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Improving STEM Capability of Islamic Boarding School Students in Batam Through Robotics Training

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Abstract: *Conducting robotics training as community service to improve the basic knowledge of Science, Technology, Engineering, and Mathematics (STEM) for the student is one of the ways to deal with the era of industry 4.0 and society 5.0. We collaborated with the Granada International Boarding School in Batam in this work to perform robotics training. The total participants were 29 students, consisting of 7 students from grade X, 15 pupils from grade XI, and the rest from grade XII. The training was carried out through lectures, discussion, and practice. Before and after the training, students are given a written exam to measure their ability level. The training results increased the average student's STEM ability by 38.15%. Moreover, activities have been successfully carried out with participant satisfaction levels above 50% for lesson materials, instructors, and training equipment. Only 17% of training participants stated that the time was insufficient, especially for the practical.*

Introduction

STEM is an educational concept that integrates science, technology, engineering, and mathematics disciplines into one unit. STEM-based education has been widely implemented in developing countries[1]. Meanwhile, research trends related to STEM

[1] Dewi Sartika, "PENTINGNYA PENDIDIKAN BERBASIS STEM DALAM KURIKULUM 2013," *JISIP (Jurnal Ilmu Sosial dan Pendidikan)* 3, no. 3 (November 2019): 89–93.

implementation in the school environment have increased in Indonesia since 2015[2]. A significant increase occurred in 2019-2020, with a total increasing about 74.1% from the previous years. This condition shows that STEM education has begun to be widely adopted and applied in Indonesia. However, from the data obtained, the application of STEM education is still concentrated in West Java and East Java Provinces. There is 44% of provinces have not implemented STEM-based education, such the Kepulauan Riau province.

The aspect supporting the distribution of STEM education is the teacher's perception and understanding. However, based on the research on 117 science teachers concluded that teachers in Indonesia did not sufficiently understand STEM education[3]. Moreover, the lack of adequate facilities and infrastructure inhibited the implementation of STEM education. Meanwhile, teachers believe that STEM education can answer the skills needed in the 21st century, like creative thinking, critical thinking, problem-solving, communication, and collaboration skills. This statement is reinforced by the research result conducted by Permanasari et al. and Hafni et al. According to Permanasari et al., through STEM education, students can be encouraged to come up with ideas, especially when learning through a project[4]. Meanwhile, according to Hafni et al., STEM education can improve students' critical thinking and problem-solving skills[5].

STEM can be introduced through interactive learning media. Robots are one of the learning media that can be used for STEM-based education[6]. The topic of robots as STEM-based learning media has been widely researched, and the results are compelling. For example, the STEM-based robot kits SpaceR by Nata et al.[7] and AGROBOT-II, introduced by Prayogo et al.[8]. Due to the advantages generated from the robots as the media learning of STEM-based education, Politeknik Negeri Batam has already developed the STEM-based educational robots kit which can be used for the high school student around Batam. The developed robot kit is also equipped with teaching materials as guidance for the teachers during the learning process. In addition to teaching materials, at the end of the

[2] Ratna Farwati et al., "STEM Education Implementation in Indonesia: A Scoping Review," *International Journal of STEM Education for Sustainability* 1, no. 1 (July 2021): 11–32.

[3] O. F. Nugroho, A. Permanasari, and H. Firman, "The Movement of STEM Education in Indonesia: Science Teachers' Perspectives," *Jurnal Pendidikan IPA Indonesia* 8, no. 3 (September 2019): 417–425.

[4] Anna Permanasari, Bibin Rubini, and Oktian Fajar Nugroho, "STEM Education in Indonesia: Science Teachers' and Students' Perspectives," *Journal of Innovation in Educational and Cultural Research* 2, no. 1 (June 2021): 7–16.

[5] R N Hafni et al., "The Importance of Science, Technology, Engineering, and Mathematics (STEM) Education to Enhance Students' Critical Thinking Skill in Facing the Industry 4.0," *Journal of Physics: Conference Series* 1521, no. 4 (March 2020): 042040.

[6] Pedro Ponce et al., "Use of Robotic Platforms as a Tool to Support STEM and Physical Education in Developed Countries: A Descriptive Analysis.," *Sensors (Basel, Switzerland)* 22, no. 3 (January 2022): 1037.

