilities in Nigerian mathematics classroom instruction.

Despite the importance of mathematics in the educational system, Nigerian pre-service mathematics teachers continue to face difficulties in both understanding and teaching mathematical problem-solving concepts. The traditional, teacher-centred pedagogical approach has been ineffective in developing the critical thinking and problem-solving skills required for success in mathematics. Pre-service teachers, who are expected to be role models for the students they teach, often lack the problem-solving skills necessary to convey mathematical concepts effectively. The quality of pre-service teachers' instruction is impacted since they frequently struggle with their own mathematical problem-solving skills, despite being expected to teach mathematics to future generations.

The limited use of innovative teaching tools, such as educational robotics, in Nigerian teacher training programs further compounds this problem. Although there is growing interest in educational robotics worldwide, its use in Nigeria remains relatively unexplored, especially in the context of teacher training. The application of educational robots in Nigerian teacher education programs remains little understood, despite evidence from other regions of the world demonstrating their potential to promote critical thinking, teamwork, and problem-solving abilities. Therefore, this study examined how pre-service instructors perceived the potential of educational robots to improve students' ability to solve mathematical problems in Nigerian mathematics classes.

3. Objective of the study

The primary objective of this study is to investigate pre-service mathematics teachers' perceptions of the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction. The specific objectives are to determine if these perceptions are:

- gender bias,
- age prejudice, and
- level partial.

Research question: What are the perceptions of the pre-service mathematics teachers on the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions?

The following null *hypotheses* were tested in the study:

H_{01}: There will be no significant gender variance in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.

H_{02}: There will be no significant age difference in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.

H_{03}: There will be no significant difference in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction, based on educational level.

4. Methodology

This study uses a quantitative survey design of the descriptive type. This research aims to provide a comprehensive and empirical understanding of pre-service mathematics teachers' perceptions of the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction, employing a descriptive survey approach.

4.1. Population and sample

The study population consisted of pre-service mathematics undergraduates in public universities in Ekiti State, Nigeria. To ensure coverage across these institutions and provide a diverse perspective on the subject matter across various demographics, a combination of non-probability sampling techniques, including stratified random, purposeful, convenience, and snowball sampling, was employed across all faculties of education in the sampled universities. We purposefully chose prominent public universities in Ekiti State, Nigeria. Using purposive, stratified, convenience, and snowball sampling techniques, the researchers could easily contact a larger number of participants and ensure they gave informed consent to participate in the study.

The study's sample consisted of Federal University Oye-Ekiti (FUOYE), Ekiti State University (EKSU), and Bamidele Olumilua University of Education, Science, and Technology (BOUESTI) in Ekiti State, Nigeria. We employed convenience and snowball sampling procedures to select students who were available, accessible, and willing to participate in the study. These original volunteers were used to identify additional students who were open to participating in the study. The study's goal and a voluntary participation option were obtained through various communication channels used by students to interact (e.g., WhatsApp and Telegram), allowing participants to decide whether to accept participation and proceed with the survey or not. A total of 242 pre-service mathematics teachers comprised the sample size, which was established using Krejcie and Morgan's [32] table for sample determination to ensure statistical power.

4.2. Data collection tool

The primary tool for gathering data was a structured questionnaire created by the researchers. Two sections made up the questionnaire, which included closed-ended items on a 4-point Likert scale that ranged from 'strongly disagree' to 'strongly agree'. Basic participant data, such as gender, age, and educational level, were recorded in the demographics section. While the section on perception contains 22 statements assessing pre-service mathematics teachers' perceptions of the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction, focusing on various facets of robotics in mathematics education (e.g., problem-solving enhancement, engagement, collaboration, STEM-readiness).

Experts in educational technology and psychometrics validated the questionnaire to ensure content validity and relevance. It was also pilot-tested within a similar cohort to ensure reliability, yielding an acceptable Cronbach's alpha reliability index of 0.89.

4.3. Data collection procedure

Data were gathered over six weeks (March-April 2025) following the acquisition of the required ethical approvals and permits from each university administrator. To simplify on-site completion and address any questions participants may have, trained research assistants distributed the questionnaire in person after lectures, allowing students 15–20 minutes to complete it. Throughout the procedure, strict adherence to confidentiality and anonymity norms was maintained.

