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Impact of Robotics Workshops on Secondary School Students' Interest in Science and Technology Fields

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Abstract

The goals of Malaysia for digitization and technical growth are seriously challenged by the country's secondary school students' dwindling interest in science and technology sectors. Motivated by this concerning trend, this study seeks to evaluate how a targeted robotics workshop can enhance students' interest and confidence in science and technology fields, contributing to the country's long-term educational and economic goals. A one-day robotic workshop involving 60 secondary school students was conducted, with pre- and post-program surveys assessing participants' knowledge, interest, and confidence levels in science and technology. A gender-specific analysis highlights a narrowing gap between male and female participants in interest levels post-program, emphasizing the need for targeted interventions to enhance female participation in science and technology activities. The study's contribution lies in demonstrating significant improvements in knowledge, interest, and confidence levels among participants, underscoring the potential of robotics education to foster enthusiasm and competence in STEM fields. These findings provide valuable insights for educators and policymakers on preparing future generations for the demands of the digital era through effective educational interventions.

Keywords: Robotics education, STEM, 21st-Century Skills, Secondary School Engagement

Introduction

The advent of digital technology and robots has become a game-changer in contemporary education, completely transforming conventional teaching approaches and significantly improving learning results in various fields. The incorporation of digital technology and robotics into educational environments during a time marked by swift technical progress and digitalization shows great potential for nurturing creativity, critical thinking, and problem-solving abilities in students (Acker et al., 2023; Connolly et al., 2022). This shift in education

paradigm signifies an increasing acknowledgment of the significance of providing students with the required skills to succeed in the digital era and actively engage in the global economy. Over the past few years, schools around the world have progressively adopted robotics instruction to improve student involvement, encourage interdisciplinary learning, and equip students for success in the digital job market. Robotics programs have become essential parts of educational curricula, from elementary schools to colleges (Eguchi, 2017; Kálózi-Szabó et al., 2022). They provide students with chances to delve into many subjects like engineering, computer science, and artificial intelligence. Schools enhance students' technical competency, problem-solving abilities, and creativity by offering practical opportunities to work with robotics gear and software. This also helps students gain a greater understanding of how digital technology can be used to tackle real-world problems.

Implementing robotics education in schools is a strategic investment in the future workforce. It equips students with the skills and competences needed to succeed in a complex and interconnected environment (Nugent et al., 2013). Through the utilization of digital technology and robotics, educators have the ability to motivate and encourage a fresh cohort of individuals who possess the skills and mindset necessary to create new ideas, solve complex problems, and effect positive change. This, in turn, will propel advancements and originality in the fields of education, industry, and society as a whole. With the ongoing adaptation and evolution of schools in response to technological breakthroughs, robotics education is positioned to have a significant impact on moulding the future of learning and equipping students for success in the digital era.

Problem Statement

However, the declining interest among Malaysian secondary school students in pursuing further education, particularly in the fields of science and technology, poses a significant challenge to the nation's aspirations for digitalization and technological advancement (Idris et al., 2023; Idris & Bacotang, 2023). With only 19% of students opting for science and technology streams at the Form 4 level in 2020, and a further decrease to 15.2% in 2023, there is a clear discrepancy between educational aspirations and societal trends. This trend is the lowest in history and far behind the 60 per cent policy set in 1967, as stated by the President of the National Council of Professors (MPN), Prof Emeritus Datuk Dr Raduan Che Rose (Halid, 2024). This downward trend not only undermines Malaysia's ambitions to emerge as a leader in the global digital and technological landscape but also hinders the development of a skilled workforce equipped to meet the demands of the digital economy. Consequently, addressing the underlying factors contributing to the lack of interest in science and technology education among Malaysian students is imperative to ensure the nation's future competitiveness and sustainability in the digital era.

Literature Review

The integration of robotics education into school curricula has garnered significant attention in recent years, with a focus on enhancing students' attitudes towards STEM fields, particularly among secondary and primary school students. This literature review synthesizes findings from several studies conducted in diverse educational contexts, shedding light on the nuanced relationship between students' attitudes towards robotics and STEM, gender differences, teaching practices, and the effectiveness of educational robotics in fostering critical skills. Kucuk and Sisman, based in Turkey, examined Turkish secondary school students'

attitudes towards robotics and STEM, revealing positive overall attitudes but notable gender differences in robotics interest and confidence (Kucuk & Sisman, 2018). While male students exhibited higher desire and confidence in learning robotics, no gender disparity was observed in STEM attitudes. This underscores the importance of addressing gender-specific factors in promoting robotics education.