[7] I Putu Raka Nata et al., "Smart Project Educational Robot (SpaceR) Sebagai Robot Edukasi," *Jurnal Aplikasi dan Inovasi Iptek (JASINTEK)* 3, no. 1 (October 2021): 56–64.

[8] Sandy Suryo Prayogo, Yogi Permadi, and Tubagus Maulana Kusuma, "RANCANG BANGUN AGROBOT-II: ROBOT EDUKASI PENANAM BENIH TANAMAN PADI DENGAN KENDALI JARAK JAUH," *Jurnal Ilmiah Teknologi dan Rekayasa* 25, no. 2 (August 2020): 89–101.

lesson, the robot will be matched at the competition to increase the student's learning motivation. According to Chung et al., competition can trigger and increase student learning motivation[9].

Currently, the educational robot that has been developed still does not directly benefit the community, especially the local community in Batam. The robot is only used in a limited way to support the learning process for early semester students at the Politeknik Negeri Batam Robotics Engineering Study Program. Community service activities were carried out to increase the benefits of the research that has been carried out. The activity was in the form of robotics training which aims to improve STEM abilities for high school students, especially in typical Islamic boarding schools. The training was conducted at the Granada International Islamic Boarding School, one of the Islamic boarding schools in Batam. This school was selected based on teachers' requests to introduce STEM education to their students. Furthermore, the location of community service activity was chosen because the school still lacks supporting infrastructure for learning. The robot kits, materials, and test questions are provided to support the training activities and measure the improvement of students' understanding before and after the training has been made during the activity. In addition to the activities, we also collected questionnaires related to the delivery of material to measure participant satisfaction with the training programs conducted.

Method

Community service activities begin with preparing learning media consisting of robot kits, training materials, test questions, and questionnaires. Furthermore, the training is carried out using a robot kit as the learning media for student practice. After the learning activities, it continued with measuring students' abilities using test questions that had been prepared and the level of satisfaction at the end of the activity.

Robot Kit as Hands-On Material

The hands-on material in this training used a robot kit called "Angry Froggie", which was previously developed by a group of robotics researchers at Politeknik Negeri Batam. The design and appearance of the "Angry Froggie" robot can be seen in Figure 1. Figure 1 (a) is the 3D mechanical design of the robot, while Figure 1 (b) is the final prototype that has been fabricated. During training activities, students must assemble robot parts, connect the electronic components, and program the robot. In terms of features, the "Angry Froggie" robot can be programmed to carry out several tasks,

[9] C J ChanJin Chung, Christopher Cartwright, and Matthew Cole, "Assessing the Impact of an Autonomous Robotics Competition for STEM Education," *Journal of STEM Education: Innovations & Research* 15, no. 2 (2014): 24–34.

(a) (b)

Figure 1. The "Angry Froggie" Robot Kit (a) CAD Design, and (b) Prototype Model

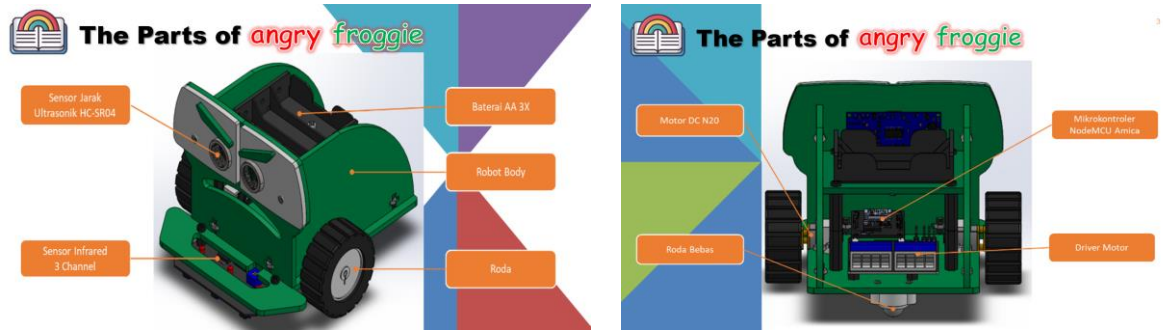
Table 1. The "Angry Froggie" Robot Kit Specifications

