The Impact of STEM activities on Students' Knowledge and Project Development Skills

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ABSTRACT

Science, Technology, Engineering, and Mathematics (STEM) education is increasingly recognized as vital in today's rapidly evolving exploration among students in driving innovation and problem-solving across various fields. As interest in STEM grows, students are being engaged with numerous hands-on STEM activities to foster learning experiences, boosting knowledge and skill, cultivating critical thinking and creativity, and collaboration while enhancing their understanding and adaptability of STEM concepts. Hence, this study was conducted to identify the impact of STEM activities on students' knowledge and project development skills. The study was carried out using the STEM Mentoring Program with five phases which involved 48 lower secondary school students from Dengkil district in Selangor aged between 13 to 17 years old. The respondents were chosen by using purposive sampling; to represent the lower secondary students' population where age is the key criterion. A quantitative approach that consists of 17 items with 2 sections was used as the instrument in this study to determine the impact of STEM activities on students' knowledge and project development skills. The result discovered that all items displayed a high mean score level. The majority of students have basic knowledge and are delighted to learn STEM. However, more effort needs to be placed on project development skills as some of the respondents are still standing at a novices' stage in problem-solving techniques. It can be concluded that suitable STEM activities strengthen the level of knowledge and project development skills simultaneously affecting the enrolments in STEM courses for secondary school students.

Keywords: STEM, project-based, project development, educational robotics

INTRODUCTION

In the rapidly evolving global economy, Science, Technology, Engineering, and Mathematics (STEM) education plays a pivotal role in equipping students with the skills necessary for innovation, critical thinking, and real-world problem solving. The integration between STEM activities such as robotics, Augmented Reality (AR) tools, project-based learning and gamification have shown important aspects in enhancing students' learning experience, knowledge acquisition and skills development [1 – 3]. Besides, the integration fosters creativity and enhances students' ability to apply theoretical knowledge to practical challenges, preparing them for future workforce demands. Numerous studies have highlighted the positive impact of STEM education on students' cognitive and project development skills.

In STEM education, students not only learn concepts and theories but also develop critical skills, creativity, scientific thinking, and innovation. STEM education encourages students to explore, create, and find solutions to real-world problems. Additionally, STEM education can strengthen the scientific and engineering foundation of students where this knowledge will open career paths in the future. Therefore, understanding and implementing STEM concepts in education is important to ensuring that students are prepared and relevant in an increasingly complex and rapidly changing world. STEM activities are designed to promote learning in an interactive and fun way, through activities such as science experiments, model building, coding, and others.

Despite the benefits of STEM activities, several issues hinder their implementation, such as limited accessibility to resources, student engagement and teacher preparedness. Many schools, particularly in rural areas and underfunded schools, lack access to modern laboratories, technological tools such as Arduino, robotics kits, and AR which prevents the integration of innovative teaching methods. While AR technology and robotics have been shown to increase motivation, not all students have the same interest or access to participate in the STEM activities, especially in competitive environments. Furthermore, teacher preparedness remains a serious issue, where many educators feel inadequately trained to deliver interdisciplinary STEM content effectively to implement STEM activities, which will affect the quality of education [4,5].

Various efforts have been made by different parties to address these STEM related issues to ensure the comprehensive involvement of students in school STEM activities. Through these STEM activities, students can improve their ability to solve real-life problems and enhance their knowledge through hands-on activities and teamwork. Thus, this research is conducted to find the answers to the following questions:

1. What is the impact of the STEM mentoring program on students' knowledge?
2. What is the impact of STEM activities on students’ project development skill?

LITERATURE REVIEW

A. The Impact of STEM Activities on Students

Learning Experience

Educational robotic, design and project-based learning have been used to assist students’ learning process in the field of STEM education, which highlights the integration of science, technology, engineering, and mathematics [6-8]. The rise of STEM activities in recent years has garnered significant interest, and previous studies have shown the potential benefits of using different kinds of activities and tools in STEM education as shown in Table 1. First, improving students' learning experience [9,10]. As conducted in [11], a study to enhance learning activities by implementing AR tools in STEM education. They reported high levels of student motivation in terms of attention, relevance, confidence and satisfaction. The impact of AR applications on learning motivation and performance among 50 undergraduate chemical engineering students were explored in a study [11]. The study aimed to assess how AR technology influences students’ engagement and educational outcomes in chemical engineering courses. The results showed that 82% of participants thought AR lessons were more beneficial than traditional teaching methods, and 92% of respondents were in favor of integrating AR as an additional resource to already-existing materials. These findings suggest that incorporating AR tools can enhance the learning experience by capturing students' attention, making the content more relevant to their interests, increasing their confidence in the subject matter, and overall providing a satisfying learning experience.