Çalişkan investigates the impact of robotics programming training on secondary school students' problem-solving skills (Çalişkan, 2020). Conducted as a pretest-posttest quasi-experimental study without a control group, the research involved 30 6th-grade students from three secondary schools in Turkey. Utilizing the VEX IQ Robot Kit over a 9-week period, the study employed problem-solving inventory and a perception scale of problem-solving skills as pre- and post-tests. Results revealed a significant improvement in students' problem-solving skills after the robotics programming intervention, supported by descriptive statistics and Wilcoxon signed-rank tests. The study underscores the effectiveness of robotics programming in enhancing problem-solving abilities among students. These findings resonate with prior research, suggesting that educational robots, including various kits like Arduino, mBot, and Lego Mindstorms EV3, foster problem-solving skills and contribute to a positive learning environment (Alimisis, 2013; Bers et al., 2014; Qu & Fok, 2022).

In a Malaysian context, Muhamad Yusof et al. delved into teachers' practices in teaching robotics programming in primary schools, highlighting the challenges faced, including language barriers and limited access to resources (Yusof et al., 2021). Despite these hurdles, educators demonstrated a commitment to integrating robotics into the curriculum, emphasizing the need for collaborative efforts among stakeholders to enhance the effectiveness of robotics education. Jawawi et al., also based in Malaysia, explored the integration of Computational Thinking concepts into secondary education through Educational Robotics workshops, demonstrating a significant improvement in students' problem-solving skills post-workshop (Jawawi et al., 2018). This underscores the potential of educational robotics in nurturing critical thinking and problem-solving abilities among students, aligning with the demands of the 21st-century workforce.

Furthermore, Fakaruddin et al., conducted their study in Malaysia, investigated creative thinking patterns in primary school students engaged in hands-on science activities involving robotics (Fakaruddin et al., 2024). Their findings revealed two key processes: idea stimulation and generation, emphasizing the role of robotics in stimulating students' creativity and imagination. Lee et al. evaluated the effectiveness of using low-cost Arduino-based robots to increase students' interest in programming and robotics, focusing on two secondary schools in Sarawak, Malaysia (Lee et al., 2020). Their study demonstrated a significant increase in STEM interest among participants, highlighting the potential of robotics education in engaging students and promoting STEM-related learning. Lastly, Zainal et al. explored primary and secondary school students' perspectives on a Kolb-based STEM module and robotic prototype, conducting their research in Malaysia (Zainal et al., 2018). Their study revealed positive responses and increased engagement in STEM subjects, underscoring the value of experiential learning approaches in fostering students' interest and competence in STEM fields.

The Research Goal

The objective of this study is to assess the effectiveness of a robotic workshop program in increasing students' interest and confidence in science and technology fields. Specifically, the study aims to evaluate the impact of the workshop on students' knowledge about robotics and technology, their level of interest in science, technology, and robotics fields, and their confidence in using Arduino technology for future projects.

To achieve this objective, the following hypotheses are proposed: (1) Participation in the robotic workshop program will lead to a significant improvement in students' knowledge about robotics and technology. (2) Engagement in the robotic workshop program will result in a significant increase in students' level of interest in science, technology, and robotics fields. (3) Students' confidence in using Arduino technology for future projects will significantly increase after participating in the robotic workshop program. Through the analysis of pre- and post-program survey responses, these hypotheses will be tested to determine the efficacy of the robotic workshop program in promoting interest and confidence in science and technology among students.

Research Methodology

A. Participants

The study involved a total of 60 secondary school students, with 30 participants from each school, enrolled in Sekolah Menengah Kebangsaan Pasir Gudang 2 and Sekolah Menengah Kebangsaan Puteri Wangsa, both situated in Johor, Malaysia. The participants were selected from students in Form 1 to Form 3, aged between 13 and 15 years old, representing a critical stage before they make decisions about their academic paths in Form 4. The distribution of participants across school levels and ages shown in Table 1:

Table 1
Student Demographics

Category	Number of Students	Percentage (%)
Form & Age		
Form 1 (13 years old)	13	21.7
Form 2 (14 years old)	12	20.0
Form 3 (15 years old)	35	58.3
Gender		
Male	36	60
Female	24	40

Table 2
Income Level Distribution

Income Level	Number of Students	Percentage (%)
Top 20% (T20)	7	11.7
Middle 40% (M40)	29	48.3
Bottom 40% (B40)	24	40

Furthermore, the gender distribution showed that 36 participants were male and 24 were female. The socioeconomic status of the participants' parents was assessed based on income levels and categorized into Top 20% (T20), Middle 40% (M40), and Bottom 40% (B40) as shown in Table 2. To ensure equitable access to the program, schools were asked to prioritize students from the B40 and M40 income groups. This decision was based on the recognition that robotics equipment can be expensive, and students from lower-income households might have limited opportunities to engage in practical learning experiences with such technology.