Specifications	Value
Dimension	13cm×12cm
Power Requirements	4.5 VDC 3×AA Battery
Controller	NodeMCU ESP8266
Actuator	2×DC Motor N20
Sensor	Ultrasound distance sensor HC-SR04 Infrared line sensor 3 channel Infrared receiver
Feature	Obstacle avoidance Line follower Remote control Sound generation with piezo buzzer

including following the line, avoiding obstacles, following the controls from the remote, and making sounds with specific tones. Detailed specifications of the "Angry Froggie" robot used in training activities can be seen in Table 1.

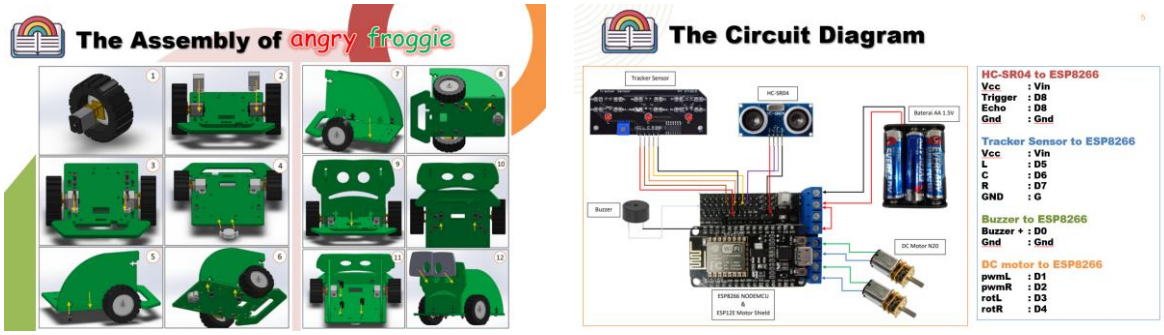
Learning Materials and Learning Method

The "Angry Froggie" robot kit is equipped with training materials specially designed for high school students and beginners in robotics. In addition, this material can be used as a guide for instructors on the learning process. The material presented includes explanations of robot parts, robot assembly stages, electronic component installation stages, and basic programming on robots.



(a) (b)

Figure 2. Part of "Angry Froggie" Robot (a) at the front, (b) at the back.



(a) (b)

Figure 3. "Angry Froggie" Robot Assembly Stages (a) mechanical parts, (b) electrical parts.

The first material presented to the training participants is about the robot's essential parts and functionality. The learning method used to deliver this material is lecture and discussion. First, the instructor explained the material using the presentation slide visualized in Figure 2. Figure 2 (a) and Figure 2 (b) show that the explanation consists of several parts of the "Angry Froggie" robot at the front and the back: the body, sensors, and electronic circuits. The robot body was made of acrylic material, designed to be easily assembled or dismantled, and driven by two wheels connected to a DC motor. Additionally, the sensors on the robot consist of an ultrasonic sensor to measure distance and a 3-channel infrared sensor to detect lines. In addition to sensors, there was an electronic module as the robot's primary controller, the NodeMCU ESP8266. This controller is also connected to the DC motor controller. In delivering material related to these robot parts, the names of the robot parts and their functions are introduced to students so that students begin to understand the basics of robot components. This lecture section is related to the science and technology aspect of STEM, which explained to the students how sensors, DC motors, motor controllers, and microcontrollers work.

After explaining the robot parts and their functionality, the training will be continued with hands-on assembling the robot. In this session, the instructor briefly explained the stages of robot assembling with presentation slides visualized in Figure 3 (a). First, students are taught about the engineering aspects of the robot, starting from