4.4. Data analysis

Using IBM SPSS Statistics 25.0 software, descriptive statistics (such as simple frequency counts, mean, standard deviation, skewness, and kurtosis) were employed to address the research question, while inferential statistics (e.g., t-tests and ANOVA) were utilised to test the hypotheses at a 0.05 level of significance.

4.5. Ethical considerations

The investigation was conducted with scrupulous adherence to the principles of ethics. Ethical approval for this study was obtained from the offices of the faculty deans at the sampled universities by having them append their signatures to the appropriate section of the ethical approval form. The study adhered to ethical guidelines, including obtaining informed consent, maintaining confidentiality, and ensuring voluntary participation. Informed consent forms outlining the goals, methods, and voluntary nature of the study were used to secure the participants' assent. Participants were offered the freedom to leave at any time without facing any consequence, and the privacy and confidentiality of all data were ensured. The researchers contacted each participant and ensured that they supplied their informed consent to participate in the study.

5. Results

The respondents' demographic details are shown in table 1. With 117 males (48.3%) and 125 females (51.7%), the gender distribution is approximately equal, indicating a gender-balanced representation. According to the statistics, 10 (4.1%) students were below 16 years of age, 180 (74.4%) were within the tertiary institution age range of 16-19 years, 32 (13.2%) were 20-23 years of age, while 20 (8.3%) were above 23 years of age. The bulk of the participants were at the lower levels, specifically the 100 level (96, 39.7%) and the 200 level (80, 33.1%), while fewer participants were in the upper levels: the 300 level (29, 12.0%) and the 400 level (37, 15.3%). 82 (33.9%) of the respondents were from FUOYE, 121 (50.0%) were from EKSU, and 39 (16.1%) were from BOUESTI.

5.1. Answering the research question

What are the perceptions of the pre-service mathematics teachers on the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions?

Table 2 provides frequency distributions, means, standard deviations, skewness, and kurtosis for each of the 22 perception items. All items have mean scores above 3.15, indicating that a majority of participants agree or strongly agree with statements about the benefits of robotics in mathematics instruction.

Table 1
Statistical descriptions of participating students ($N = 242$).

Item	Response	Frequency	%
Students' gender	Male	117	48.3
	Female	125	51.7
	Total	242	100.0
Students' age range	Below 16 years	10	4.1
	16-19 years	180	74.4
	20-23 years	32	13.2
	Above 23 years	20	8.3
	Total	242	100.0
Students' level of education	100 level	96	39.7
	200 level	80	33.1
	300 level	29	12.0
	400 level	37	15.3
	Total	242	100.0
School	FUOYE	82	33.9
	EKSU	121	50.0
	BOUESTI	39	16.1
	Total	242	100.0

Table 2: Descriptive statistics of pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

Item	Response	Freq.	%	Mean	SD	Skewness	Kurtosis
Students' ability to solve mathematical problems can be greatly enhanced by educational robotics.	Strongly disagree	10	4.1	3.51	0.81	-1.65	1.95
	Disagree	19	7.9				
	Agree	51	21.1				
	Strongly agree	162	66.9				
	Total	242	100.0				
Learning becomes more dynamic and interesting when educational robots is used in mathematics classes.	Strongly disagree	5	2.1	3.43	0.70	-1.19	1.44
	Disagree	14	5.8				
	Agree	95	39.3				
	Strongly agree	128	52.9				
	Total	242	100.0				
Students' ability to visualize and solve challenging mathematics problems is improved by educational robotics technology.	Strongly disagree	10	4.1	3.38	0.75	-1.35	2.03
	Disagree	9	3.7				
	Agree	102	42.1				
	Strongly agree	121	50.0				
	Total	242	100.0				
Students are encouraged to develop the critical thinking abilities needed to solve mathematical problems using educational robotics.	Strongly disagree	9	3.7	3.26	0.71	-1.06	1.86
	Disagree	10	4.1				
	Agree	132	54.5				
	Strongly agree	91	37.6				

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Table 2 – continued from previous page