B. Case Study Procedures

Our research methodology involves a case study of a one-day robotic workshop aimed at teaching students how to develop a remotely controlled robot using an Android phone. Before the workshop begins, participants are required to complete a Google Form with their details and responses to a preliminary research survey. The workshop starts with a 3-hour session introducing digital and robotic technology, followed by a detailed exploration of the hardware components and Arduino software, as depicted in Figure 1. With 30 students per school, participants are divided into 15 groups of 2 students each and are assigned a facilitator from UiTM, which may be either lecturers or students, as shown in Figure 2.

Figure 1. Introduction session of robotic technology.

Figure 2. The coaching in small group.

This small group format aims to optimize learning experiences, encourage active engagement, and facilitate effective interaction between facilitators and students throughout the workshop. Following this, hands-on activities are conducted to build the robot, providing participants with practical experience in assembly and programming. Additionally, a competition is held at the end of the program to enhance excitement and motivation, injecting an element of fun and stimulating participants' enthusiasm while fostering skill development and teamwork. Upon completion of the session, a post-survey is administered to gather feedback on the workshop's effectiveness and participants' learning outcomes.

C. Data Collection

The methodology for data collection in this study is focused on a quantitative approach to provide a comprehensive understanding of the impact of the robotic workshop on participants' knowledge, interest, and confidence levels in robotics, technology, and STEM fields. Quantitative data collection begins with a pre-workshop survey administered to participants before the commencement of the workshop. This survey consists of structured questionnaires designed to gather quantitative data on participants' baseline knowledge, interest, and confidence levels. Closed-ended questions with Likert-scale responses are utilized to assess participants' familiarity with robotics concepts, their attitudes towards technology, and their intentions to pursue STEM-related studies in the future.

Following the workshop, participants are administered a post-workshop survey that mirrors the structure of the pre-workshop survey. This survey allows for the collection of quantitative data on changes in participants' knowledge, interest, and confidence levels after completing the workshop. Similar Likert-scale questions are included to enable direct comparison of responses before and after the workshop, facilitating the measurement of any shifts in participants' attitudes and aptitude towards robotics and technology. The collected responses are analyzed using Microsoft Excel spreadsheet software, allowing for systematic data management, visualization, and statistical analysis to derive meaningful insights from the survey results.

Results and Discussion

The findings from figure 3 demonstrates a notable enhancement in participants' understanding of science, technology, and robotics after completing the workshop program. Before the workshop, most participants claimed to have either low (2) or medium (3) levels of knowledge, while only a small number indicated good (4) or outstanding (5) levels of understanding. More precisely, out of the total participants, 7 individuals (11.7%) assessed their knowledge as extremely limited (1), 15 individuals (25%) as limited (2), 24 individuals (40%) as moderate (3), 13 individuals (21.7%) as proficient (4), and 1 individual (1.7%) as outstanding (5).

After implementing the program, a significant improvement in knowledge levels is noticed, as most participants report better results. Significantly, no participants rated their knowledge as very low or low after the workshop. Conversely, most participants assessed their expertise as either moderate, proficient, or exceptional. None of the participants rated their knowledge as very low or low. Only 6 participants (10%) rated their knowledge as medium. Interestingly, a significant increase was observed in participants rating their knowledge as good and excellent, with 31 participants (51.7%) and 23 participants (38.3%) respectively.