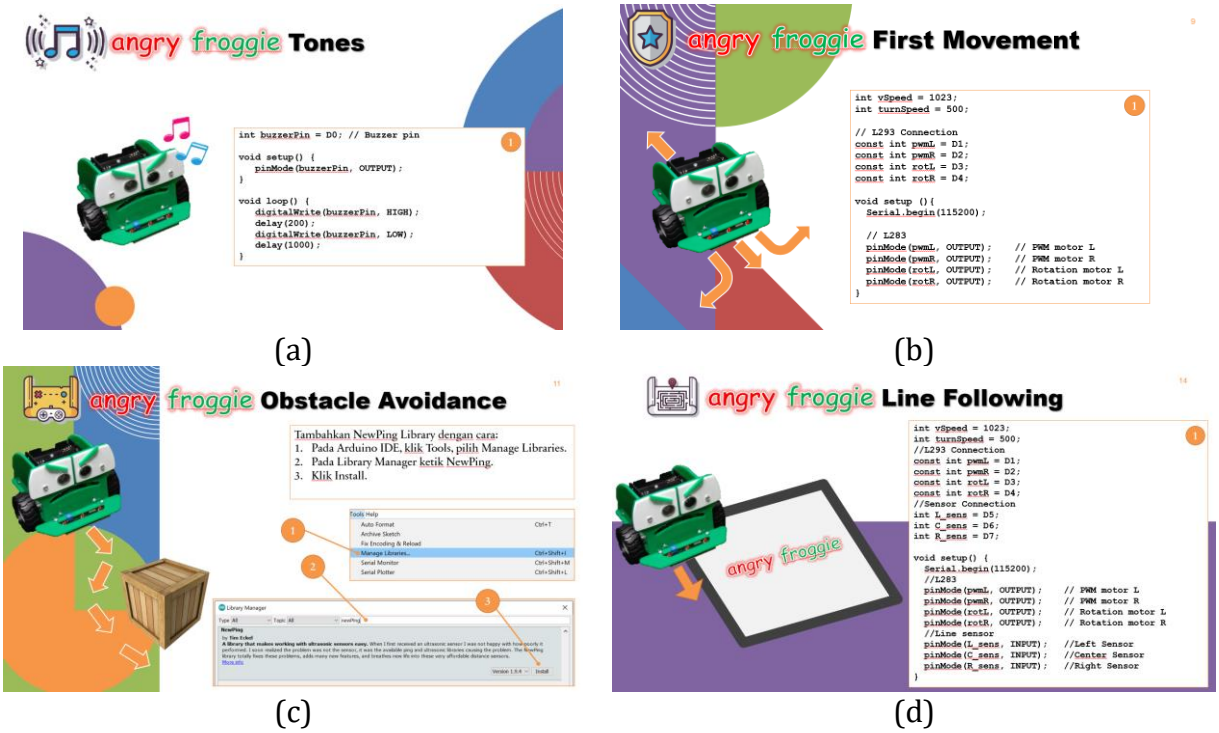


Figure 4. Programming Lesson with "Angry Froggie" Robot (a) making tone from robot, (b) moving the motors, (c) avoiding obstacle, (d) following the lines.

the installation of nuts and bolts to the electrical installation of the robot. In the presentation slide, the robot assembly stages are given a number code at the top right of the image to minimize installation errors. The assembly process began with installing the wheels on the robot body and ended up installing the ultrasonic sensor holder as the robot's eye. After that, the installation of the electrical system can proceed. For electrical installation, circuit drawings are provided as visualized in Figure 3 (b), which students can follow as guidance. For robot assembly material, students must do it in group practice directly. Therefore, the student's communication and collaboration skills can be trained during this lesson.

The last lesson presented by the instructor was basic robot programming. In this lesson, an essential program was included in the teaching materials. The goal was to form a basic understanding of aspects of programming and algorithms, which was part of the technology and mathematics of STEM. The materials used for teaching programming are shown in Figure 4. Figure 4 (a) describes a lesson about generating a sound with the robot. In this material, students were trained in basic writing code, compiling, and uploading programs to the robot. This practice was followed by programming the basic robot movement, as shown in Figure 4 (b). In this lesson, students were taught the basic concept of robot movement formed by rotating the two DC motors. Next, students were introduced to sensor programming and essential algorithms in the following material. These sensors and basic algorithms material are shown in Figure 4 (c). Students were