In another study [9], open-source hardware, software and programmable tools, namely Arduino were used, to design robots with programming and found it had positive impact on the learning experience including interest and attitude of 53 middle school students in Türkiye. Additionally, the use of Educational Robotic (ER) applications can improve students' attitudes towards STEM education. It is worth to note that students with robotic experience had positive attitudes towards STEM, with significant improvements in teamwork, confidence, and a desire to learn science and technology [7]. Previous study also claimed a program that integrates both theoretical and hands-on learning has been shown to greatly benefit students while also sparking their interest in the realm of robotics [12]. Furthermore, all respondents expressed interest in taking part in robotics competitions or tournaments organized by educational institutions or external entities.

On the other hand, some schools in Greece [13] faced difficulties in learning programming’s subject. The problem involved teachers and students who still used conventional teaching methods which led to create unexcited moments among students. Thus, new way has been introduced by implementing robotics Lego Mindstorm with visual programming environment App Inventor in turn to understand basic programming techniques. Research has confirmed that utilizing ubiquitous technology such as smart device [14] in classroom is one of effective methods in developing teaching and learning process. Apart from that, it stimulating student’s awareness about education benefit of having technology during learning and applying STEM’s activities.

Educational robotic kits in classroom offered excitement and enjoyable experience to students. However, this task is considerable as challenges to certain teachers as they need to master the syllabus, deploying the tool and facing new technology [15]. Thus, teachers must take prompt action in turn to improve teaching methods in realizing STEM objectives.

Knowledge and Skills

There is a growing body of evidence indicating that STEM activities have a beneficial impact on enhancing students' knowledge [6,8,11], coding skill [8] and problem-solving skill [12]. Instead of simply receiving information from teachers, students are able to grasp STEM-related concepts through STEM activities, robotic design and project-based learning. For instance, research [6] that delves into the efficacy of STEM proficiency through the creation of an electronic musical pencil for non-engineering students. The findings revealed a significant enhancement in learners' STEM knowledge and skills. The instructional activities successfully improved learners' abilities to remember, comprehend, and apply knowledge. These results underscore the impact of structured interventions in promoting positive outcomes in STEM education and cultivating a conducive learning environment for students. As mentioned by [10] implemented a robotics and coding intervention program for children aged 7-10, which resulted in a favourable impact on students' understanding of robotics design, enhanced coding skills in robotics contexts, and an increase in students' career aspirations in computing fields. While a project-based learning using turtlebot3 and AiBOT Challenge Program have claimed that students' knowledge and skills related to the robots and the Python language increased [16].

The effect on problem-solving skills before and after applying STEM education to 70 students in the 10th grade of one of high school was reported by [12]. The results show a significant increase in student problem-solving ability as it involves practical application in real-world contexts through contextual problem-solving based on inquiry. Through STEM education, it is necessary for students' comprehension of fundamental concepts to be applied in discovering solutions and resolving issues. In a way, the learning process employs active learning methodologies that encompass communication, collaboration, problem-solving, leadership, creativity, and more. It is believed that this learning mechanism will equip generation Z with the knowledge and perspectives necessary to navigate the challenges of the future world. Another study [16] evaluated the impact of STEM-based learning materials on students' literacy and knowledge in science and physics education. The study found that STEM-based learning materials significantly enhance students' knowledge and literacy skills, particularly when implemented in high school settings. This study also emphasized that the electronic learning materials can be considered as an impact to educational outcome more than any other types of STEM resources. For instance, on average studies that had a STEM materials component produced effect sizes of 1.02 for student literacy and an impressive 1.26 with respect to knowledge among students. Other scholars reported that the experimental group in their study has significantly improved in both science process skills and STEM career interest although their motivation level was also higher than control one [17]. These results suggest that integrating STEM learning materials into high school curriculums, especially in electronic format, may be effective for improving scientific literacy and knowledge of students. In short, students engage with theoretical concepts independently, allowing more time in class for hands-on experiments and collaborative projects. This participation not only extends understanding but also cultivates problem-solving skills crucial in STEM fields, especially for low-achiever students [18].