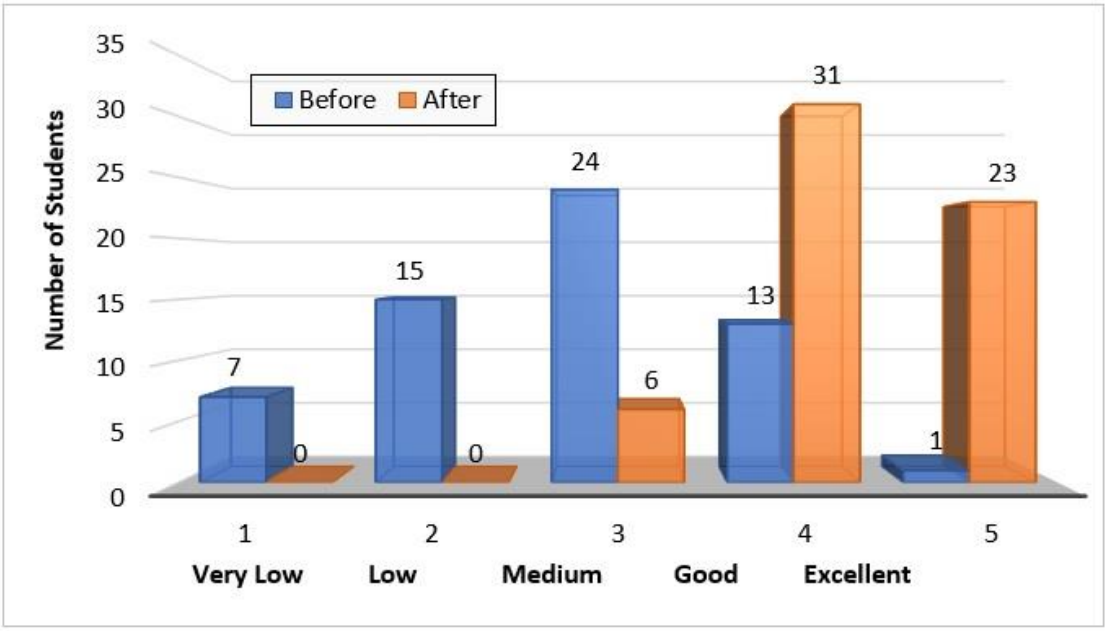

Figure 3. Data before and after program for the level of knowledge about science, technology, and robotics

The significant enhancement in participants' knowledge levels after the program can be attributed to the carefully designed curriculum and intensive experiential learning opportunities offered throughout the workshop. Through the utilization of diverse activities such as hands-on demonstrations and interactive workshops, participants were able to thoroughly explore themes related to science, technology, and robotics. The hands-on approach of the course fostered a deeper comprehension of intricate subjects, allowing participants to comprehend theoretical concepts and implement them in real-world scenarios. Furthermore, the individualized instruction and assistance provided by facilitators, who were highly knowledgeable in the subject, played a crucial role in strengthening participants' comprehension and resolving any misunderstandings or deficiencies in

knowledge. The facilitators' capacity to modify instructional approaches to accommodate various learning styles significantly improved the efficacy of the learning process, guaranteeing that participants acquired a thorough comprehension of the subject matter.
Consistent with the findings of question 1, the results demonstrate a significant rise in participants' interest in the fields of science, technology, and robotics after completing the program, as depicted in figure 4. Before the program, participants expressed different levels of interest, with most falling within the moderate to good range. More precisely, one person, accounting for 1.7% of the total, assessed their interest as very low. Six participants, representing 10% of the total, rated their interest as low. Eighteen participants, making up 30% of the total, rated their interest as medium. Twenty-three participants, accounting for 38.3% of the total, rated their interest as good. Lastly, twelve participants, representing 20% of the total, rated their interest as exceptional.