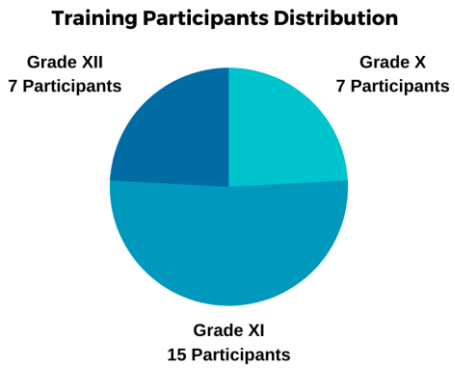


Figure 5. Training Participants Distribution.

expected to program robots to avoid obstacles using ultrasonic sensor readings in this material. Furthermore, the last lesson was the line follower coding, presented in Figure 4 (d) slides. In this last lesson, students must program the robot to follow a line using an infrared sensor.

Evaluation Methods

We delivered pre-tests and post-tests to the training participants to determine the effectiveness of the training. The pre-test and post-test are identical questions consisting of 10 questions related to STEM. Students must complete the test within 20 minutes. The pre-test was delivered before training began, and the post-test was given after the training had been completed. The pre-test and post-test were used to measure the participants' knowledge gained after the training. After the post-test was completed, participants in the program were also handed a questionnaire upon completing the activities. This questionnaire contains participants' responses to the material, presenters, equipment, training duration, and additional suggestions related to training activities.

Training Participants

There were 29 student training participants from the Granada International Islamic Boarding School. A pie chart displays the distribution of involvement in Figure 5. According to the pie chart, most participants in this training exercise were in grade XI, and it reached about 15 people and 7 people from grade X and grade XII. During training activities, the participants were divided into ten groups by randomly dividing the group members. Each group was accompanied by an assistant instructor who was a student of the Robotics Engineering Study Program, Politeknik Negeri Batam.

Figure 6. Implementation of Robotics Training, (a) opening ceremony, (b) lecturing the training materials, (c) practicing the training, (d-e) closing ceremony.

Result

The results and discussion obtained from this robotics training activity are described in this section. First, we describe the results of implementing the activities that have been carried out. Second, we will explain the results of increasing the knowledge gained by the training participants. While the final section explains the level of satisfaction with the activities held. Details of the results we have obtained and their discussion are explained in the following sub-section.