Combining the flipped classroom model with gamification in STEM education not only enhances students' knowledge but also makes the learning session more enjoyable and impactful [19]. Integrating gamification into STEM education further enhances effectiveness by leveraging game elements such as competition, rewards, and immediate feedback to motivate students and simultaneously to tackle challenges with enthusiasm and creativity [20]. By integrating game mechanics such as points, levels, and leaderboards into lessons, educators can effectively capture and sustain students' interest in STEM subjects. Implementing digital games with other technologies was found has the potential to encourage students to actively more in applying STEM in education [21]. This approach not only boosts engagement but also encourages continuous learning as students strive for more achievement. Overall, the combination of STEM education, the flipped classroom model, and gamification creates a dynamic learning environment that empowers students to develop a strong foundation in STEM disciplines while fostering creativity and innovation. This holistic approach prepares them to excel in a rapidly evolving world driven by science, technology, engineering, and mathematics.

Critical Thinking

Prior studies have demonstrated the potential of STEM activities and educational robotics in fostering critical thinking in the context of STEM education [7, 22]. This includes the ability of students to compute assigned task during learning, along with their ability to do analysis, interpret, evaluate and write in STEM lessons. Educational robotics in STEM education serves as a concrete element that can act as a learning companion, encouraging students to enhance their critical thinking skills [23]. STEM activities could improve student critical thinking and students' perception towards STEM disciplines [22]. They developed STEM activities based on specific topics, and the results showed that these activities positively affected students' critical thinking and perceptions towards STEM disciplines in real-life contexts. Furthermore, a qualitative study [18] showed that students' involvement in the STEM interventions built an interdisciplinary mindset and 21st-century skills such as creativity, collaboration, critical thinking. These results underscore the potential of STEM activities to not only boost academic performance but also to cultivate essential skills and positive perceptions of STEM education among secondary school students.

In another review, coding and computational thinking concept also played an important role in problem solving technique in STEM [24]. Computational thinking emphasized thinking skill simultaneously sparked critical thinking ability for understanding a problem and formulating various solutions. In fact, it will engage students with powerful ideas and unleash their new creativity.

Engaging students in STEM competitions is a strategy to increase students' interest in the field. These competitions, such as robotics, design, and other STEM events, encourage students to work together to solve problems. They also inspire students to explore new ideas and conduct research on the latest technology, which can enhance and expand their understanding.

B. STEM Mentoring Program Structure

In this study, researchers used the STEM Mentoring Program Structure. As this study aims to assess the impact of STEM activities on students' knowledge and project development skills, it is essential to complete the entire program cycle to accurately measure how STEM affects students' learning and skill development. Through this program, 48 students aged between 13 to 17 years old, and 10 STEM teachers were selected. Besides the participants, 20 computer science lecturers were also involved as instructors, facilitators, and mentors. All parties were involved in all 5 phases of the STEM Mentoring Program. The STEM Mentoring Program Structure is illustrated in Fig. 1.