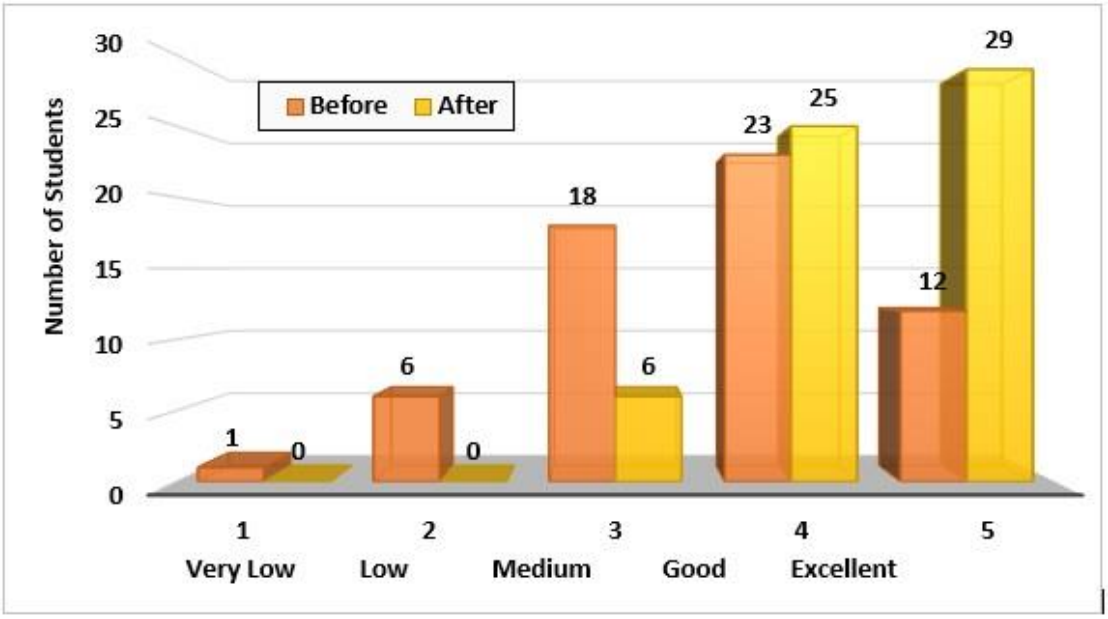

Figure 4. Data before and after program for the level of interest in the fields of science, technology, and robotics.

Following the session, a notable change in interest levels is seen, with the majority of participants indicating increased ratings. No participants rated their interest as very low or low following the program. Conversely, most participants indicated that their level of interest fell within the categories of medium, good, or exceptional. None of the participants rated their interest as very low or low. Only 6 participants (10%) rated their interest as medium. Moreover, a significant increase was observed in participants rating their interest as good and excellent, with 25 participants (41.7%) and 27 participants (45%) respectively.

The session not only enhanced participants' understanding, but also greatly heightened their enthusiasm in the subjects of science, technology, and robotics. The workshop activities, which were dynamic and engaging, and included a competitive element, ignited the participants' curiosity and excitement for the subject matter. The use of interactive learning activities and real-life examples successfully engaged participants and stimulated their curiosity and enthusiasm. The workshop fostered a collaborative and supportive atmosphere that boosted participants' involvement, motivating them to actively engage in conversations, exchange ideas, and work together on projects. Additionally, the workshop successfully to

made everyone feel like they belonged and were friends, which made them more interested in the topic and excited to keep learning about science, technology, and robotics.

The outcomes depicted in Figure 5 demonstrates a noteworthy enhancement in participants' bravery and confident in utilizing Arduino technology for forthcoming tasks subsequent to the program's conclusion. Before the training, participants indicated different degrees of courage and self-assurance, with most falling within the moderate to high range. More precisely, 7 participants, accounting for 11.7% of the total, reported their level of bravery and confidence as very low. Similarly, 15 participants, representing 25% of the total, rated their level as low. Additionally, 18 participants, comprising 30% of the total, considered their level as medium. Moreover, 14 participants, making up 23.3% of the total, described their level as good. Lastly, 6 participants, constituting 10% of the total, assessed their level as excellent.

Following the session, a significant increase in levels of courage and self-assurance is seen, with the majority of participants reporting elevated scores. No participants rated their degree of bravery and confidence as extremely low or low following the program. Conversely, most individuals assessed their level of bravery and confidence as either moderate, high, or outstanding. None of the participants rated their level of bravery and confidence as very low or low. Only 10 participants (16.7%) rated their level as medium. However, a significant increase was observed in participants rating their level as good and excellent, with 19 participants (31.7%) and 29 participants (48.3%) respectively.