Item	Response	Freq.	%	Mean	SD	Skewness	Kurtosis
	Total	242	100.0				
Modernizing teaching methods in Nigerian mathematics classrooms requires the introduction of educational robotics.	Strongly disagree	9	3.7	3.38	0.71	-1.32	2.46
	Disagree	5	2.1				
	Agree	114	47.1				
	Strongly agree	114	47.1				
	Total	242	100.0				
Educational robotics enhances mathematical comprehension through experiential learning.	Strongly disagree	9	3.7	3.41	0.76	-1.37	1.70
	Disagree	14	5.8				
	Agree	87	36.0				
	Strongly agree	132	54.5				
	Total	242	100.0				
Students work together to solve problems when educational robotics is used in mathematics classes.	Strongly disagree	10	4.1	3.42	0.73	-1.48	2.61
	Disagree	5	2.1				
	Agree	101	41.7				
	Strongly agree	126	52.1				
	Total	242	100.0				
By using real-world examples, educational robotics can make abstract mathematical ideas easier to understand.	Strongly disagree	9	3.7	3.40	0.76	-1.32	1.63
	Disagree	14	5.8				
	Agree	91	37.6				
	Strongly agree	128	52.9				
	Total	242	100.0				
By incorporating educational robotics into mathematics, the gap between theoretical understanding and real-world implementation is lessened.	Strongly disagree	14	5.8	3.51	0.82	-1.82	2.71
	Disagree	9	3.7				
	Agree	59	24.4				
	Strongly agree	160	66.1				
	Total	242	100.0				
Educational robotics is a useful instrument for getting students ready for jobs in STEM fields.	Strongly disagree	14	5.8	3.47	0.80	-1.73	2.75
	Disagree	5	2.1				
	Agree	77	31.8				
	Strongly agree	146	60.3				
	Total	242	100.0				
The integration of robotics into mathematics instruction should be a priority in teacher training programs.	Strongly disagree	14	5.8	3.34	0.81	-1.37	1.75
	Disagree	9	3.7				
	Agree	99	40.9				
	Strongly agree	120	49.6				
	Total	242	100.0				
Students' participation in mathematical problem-solving exercises is enhanced by educational robotics.	Strongly disagree	14	5.8	3.20	0.79	-1.09	1.25
	Disagree	14	5.8				
	Agree	123	50.8				
	Strongly agree	91	37.6				
	Total	242	100.0				
The potential of educational robotics to improve mathematics instruction outweighs the cost of implementation.	Strongly disagree	14	5.8	3.34	0.81	-1.37	1.75
	Disagree	9	3.7				
	Agree	99	40.9				

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Table 2 – continued from previous page

Item	Response	Freq.	%	Mean	SD	Skewness	Kurtosis
	Strongly agree	120	49.6				
	Total	242	100.0				
Robotics fosters a growth mindset among students, which enhances their mathematical problem-solving abilities.	Strongly disagree	9	3.7	3.37	0.75	-1.26	1.62
	Disagree	13	5.4				
	Agree	99	40.9				
	Strongly agree	121	50.0				
	Total	242	100.0				
Students are more motivated to learn mathematics when educational robotics is incorporated into lessons.	Strongly disagree	10	4.1	3.23	0.78	-0.94	0.70
	Disagree	23	9.5				
	Agree	111	45.9				
	Strongly agree	98	40.5				
	Total	242	100.0				
Educational robotics promotes creativity in mathematical problem-solving.	Strongly disagree	9	3.7	3.46	0.75	-1.53	2.35
	Disagree	10	4.1				
	Agree	83	34.3				
	Strongly agree	140	57.9				
	Total	242	100.0				
Educational robotics can reduce students' fear of mathematics by making lessons more engaging.	Strongly disagree	13	5.4	3.44	0.80	-1.59	2.22
	Disagree	9	3.7				
	Agree	79	32.6				
	Strongly agree	141	58.3				
	Total	242	100.0				
Students may find abstract ideas more relatable when educational robotics is included in mathematics lessons.	Strongly disagree	18	7.4	3.34	0.87	-1.41	1.41
	Disagree	10	4.1				
	Agree	85	35.1				
	Strongly agree	129	53.3				
	Total	242	100.0				
Educational robotics-based teaching improves both the teacher's and students' technological skills in addition to mathematical problem-solving skills.	Strongly disagree	9	3.7	3.62	0.71	-2.20	4.90
	Disagree	5	2.1				
	Agree	55	22.7				
	Strongly agree	173	71.5				
	Total	242	100.0				
Integrating educational robotics can help pupils perform better academically in mathematics.	Strongly disagree	10	4.1	3.15	0.76	-0.84	0.77
	Disagree	24	9.9				
	Agree	127	52.5				
	Strongly agree	81	33.5				
	Total	242	100.0				
Pre-service teacher training on educational robotics is necessary for the effective integration of robotics into mathematics classrooms.	Strongly disagree	14	5.8	3.32	0.80	-1.32	1.70
	Disagree	9	3.7				
	Agree	105	43.4				
	Strongly agree	114	47.1				
	Total	242	100.0				