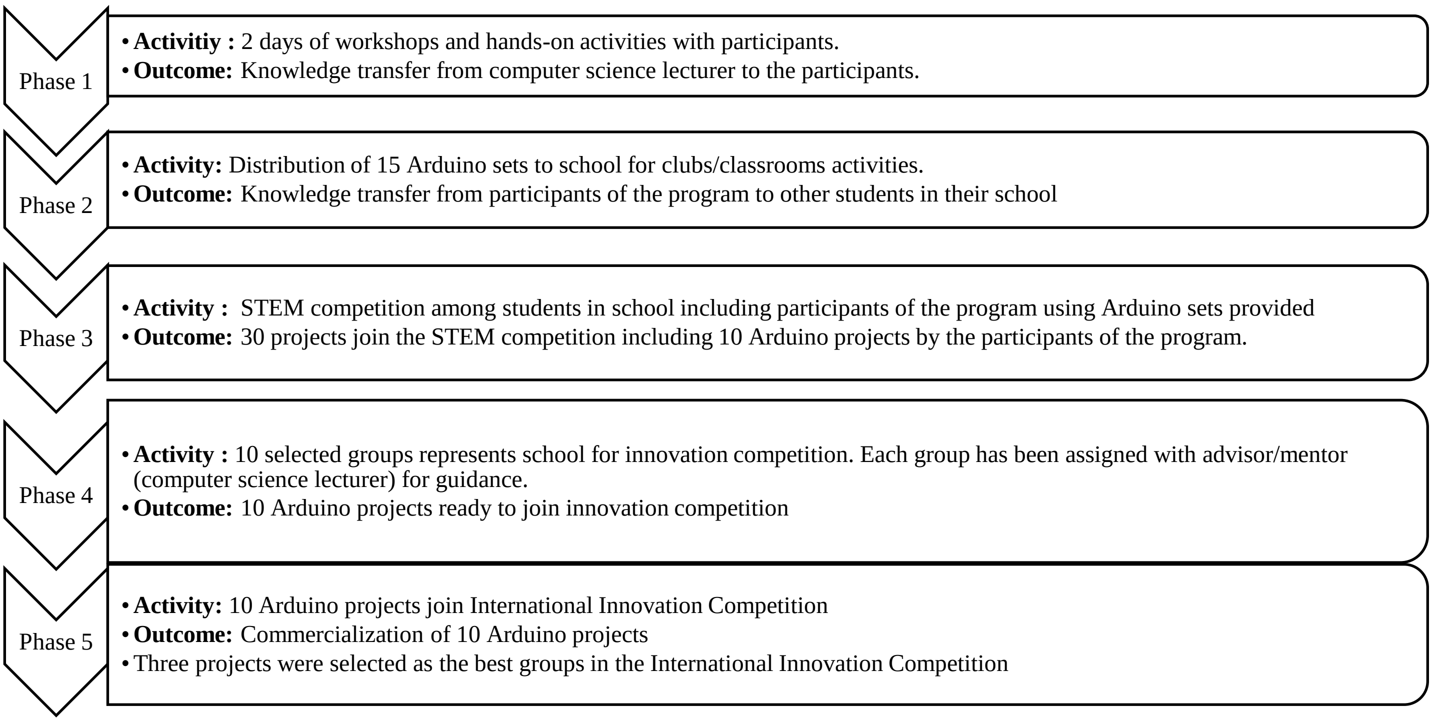

Fig. 1 STEM Mentoring Program Structure

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Fig.1 shows the STEM mentoring program structure used in this study, which consists of five phases.

i. Phase 1: The outcome of this phase is transferring knowledge from computer science lecturer to the participants. The program activity was conducted for 2 days workshop. The participants were given practical experiences building electronic circuits and coding program.

ii. Phase 2: The outcome of this phase is transferring knowledge from the participants attended the program to another student at their school. After a 2-day workshop, the organizer distributed 15 sets of Arduino sets to the school for club or classroom activities. The STEM activities at the school have been conducted by the teacher and assisted by the students who have attended the workshop.

iii. Phase 3 : In this phase, students have used the Arduino set provided earlier to build their STEM projects for STEM competitions at their school level. This includes students who have attended workshop programs earlier. 30 STEM projects participated in the STEM competition organized by the school, of which 10 Arduino projects were from students who attended a 2-day workshop. There were 10 best projects selected to represent the school at the Innovation Competition under the school category.

iv. Phase 4: The 10 selected projects were assigned an advisor or mentor (computer science lecturer) for guidance in improving their current projects and preparing them for the project presentation during the innovation competition. The outcome: 10 projects ready to join the innovation competition.

v. Phase 5: In the final phase, 10 Arduino projects were registered in International Innovation Competition. The outcome of this mentoring program is to commercialize 10 Arduino projects. From the 10 projects that were presented, at least 3 projects were selected as the best groups in the International Innovation Competition.

Mentoring was conducted in phases 1 and 4. The participants were guided by the computer science lecturer in STEM Mentoring Program Structure. While, in phases 2, 3, 4, and 5, students acquired knowledge and project development skills in Arduino.

METHODOLOGY

This research employed a quantitative approach for two primary reasons: (1) Quantitative research is effective for measuring and analyzing the experiences, beliefs, attitudes, and behaviors of a target population, and for assessing their stance on specific issues [25, 26], which align the goals of this study; and (2) It provides a practical and accessible method for novice researchers to describe and examine various phenomena. As this study aims to assess the impact of STEM activities on students' knowledge and project development skills, the data collection was carried out after students went through the whole Mentoring Program as discussed in the previous section.

The study submitted the consent application to the Ethical Committee Board and the school principal to ensure confidentiality the data was collected solely for research purposes. The application was approved by the Ethical Committee of University Teknologi MARA (UiTM) with reference number REC/08/2024 (ST/MR/156). Additionally, approval was obtained from the District Education Office and the school principal. The participants were briefed on the purpose of data collection for the program conducted.