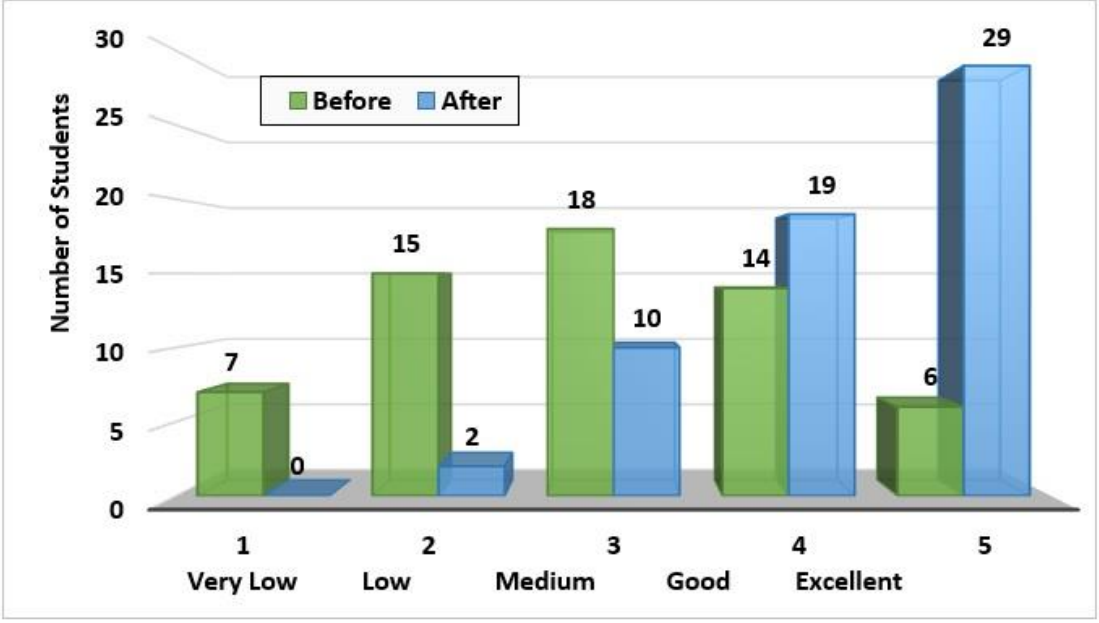

Figure 5. Data before and after program for the level of bravery and confident in utilizing Arduino technology project.

Furthermore, the notable enhancement in participants' courage and self-assurance in utilizing Arduino technology can be ascribed to the engaging and practical learning encounters offered throughout the course. Participants acquired practical skills and confidence in leveraging Arduino technology for future projects through supervised experimentation and project-based activities. By working together with peers and receiving advice from experienced facilitators, participants were able to overcome any early hesitations or worries and

confidently embrace Arduino technology. The workshop's nurturing atmosphere facilitated participants in taking risks, delving into novel concepts, and pushing the limits of their knowledge and abilities. Consequently, the participants left the session with increased self-assurance and a fresh feeling of empowerment, prepared to confront upcoming obstacles and pursue their technology-related projects with excitement and commitment.

The analysis of the data presented in Tables 2 provides insights into the impact of a robotics education program on participants' interest in STEM, categorized by gender.

Table 3

Comparison of Interest Levels in Science, Technology, and Robotics Before and After Program by Gender

Gender	Male		Female	
Level	**Before**	**After**	**Before**	**After**
1	0.0	0.0	1.0	0.0
2	3.0	0.0	3.0	0.0
3	12.0	4.0	6.0	2.0
4	14.0	13.0	9.0	12.0
5	7.0	19.0	5.0	10.0
Mean	**7.2**	**7.2**	**4.8**	**4.8**
Variance	**34.7**	**71.7**	**9.2**	**33.2**
Standard Deviation	**5.9**	**8.5**	**3.0**	**5.8**

Table 3 provides a gender-specific comparison of interest levels in science, technology, and robotics before and after the program. Analyzing the data provides important information about how well the program succeeds in sparking students' interest in these subjects and reveals any differences between male and female participants. The program had a positive impact on interest levels in science, technology, and robotics for both male and female participants. Male students began with a slightly higher mean interest level of 7.2 compared to females, whose mean interest level was 4.8 before the program. After the program, both genders exhibited improvements in their interest levels, with mean scores remaining consistent at 7.2 for males and 4.8 for females. However, it's noteworthy that the variance and standard deviation were higher for females both before and after the program, indicating a wider range of interest levels among female participants compared to males. While males generally started with higher baseline levels, both genders demonstrated comparable improvements after program participation. However, it's essential to address the wider spread of knowledge, interest, and confidence levels among female participants, possibly through targeted interventions aimed at enhancing participation and engagement in STEM-related activities.

Conclusion

The journey through the realm of robotics education unveils a landscape rich with promise and potential. Our study, alongside existing research, demonstrates the profound impact of robotics programs in fostering students' knowledge, interest, and confidence in science and technology domains. From the humble beginnings of introductory workshops to the intricate challenges of advanced robotics projects, students are empowered to engage with cutting-edge technology and develop essential skills for the 21st century. One of the key takeaways

from our investigation is the significance of tailored interventions to address gender disparities in STEM engagement. By implementing targeted strategies to enhance female participation in robotics education, we can create more inclusive learning environments and ensure that all students have equal opportunities to explore and excel in science and technology fields.

The study on robotics education offers valuable insights, but further research is needed to understand gender participation, long-term impact on students' academic and career paths, and innovative curriculum design. Researchers should explore instructional strategies like project-based learning and virtual simulations, and stay updated with emerging trends in robotics and related fields. Interdisciplinary intersections like artificial intelligence, healthcare, and sustainability can provide new insights and open new frontiers for robotics education.

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