Continued on next page

Table 2 – continued from previous page

Item	Response	Freq.	%	Mean	SD	Skewness	Kurtosis
Introduction of educational robotics in mathematics classrooms will positively transform Nigerian education.	Strongly disagree	10	4.1	3.52	0.78	-1.75	2.52
	Disagree	14	5.8				
	Agree	57	23.6				
	Strongly agree	161	66.5				
	Total	242	100.0				

Item 19 recorded the highest mean (3.62) and 71.5% strongly agree, signifying a strong belief that robotics benefits not only learners but also instructors, thus aligning with calls for contemporary teacher training. Item 22 had a mean score of 3.52 with 66.5% strongly agreeing, reflecting optimism about the systemic transformation of robotic instruction. Items 1, 6, 7, 16, and 17 (relating to problem-solving, experiential learning, collaboration, creativity, and reduced mathematics anxiety) each have mean scores above 3.40 and negative skewness values (e.g., –1.65 for Item 1, –1.37 for Item 17) indicate responses are clustered at the agree/strongly agree end. Item 20 had the lowest mean score (3.15), although it was still above the neutral cutoff. This suggests some caution, while many believe robotics can improve learning outcomes, fewer are fully convinced about measurable academic performance gains. Item 13 on cost-benefit consideration has a mean score of 3.34, indicating that a majority believe the benefits justify the expenditure, which is critical in low-resource contexts. Negative skewness values reveal clustering toward strongly agree, while positive kurtosis suggests a leptokurtic distribution, indicating consensus among participants regarding the technological potential of robotics for skill-building. These descriptive statistics indicate that pre-service mathematics teachers generally view educational robotics as a valuable tool for enhancing mathematical problem-solving, fostering engagement, and bridging the gap between theory and practice.

5.2. Testing the hypotheses

H_{01}: *There will be no significant gender variance in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.*

An independent-samples t-test, as shown in table 3, was used to compare overall perception scores between male and female participants. Male ($M = 74.64$, $SD = 3.70$) and female ($M = 74.38$, $SD = 2.70$) with mean difference of 0.26. Although the mean difference is small, Levene's test is statistically significant ($p = 0.004$), indicating unequal variances; the t-test for unequal variances yields $p < 0.05$. Hence, there is a statistically significant difference in perceptions by gender.

Table 3

T-test analysis of gender variance in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

	N	*M*	*SD*	*SEM*	*MD*	SE_{Diff}	*df*	*t*	*p*	*F*	Remark
Male	117	74.64	3.70	.34216	.26503	.41436	240	.640	.004	8.475	Significant
Female	125	74.38	2.70	.24114	.26503	.41860	211.126	.633	.004	8.475	Significant

H_{02}: *There will be no significant age difference in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.*

Table 4 assessed the mean values and F-statistics of pre-service mathematics teachers' perception across four age groups with $F(3, 238) = 6.503$ and $p = 0.000$. The robust tests (table 5), shows

Welch's $F(3, 31.446) = 9.261$ with $p = 0.000$, and Brown-Forsythe's $F(3, 42.235) = 8.035$ with $p = 0.000$. Scheffe's post hoc tests in table 6 shows that the mean difference (-3.783) between, below 16 years and 16-19 years is statistically significant ($p = 0.003$), and the mean difference (-3.969) between, below 16 years and 20-23 years is statistically significant ($p = 0.007$). Other pairwise differences are not statistically significant at $\alpha = 0.05$.