Instrument

The study utilized a set of structured questionnaires comprising 17 questions, divided into two distinct sections, as the primary data collection instrument. The first section, with eight questions, aimed to evaluate the impact of STEM activities on students' knowledge acquisition, assessing their understanding and retention of STEM concepts. The second section, consisting of nine questions, focused on measuring project development skills, such as critical thinking, problem-solving, creativity, and teamwork. The design of the questionnaire ensured clarity and relevance, making it an effective tool for gathering data. By targeting specific aspects of STEM education, the instrument provided comprehensive insights into both cognitive and practical skill development.

The division into two sections allowed for a focused analysis of knowledge enhancement and skill-building separately. The structured format facilitated consistent responses, enabling easy comparison and statistical analysis. Overall, the questionnaires proved effective in capturing nuanced data to evaluate the outcomes of STEM activities

Sampling Method

This study employed a purposive sampling technique, a widely used non-random sampling method where participants are deliberately chosen based on specific characteristics relevant to the research objectives. This approach is commonly employed when the researcher seeks to target a specific subgroup or individuals with particular expertise or experiences relevant to the study [27]. In this case, students enrolled in STEM education were selected as the sampling group, aligning with the study's aim to evaluate the impact of STEM programs on student outcomes. The total population of students enrolled in STEM education at the school was 97. To determine the appropriate sample size, Slovin's formula was applied [28] as shown in Fig 2 where N is the population size and e is the margin of error (set at 10%), and n is the required sample size.

$$n = \frac{N}{1+Ne^2}$$

Fig 2: Sloving formula [23]

Substituting the values shown in Fig 3.

$$n = \frac{97}{1+97(0.1)^2} = \frac{97}{1+0.97} = \frac{97}{1.97} \approx 49$$

Fig 3: Sample size calculation

The calculated sample size was approximately 49. For practical purposes, 48 students aged 13 to 17 years old were selected, along with 10 STEM teachers, ensuring a representative subset for the study. The use of Slovin's formula is widely justified in research, particularly when the population size is known but comprehensive data collection from the entire population is impractical due to constraints such as time, resources, or logistical challenges. This formula is valued for its simplicity and effectiveness in determining an adequate sample size that balances precision and feasibility. By applying Slovin's formula, the researchers ensured that the sample size was statistically robust, providing reliable insights while optimizing the study's efficiency. The selected sample size sufficiently represents the population, allowing for valid conclusions about the program's impact on students' knowledge and project development skills.

Data Analysis

Data collected is then analyzed using descriptive statistical analysis. The descriptive statistical analysis chosen for this study is mainly based on the type of data which is the essential determinant of the alternative in analyzing the data received from the respondents. Table 1 shows the mean score interpretation [29] that was used in this study. The mean score interpretation measure helps researchers understand general trends, compare groups, and assess the overall impact of interventions or conditions. By analyzing mean scores, researchers can draw meaningful conclusions about the data, evaluate hypotheses, and make informed decisions [30].

Table I Mean Score Interpretation

Mean Score	Interpretation
1.0 – 1.50	Very Low
1.51 – 2.50	Low
2.51 – 3.50	Moderate

3.51 – 4.50	High
4.51 – 5.00	Very High

FINDINGS

Fun activities are essential in STEM education, and a low students' engagement with minimal experience can significantly impact students' knowledge and interest in many aspects including pursuing academic study in the science and technology field. Activity in STEM program is a valuable practice for enhancing the students' experience and interest, but it often presents challenges, especially in obtaining active participation, time consuming, high cost and limited creativity.

The data analysis results for the impact of participation in a STEM program on students' knowledge and project development skills are displayed in Table 2. This section includes 8 items that measure how the organized STEM program has affected students' knowledge, and 9 items that measure the program's impact on students' project development skills. Overall, it was discovered that all of the question items displayed a high mean score level.

It can be inferred from items 1 through 8 that student participation in this program increases the degree of student knowledge in STEM topics. Through the highest mean and acceptable SD value (M = 4.44, SD = 0.74), STEM innovation projects have effectively given students more chances to participate actively in STEM education. Response distribution of 48 students on the item of "Innovation competitions has strengthened my STEM knowledge" can be seen through a smaller SD value (SD = 0.64) with M = 0.42. This suggests that the innovation competitions held as part of the STEM program have been successful in raising students' knowledge levels.