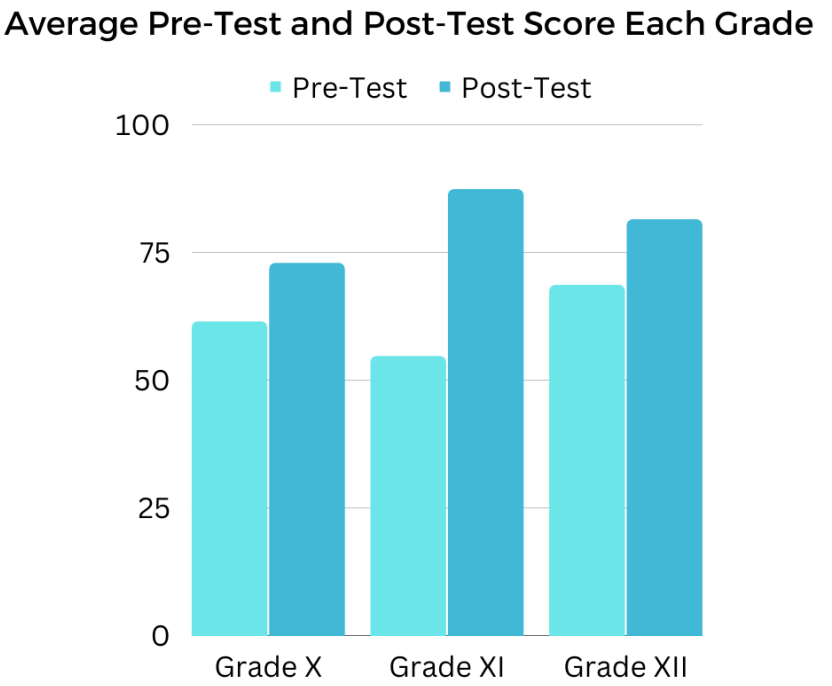


Figure 7. Average Pre-Test and Post-Test Score Each Grade

Implementation of Robotics Training Activities

Robotics training sessions were held at the Granada International Islamic Boarding School, located at Jl. Hang Kesturi, Kampung Jabi, Batu Besar, Batam. About 29 students, 3 teachers, and 1 Islamic boarding school leader attended this event. Activities were conducted in the school's mosque room. Activities start at 9.00 am and end at 16.00, with a break from 12.00 to 13.00. Documentation of this activity can be seen in Figure 6. The activity was opened with remarks from the leader of the Islamic boarding school and instructor representatives from the Politeknik Negeri Batam, denoted in Figure 6 (a). After the opening ceremony, further training activities began to be carried out. This activity can be seen in Figure 6, where Figure 6 (b) is an activity for delivering material, while Figure 6 (c) shows a practical session on assembling the "Angry Froggie" robot. After all the activities were completed, the instructor team and the training participants took a group photo which can be seen in Figure 6 (d-e).

Increasing the Knowledge of Training Participants

The results of the pre-test and post-test questions showed a significant increase in the participants' basic understanding of the material. Statistical data showed that the average score obtained by students was 59.66 points before participating in the training. Meanwhile, the average student score was 82.41 points after attending the training. There was an exponential increase of 22.76 points after the students attended the

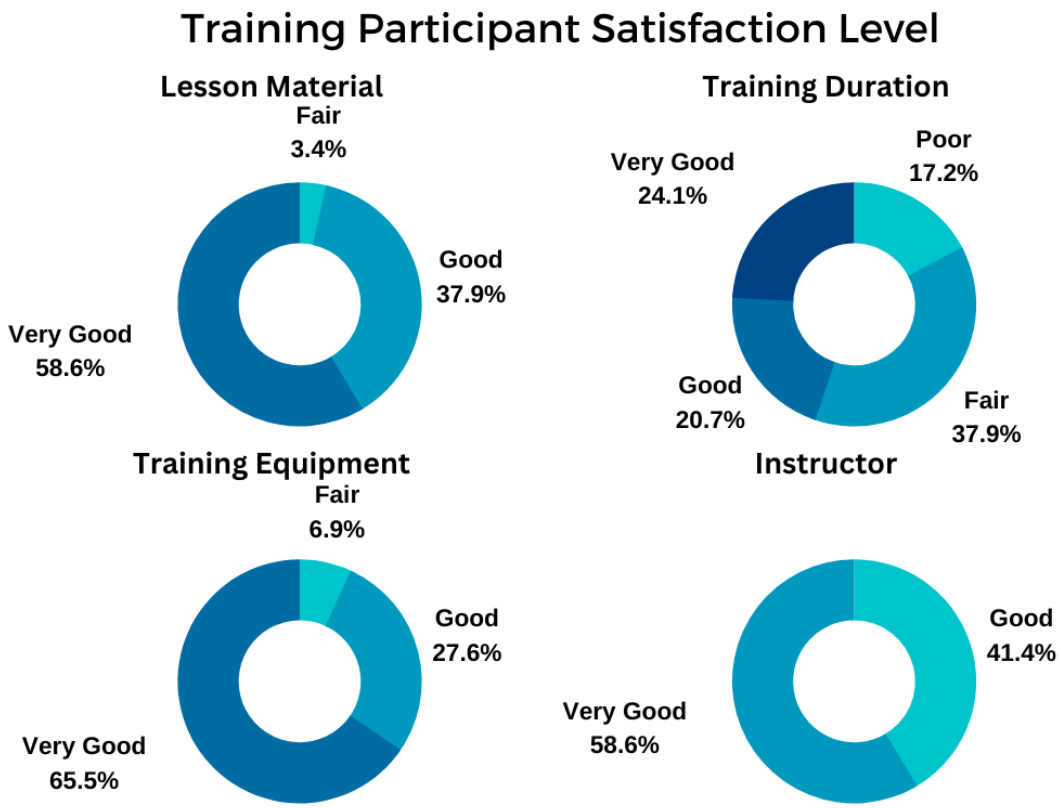


Figure 8. Training Participant Satisfaction Level

training. From these results, it can be concluded that this activity increased the trainees' ability by 38.15%.