Table 4
ANOVA of age difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

	N	*M*	*SD*	*SE*	**Between-component variance**
Below 16 years	10	71.0000	3.16228	1.00000	
16-19 years	180	74.7833	3.21358	.23953	
20-23 years	32	74.9688	3.19762	.56527	1.57060
Above 23 years	20	73.0000	1.62221	.36274	
Total	242	74.5041	3.21724	.20681	
	SS	***df***	***MS***	***F***	***p***
Between groups	188.977	3	62.992		
Within groups	2305.519	238	9.687	6.503	.000
Total	2494.496	241			

Table 5
Robust tests of equality of means of age difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

	Statistic	***df*1**	***df*2**	***p***
Welch	9.261	3	31.446	.000
Brown-Forsythe	8.035	3	42.235	.000

Table 6
Scheffe post hoc tests of age difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions

(I) Students' age range	**(J) Students' age range**	***MD* (I-J)**	***SE***	***p***
Below 16 years	16-19 years	-3.78333*	1.01120	.003*
Below 16 years	20-23 years	-3.96875*	1.12758	.007*
Below 16 years	Above 23 years	-2.00000	1.20543	.433
16-19 years	Below 16 years	3.78333*	1.01120	.003*
16-19 years	20-23 years	-.18542	.59711	.992
16-19 years	Above 23 years	1.78333	.73360	.119
20-23 years	Below 16 years	3.96875*	1.12758	.007*
20-23 years	16-19 years	.18542	.59711	.992
20-23 years	Above 23 years	1.96875	.88717	.180
Above 23 years	Below 16 years	2.00000	1.20543	.433
Above 23 years	16-19 years	-1.78333	.73360	.119
Above 23 years	20-23 years	-1.96875	.88717	.180

*Significant at 0.05 level

These results show that under-16 pre-service mathematics teachers scored significantly lower than both the 16-19-year-old and the 20-23-year-old groups. The largest perception scores are found in the

20–23 year-old cohort. The above 23-year group is intermediate and not significantly different from other groups aside from the extremes. These findings suggest that age has a significant impact on the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction. This finding may reflect limited exposure to robotics or fewer cognitive/experiential resources to appreciate its value.

H_{03}: *There will be no significant difference in the perceptions of pre-service mathematics teachers regarding the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction, based on educational level.*

Table 7 examined the mean values and F-statistics of pre-service mathematics teachers' perception across four academic levels, with $F(3, 238) = 5.239$ and $p = 0.002$. The robust tests (table 8), shows Welch's $F(3, 107.693) = 12.805$ with $p = 0.000$, and Brown-Forsythe's $F(3, 188.328) = 6.567$ with $p = 0.000$. Scheffe post hoc tests in table 9 shows that the mean difference (1.922) between, 100 and 300 levels is statistically significant ($p = 0.041$), and the mean difference (2.385) between, 200 and 300 levels is statistically significant ($p = 0.007$). Other pairwise differences are not statistically significant at $\alpha = 0.05$.

Table 7

ANOVA of age difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions, based on educational level.

	N	*M*	*SD*	*SE*	**Between-component variance**
100 Level	96	74.7500	3.29912	.33672	.74280
200 Level	80	75.2125	3.44466	.38512	.74280
300 Level	29	72.8276	1.25553	.23315	.74280
400 Level	37	73.6486	3.00200	.49353	.74280
Total	242	74.5041	3.21724	.20681	.74280
	SS	***df***	***MS***	***F***	***p***
Between Groups	154.538	3	51.513	5.239	.002
Within Groups	2339.958	238	9.832		.002
Total	2494.496	241			.002

Table 8

Robust tests of equality of means of level difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

	Statistic[a]	***df*1**	***df*2**	***p***
Welch	12.805	3	107.693	.000
Brown-Forsythe	6.567	3	188.328	.000

[a]. Asymptotically F distributed.

These results indicate that 300-level pre-service mathematics teachers have a significantly lower perception compared to both 100- and 200-level students. 400-level pre-service mathematics teachers do not significantly differ from any other group at the 0.05 level, though they are numerically closer to the 300-level group. These findings suggest that the academic level significantly influences pre-service mathematics teachers' perceptions of the potential of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instruction.

Table 9
Scheffe post hoc tests of level difference in pre-service mathematics teachers' perceptions of the potentials of educational robotics to enhance mathematical problem-solving skills in Nigerian mathematics classroom instructions.