With a mean value of 4.38, it can be said that the students are very happy to learn STEM courses. This indicates that in general the STEM program participated by the group of students in this study has left a positive impact on their learning experience and could be an interesting alternative space to increase enjoyment in STEM-related learning.

Table II Mean Scores of students' knowledge and project development skills

Knowledge			
Item	**Mean**	**Mean Interpretation**	**Std. Deviation**
1. My understanding of STEM concepts has improved through projects.	4.17	High	0.77
2. My understanding of STEM concepts has improved through innovation competitions.	4.17	High	0.9
3. Learning through STEM projects has strengthened my memory of STEM concepts.	4.15	High	0.76
4. I am happy to study STEM courses.	4.38	High	0.73
5. Innovation competitions has strengthened my STEM knowledge.	4.42	High	0.64
6. I can relate STEM knowledge through innovation competition projects.	4.31	High	0.77
7. STEM innovation projects allows me to actively involve in STEM learning.	4.44	High	0.7

8. I am able to identify opportunities for project improvement.	4.31	High	0.74
Mean	4.29	High	
Project Development Skill			
Item	**Mean**	**Mean Interpretation**	**Std. Deviation**
9. I am able to discuss my ideas with group members.	4.17	High	0.85
10. I am able to explain a problem.	4.06	High	0.75
11. I am able to convince listeners with my knowledge.	4.04	High	0.89
12. I am able to use the knowledge I have learned in solving problems.	4.21	High	0.76
13. I am able to find information to solve a problem.	4.06	High	0.88
14. I am able to solve problems in a systematic way.	3.88	High	0.88
15. I am able to work in a group.	4.13	High	0.95
16. I can tell new ideas.	4.31	High	0.74
17. I am able to describe my ideas using diagrams or story lines.	3.94	High	0.88
Mean	4.2	High	

It can be concluded that students are extremely delighted to learn STEM courses based on the mean value of 4.38. This suggests that the STEM program in which the students participated has, on the whole, had a good effect on their educational experience and may offer an intriguing substitute setting for raising student satisfaction with STEM-related coursework.

Despite the result shows the students highly agreed that their understanding of STEM concepts has improved through innovation competitions (M = 4.17), the dispersion of the answers among respondents is quite high (SD = 0.90) where three students reported disagree and seven students unsure of whether that their understanding of STEM concepts has improved through innovation competitions. This could be due to some students whose ages are between 13 – 17 years old had never involved or had minimal experience in innovation competitions. Thus, future study should consider respondents' number of experience in innovation competitions to at least get fair responses.

Responses on the score of unsure (10 people), disagree (one person) and strongly disagree (one person) have contributed to a high standard deviation value (SD = 0.95) on the item "I am able to work in a group". This shows that there are some students who are not able to work in groups or collaborative learning. Thus, this finding highlights the need for project-based interventions in classroom because the skill of working in groups is important as it could help to improve understanding STEM, enhance productivity, build trust and interest. Therefore, collaborative learning through STEM project-based activities needs to be emphasized to enable students to benefit from it throughout their lives.

The project development skill indicator has the lowest mean (M = 3.88) indicates a need for greater emphasis on structured problem-solving techniques within the mentoring program. More work needs to be done and needs to be honed more actively to improve the skill of solving problems in a systematic way so that it goes hand in hand with other skills that support STEM learning. The findings show that some students struggle with systematic problem-solving highlights the need for targeted interventions and could be personalized according to students' learning pace and ability.

The findings suggest that some students struggle to effectively discuss and express their ideas, as well as to persuade their audience, indicating a challenge in their communication skills. This highlights the need for more opportunities for students to practice presentations in the classroom, along with structured programs like the STEM Mentoring Program used in this study. Such initiatives could be expanded to help students progress to a higher level, enabling them to participate in innovation competitions outside of school.

The positive impact of the STEM Mentoring Program and STEM activities can further address broader issues. In terms of long-term knowledge retention, STEM education helps solidify students' scientific and engineering foundations, which can open up future career opportunities. Additionally, it can boost students' aspirations in computing-related fields.