As for the increase in value based on grade level, it was presented graphically in Figure 7. The highest increase in understanding occurred in class XI, with a total rise of about 59.76%. Before the training, the average score of class XI students was 54.67, but after attending the training, the average score showed a rapid surge of about 87.33. While class X and class XII tend to get a similar improvement in test scores, class X was around 18.60%, and class XII in about 18.75%.

Training Participant Satisfaction Levels

The level of participant satisfaction with the training is illustrated by the pie chart in Figure 8. These results were obtained through a questionnaire given to 29 training participants. We classified the questionnaire results into four parts related to the quality of the materials, instructors, equipment, and duration of the training. The questionnaire results from the respondents can be seen in Figure 8. From the data obtained, it can be concluded that most of the training participants were satisfied with the activities that had

been carried out. Regarding the quality of the material provided, around 59% of respondents answered that the material provided was excellent. Moreover, no respondents stated that the material was lacking. Meanwhile, from the speaker's point of view, 59% of the respondents stated that the presenter had provided the material very well. The remaining 41% of respondents answered that the speaker had provided the material well. In terms of equipment, about 65% of respondents stated that the equipment was adequate for implementing the training. Nevertheless, regarding training duration, around 17% of respondents stated that training time was insufficient. This result was reinforced by four respondents complaining about the lack of duration of the training provided. Furthermore, four respondents complained about this training activity's lack of practicum duration. The questionnaire results serve as a benchmark for evaluating the training effectiveness that has been implemented and as a guide for enhancing future community service activities.

Discussion

From the data results above, this mentoring activity was able to increase the ability of the trainees by 38.15%. This confirms several studies, including by Nugen which states that Robotics has been shown to have a positive impact on students' STEM learning, problem-solving skills, and interest in engineering careers.[10] The use of robotics in education has been shown to increase students' interest in STEM, encourage creativity, problem-solving, teamwork, and communication skills, and enhance learning in other subjects.[11] In addition, the integration of robotics technology in STEM education has been shown to improve student engagement and learning outcomes in STEM disciplines.[12]

Research has also shown that robotics programs can increase student interest in STEM-related fields and success in robotics and STEM learning in general.[13] However, it is important to note that while robotics programs have been shown to improve students' academic performance in STEM fields, there is evidence that females may not benefit to the same extent as males. Therefore, it is crucial to consider gender-specific factors when implementing robotics training to ensure equitable outcomes for all students.

In addition, the use of robotics in education has been shown to benefit STEM learning, and teachers can utilize robotics programs to enhance STEM education in

[10] Gwen Nugent et al., "Robotics Camps, Clubs, and Competitions: Results From a US Robotics Project," *Robotics and Autonomous Systems* (2016).

[11] Liangfu Jiang and Hua Yuan, "Stable Parallel Algorithms for Interdisciplinary Computer-Based Online Education With Real Problem Scenarios for STEM Education," *Complexity* (2021).

[12] S M M Rahman, Veena J Krishnan, and Vikram Kapila, "Fundamental: Optimizing a Teacher Professional Development Program for Teaching STEM With Robotics Through Design-Based Research" (n.d.).

[13] Daniel G Bates, Geoff Wright, and Steven Shumway, "An Investigation of the Impact an ROV Competition Curriculum Has on Student Interest in STEM, Specifically Technology and Engineering" (n.d.).

schools.[14] Furthermore, the implementation of robotics in K-12 environments has implications for STEM teaching and learning, and it is imperative for teachers to understand how to effectively incorporate robotics into their curriculum.[15]

Conclusion

This paper discusses community service activities through a robotics training program at the Granada International Islamic Boarding School to increase students' understanding of STEM. As a result, there was about a 38.15% improvement in the average student's knowledge obtained during community service activities. This data concluded that this training activity had increased students' STEM knowledge. In addition to STEM, in general, the training participants were satisfied with the training carried out. It was concluded from the data that above 50% of respondents stated that the materials, presenters, and equipment used for training were excellent. However, there were 17% of respondents stated that the duration of the training provided was insufficient. Apart from that, several comments from the trainees wanted the time duration to be more optimized, especially practicum time. This questionnaire result will be evaluated by the service team and will be increased in future community service activities.

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