(I) Students' level of education	(J) Students' level of education	*MD* (I-J)	*SE*	*p*
100 level	200 level	-.46250	.47467	.813
100 level	300 level	1.92241*	.66441	.041*
100 level	400 level	1.10135	.60674	.351
200 level	100 level	.46250	.47467	.813
200 level	300 level	2.38491*	.67965	.007*
200 level	400 level	1.56385	.62339	.101
300 level	100 level	-1.92241*	.66441	.041*
300 level	200 level	-2.38491*	.67965	.007*
300 level	400 level	-.82106	.77766	.774
400 level	100 level	-1.10135	.60674	.351
400 level	200 level	-1.56385	.62339	.101
400 level	300 level	.82106	.77766	.774

*Significant at 0.05 level

6. Discussion

The findings demonstrate a largely positive alignment among Nigerian pre-service mathematics teachers regarding the adoption of educational robotics to enhance problem-solving and other instructional outcomes. This aligns with global research emphasising the importance of robotics in enhancing experiential learning, critical thinking, and STEM preparedness [15, 36].

The results disclose a broad consensus that educational robotics enhances conceptual understanding, makes lessons more engaging and dynamic, fosters critical thinking and creativity, bridges theory and real-world application, prepares students for STEM careers, and reduces mathematics anxiety, a known barrier to student achievement. The findings corresponded with the study by Afari and Khine [2], which found that integrating technology (especially robotics) into education can enhance learning and support mathematical problem-solving skills.

Pre-service mathematics teachers recognise robotics as a multifaceted tool that can simultaneously address cognitive (problem-solving, conceptual understanding), affective (motivation, reduced anxiety), and psychomotor (collaboration) domains. This suggests a readiness to adopt inquiry-based, student-centred pedagogies if provided with the necessary tools and training. These findings are consistent with those of Hoyo et al. [28], who found that robotics fosters computational thinking, critical reasoning, and creativity, all of which are critical for effective problem-solving, and Gratani and Giannandrea [24] and Lee, Yunus and Lee [35], who demonstrated that incorporating programmable robots into the curriculum exposes students to hands-on activities that promote exploration, collaboration, and real-world application of mathematical concepts. According to Mangina et al. [36], robotics enables students to interact with abstract ideas in a concrete, engaging manner, leading to a deeper comprehension.

The use of robotics programs in schools will improve problem-solving skills by encouraging students to engage in hands-on tasks that require mathematical reasoning [2, 15], as robotics has long been regarded as an effective tool for promoting problem-solving skills, particularly in STEM fields [22, 23, 47].

Although males and females manifest only a minor mean difference, the statistical test indicates significance, suggesting nuanced gendered attitudes. This is an indication that female students might internalise societal stereotypes about technology being 'male-dominated', influencing self-efficacy regarding robotics. Males may have had more exposure to electronics, coding clubs, or robotics competitions, which could have shaped their perceptions. This finding aligns with those of Aristovnik et al. [8], Adams et al. [1], and Zhang, Chen and Wang [56], which found that male students were more eager than female students to adopt and use electronic or technological systems for learning. However, the finding is at variance with those of Almasi et al. [6], who found no gender differences in the use of electronic or technological systems; and Eshun Yawson and Amofa Yamoah [19], who did not discover any gender disparities in the use of technology or electronic systems for educational purposes.

Moreover, the findings reveal that pre-service mathematics teachers below 16 years likely have had minimal prior contact with robotics, compared to their slightly older peers who may have encountered robotics clubs or introductory coding courses in 100- or 200-level courses. Older pre-service mathematics teachers display a high level of appreciation for robotic instruction, possibly because students in this age bracket have had at least one foundational technology module, affording them a 'sweet spot' of novelty and capability to understand robotics' instructional affordances. This suggests that problem-solving and metacognitive skills, which are necessary for appreciating robotics-based abstraction, may develop more fully in late adolescence. These findings corroborate those of Almasi et al. [6], which discovered significant differences in the year of study in terms of employing electronic or technological systems for learning purposes. Their study also noted notable differences in how first-, second-, and third-year students use technical or electronic systems for learning.

Besides, the third-year students show significantly lower perceptions of the potentials of educational robotics to enhance problem-solving and other instructional outcomes, probable reasons might be that, third-year mathematics curricula often intensify theory (e.g., advanced calculus, geometry) with limited technology integration, causing students to revert to traditional problem-solving mindsets, by 300 level, some pre-service teachers may experience burnout or 'tech fatigue' if robotics has not been integrated in prior years, diminishing enthusiasm. Additionally, preparation for professional examinations or final-year projects takes precedence over elective robotics activities.