CONCLUSION

This study reinforces the significant role of STEM activities in enhancing student's knowledge and project development skills. The STEM program has had a positive impact on student engagement and knowledge acquisition, which is the findings demonstrate that engaging in hands-on STEM activities help foster critical thinking, creativity, and problem-solving skills, which are essential for success in the modern workforce. A key contribution of this research is focused analysis of how structured STEM mentoring in secondary school can bridge the gap between theoretical knowledge and practical application. Innovation competitions have proven effective in enhancing students' STEM knowledge, though variations in student responses suggest that experience levels may affect the depth of understanding. This makes STEM an essential component of modern education, aimed at cultivating a generation of innovators and problem solvers. It is worth noting that STEM education can improve students' critical thinking skills and prepare them to meet the challenges of industry 4.0.

Several actionable recommendations are proposed to empower STEM education. Firstly, schools should focus on ensuring equal access to STEM resources, particularly in underserved communities, by using affordable technologies and building partnerships with industry stakeholders. Second, schoolteachers should receive continuous professional development to effectively teach project-based STEM learning, ensuring they have both subject expertise and innovative teaching strategies.

In future, the research could explore the students' career pathways in the STEM field, further solidifying the importance of early engagement in science, technology, engineering, and mathematics to school students.

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REFERENCES

1. Alam, A., & Mohanty, A. (2024). Integrated constructive robotics in education (ICRE) model: a paradigmatic framework for transformative learning in educational ecosystem. Cogent Education, 11(1). https://doi.org/10.1080/2331186X.2024.2324487
2. Ou Yang, F.., Lai, H.M., & Wang, Y.-W. (2023). Effect of augmented reality-based virtual educational robotics on programming students' enjoyment of learning, computational thinking skills, and academic achievement. Computers & Education, 195. https://doi.org/https://doi.org/10.1016/j.compedu.2022.104721
3. Pou, A. V., Canaleta, X., & Fonseca, D. (2022). Computational Thinking and Educational Robotics Integrated into Project-Based Learning. Sensors, 22(10). https://doi.org/10.3390/s22103746
4. Tucker, C. B., Byrd, K. O., Gossen, D., & Morrison, K. (2024). Teacher Self-Efficacy and Preparedness for Integrating STEM Education Using a Project-Based Learning Approach. Journal of Research in Science, Mathematics and Technology Education, 7(SI), 43-59. https://doi.org/10.31756/jrsmte.313SI
5. Ramli, N. F., Talib, O., Hassan, S. A., & Manaf, U. K. A. (2020). Development and validation of an instrument to measure STEM teachers' instructional preparedness. Asian Journal of University Education,

16(3), 193-207.