This finding aligns with the results of the study by Almasi et al. [6], which revealed significant variations in the use of electronic or technological systems for learning throughout the study year. Their study uncovered notable differences in how first-, second-, and third-year students use technical or electronic systems for learning. In particular, they found that third-year students used technology and electronic devices for learning more frequently than first- and second-year students. The findings also corroborated the proclamation of Ngoasong [40] who asserted that, it was difficult for students who had little to no prior experience using ICT or technological systems for learning to adjust to learning at first, in agreement with the assertion of Adams et al. [1], who stated that compared to undergraduate students, postgraduate students are more driven and utilise electronic or technology systems for learning. This finding is also consistent with the results of Johannsen et al. [30], who found that the earlier students begin using technical or electronic systems for educational purposes, the better their learning outcomes. The observed differences in perceptions can be attributed to Nigerian students' low exposure to educational robotic tools, as they mainly experienced them at the workplace level, if at all.

7. Conclusion

Recent advances in educational technology have underscored the potential of educational robotics to transform traditional mathematics instruction, since robotics naturally fits with constructivist pedagogies, which emphasise active inquiry as the foundation for learning. Deeper learning happens when students actively engage with materials rather than passively listening to lectures. The idea that robotics can alleviate anxiety is especially noteworthy, as mathematical anxiety can impair performance. Students' abstract apprehension is lessened when they witness a robot executing their algorithms, giving them confidence that mathematics is applicable in everyday situations. This underscores a consensus among pre-service teachers that robotics should not be an afterthought but a core component of pedagogical preparation. This calls for public-private partnerships, government grants, or international grants (e.g., from UNESCO or the World Bank) to subsidise robotics integration. It also underscores the necessity for low-cost, context-appropriate robotics kits (such as those built for low-resource situations) that prioritise price without losing functionality.

Based on the findings of this study, the following recommendations are proposed for teacher-education programs, educational policymakers, and funding agencies:

- Educational policymakers should integrate robotics instruction into the curriculum early and systematically.
- Educational policymakers should design gender-inclusive robotics experiences by establishing women-in-STEM robotics clubs or mentorship programs (e.g., featuring female robot engineers, showcasing applications beyond stereotypically technical domains).
- University management should conduct faculty workshops and certifications on robotics pedagogy, ensuring that lecturer expertise grows in tandem with student readiness.
- University management should encourage collaboration between education departments and engineering/computer science departments to co-teach interdisciplinary robotics courses.
- National Universities Commission and Teachers Registration Council of Nigeria should include robotics integration as a criterion for accrediting teacher-education programs.
- The National Universities Commission and the Teachers Registration Council of Nigeria should require pre-service teachers to design and implement at least one robotics-infused mathematics lesson during their final teaching internship, thereby strengthening their real-world application skills.

While this study provides a robust baseline of pre-service mathematics teachers' perceptions, additional research is needed to deepen and broaden understanding by:

1. Conducting focus group discussions and semi-structured interviews to explore the 'why' behind positive or negative perceptions, uncovering lived experiences, frustrations, and aspirations not captured by Likert-scale items.
2. Designing quasi-experimental, longitudinal follow-ups, and mixed-methods triangulation research to compare mathematics achievement, engagement, and teaching efficacy across groups.
3. Replicate the study in another geographical area/region.

Data availability statement

The datasets generated and/or analysed during the current study are not publicly available because the study prioritised participant privacy, collecting data under strict confidentiality agreements to protect their personal and sensitive information. Publicly sharing the dataset might risk exposing identifiable details, even after anonymisation, due to advancements in data re-identification techniques. Providing data upon reasonable request from the corresponding author ensures compliance with ethical standards while allowing controlled access under safeguards that respect participant rights. Therefore, the datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors declare that they have no competing interests.

Funding

The authors declare that the study was self-funded.

Author contributions

With their distinct areas of expertise, each author made significant contributions to the manuscript's development, ensuring the study's success. The group produced a strong, creative, and influential research output as a result of their cooperative synergy.

Acknowledgments

We sincerely acknowledge the students who took part in this study. The success of this study was greatly aided by their priceless contributions, which included their readiness to offer their opinions, experiences, and expertise on robotics-enhanced problem-solving instruction. Despite their hectic schedules, we sincerely appreciate the time and effort they invested in filling out the surveys. Their observations have provided a solid foundation for understanding robotics-enhanced problem-solving instruction.

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