6. Hu, C. C., Yeh, H. C., & Chen, N. S. (2020). Enhancing STEM competence by making electronic musical pencil for non-engineering students. Computers and Education, 150(123), 103840. https://doi.org/10.1016/j.compedu.2020.103840
7. Kucuk, S., & Sisman, B. (2020). Students' attitudes towards robotics and STEM: Differences based on gender and robotics experience. International Journal of Child-Computer Interaction, 23–24, 100167. https://doi.org/10.1016/j.ijcci.2020.100167
8. Ragusa, G., & Leung, L. (2023). Understanding of Coding , Robotics Design , and Interest in. Sensors, 23(23).
9. Erol, O., Sevim-Cirak, N., & Baser Gulsoy, V. G. (2023). The Effects of Educational Robotics Activities on Students' Attitudes towards STEM and ICT Courses. International Journal of Technology in Education, 6(2), 203–223. https://doi.org/10.46328/ijte.365
10. Kaur, D. P., Mantri, A., & Horan, B. (2020). Enhancing student motivation with use of augmented reality for interactive learning in engineering education. Procedia Computer Science, 172(2019), 881–885. https://doi.org/10.1016/j.procs.2020.05.127
11. Low, D. Y. S., Poh, P. E., & Tang, S. Y. (2022). Assessing the impact of augmented reality application on students' learning motivation in chemical engineering. Education for Chemical Engineers, 39(September 2021), 31–43. https://doi.org/10.1016/j.ece.2022.02.004
12. Rohana, H., Adibah, A., & Shellie, S. S. (2021). Kajian Tahap Pengetahuan , Kemahiran Dan Minat Pelajar Dalam Minat Pelajar Dalam Bidang Robotik Program Aibot Challenge 2020 Di Politeknik Ibrahim Sultan (PIS). E-Proceedings of the National Technology Research in Engineering, Design and Social Science Conference (NTrends'21).
13. Alatas, F., & Yakin, N. A. (2021). The Effect of Science, Technology, Engineering, and Mathematics (STEM) Learning on Students' Problem Solving Skill. JIPF (Jurnal Ilmu Pendidikan Fisika), 6(1), 1. https://doi.org/10.26737/jipf.v6i1.1829
14. Papadakis, S., Orfanakis, V. (2017). The Combined Use of Lego Mindstorms NXT and App Inventor for Teaching Novice Programmers. In: Alimisis, D., Moro, M., Menegatti, E. (eds) Educational Robotics in the Makers Era. Edurobotics 2016 2016. Advances in Intelligent Systems and Computing, vol 560. Springer, Cham. https://doi.org/10.1007/978-3-319-55553-9_15
15. Kalogiannakis, M., & Papadakis, S. (2020). The use of developmentally mobile applications for preparing pre-service teachers to promote STEM activities in preschool classrooms. In S. Papadakis & M. Kalogiannakis (Eds.), Mobile learning applications in early childhood education (pp. 82-100). IGI Global. https://doi.org/10.4018/978-1-7998-1486-3.ch005
16. Papadakis, S., Vaiopoulou, J., Sifaki, E., Stamovlasis, D., Kalogiannakis, M., & Vassilakis, K. (2021). Factors That Hinder in-Service Teachers from Incorporating Educational Robotics into Their Daily or Future Teaching Practice. Proceedings of the 13th International Conference on Computer Supported Education. https://doi.org/10.5220/0010413900550063
17. Annisa, N., Asrizal, & Festiyed. (2022). Effects of STEM-based learning materials on knowledge and literacy of students in science and physics learning: A meta-analysis. Journal of Physics: Conference Series, 2309(1). https://doi.org/10.1088/1742-6596/2309/1/012063
18. Hiğde, E., & Aktamış, H. (2022). The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views. Thinking Skills and Creativity, 43(September 2021). https://doi.org/10.1016/j.tsc.2022.101000
19. Bahrum, N. B., & Samsudin, M. A. (2021). Kesan Pendekatan Pembelajaran STEM Secara Teradun Dalam Bilik Darjah Sains. Innovative Teaching and Learning Journal, 5(1), 12–22.
20. Gong, J., Cai, S., & Cheng, M. (2024). Exploring the Effectiveness of Flipped Classroom on STEM Student Achievement: A Meta-analysis. Technology, Knowledge and Learning, 29(2), 1129–1150. https://doi.org/10.1007/s10758-023-09700-7
21. Asigigan, S. I., & Samur, Y. (2021). The effect of gamified stem practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills. International Journal of Education in Mathematics, Science and Technology, 9(2), 332–352. https://doi.org/10.46328/IJEMST.1157
22. Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. International Journal of STEM

Education, 9(1). https://doi.org/10.1186/s40594-022-00344-0

23. Hacioglu, Y., & Gulhan, F. (2021). The Effects of STEM Education on the Stud ents ' Critical Thinking Skills a nd To cite this article : The Effects of STEM Education on the Stud ents ' Critical Thinking Skills and STEM Perceptions. Journal of Education in Science, Environment and Health, 7(2), 139–155.
24. Ou Yang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: a multilevel meta-analysis. International Journal of STEM Education, 11(1). https://doi.org/10.1186/s40594-024-00469-4
25. Papadakis, S. (2020). Apps to promote computational thinking concepts and coding skills in children of preschool and pre-primary school age. In Mobile learning applications in early childhood education (pp. 101–121).
26. Sukamolson, S. (2007). Fundamentals of quantitative research. Language Institute Chulalongkorn University, 1(3), 1-20.
27. Mohajan, H. K. (2020). Quantitative research: A successful investigation in natural and social sciences. Journal of Economic Development, Environment and People, 9(4), 50–79. https://doi.org/10.26458/jedep.v9i4.679
28. Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. American Journal of Theoretical and Applied Statistics, 5(1), 1-4. https://doi.org/10.11648/j.ajtas.20160501.11
29. Torres, C. A. (2013). Introduction to Applied Statistics: A Non-Calculus Based Approach. Pearson Education.
30. Moidunny, K. (2009). The Effectiveness of the National Professional Qualification forEducational Leaders (NPQEL). Unpublished Doctoral Dissertation, Bangi: The National University of Malaysia.
31. Field, A. (2013). Discovering Statistics Using IBM SPSS Statistics. Sage Publications.