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Robotics training to improve STEM skills of Islamic boarding school students in Batam

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ABSTRACT

One potential approach to addressing the challenges posed by the advent of Industry 4.0 and Society 5.0 is to offer robotics training. This endeavor aims to enhance students' foundational understanding of STEM (Science, Technology, Engineering, and Mathematics) disciplines. The study involved collaborating with the Pondok Pesantren Granada, an Islamic Boarding School located in Batam, to provide robotics training as community service activities. The study included 29 trainees: 15 from class XI and 7 from classes X and XII. The teaching was conducted using a combination of didactic instruction, interactive discourse, and hands-on exercises. Trainees are administered a written examination to assess their proficiency level before and after the training program. The training outcomes exhibited a significant improvement in the mean STEM proficiency of trainees, with an increase of 38.15%. Furthermore, a series of activities have been effectively implemented, resulting in trainee satisfaction ratings exceeding 50% concerning course materials, trainer, and teaching equipment. A mere 17% of the individuals undergoing training expressed dissatisfaction with the allocated time, particularly the hands-on component's duration.

Kata Kunci
Edukasi robotika
Pelatihan robotika
Pelatihan STEM
Pendidikan STEM
Pondok pesantren

Pelatihan robotika untuk meningkatkan keterampilan STEM santri pondok pesantren di Batam. Salah satu pendekatan potensial untuk menghadapi tantangan yang ditimbulkan oleh munculnya Industri 4.0 dan Masyarakat 5.0 adalah dengan memberikan pelatihan robotika. Upaya ini bertujuan untuk meningkatkan pemahaman dasar siswa tentang disiplin ilmu STEM (Sains, Teknologi, Teknik, dan Matematika). Penelitian ini melibatkan kerja sama dengan Pondok Pesantren Granada, sebuah pondok pesantren yang berlokasi di Batam, untuk memberikan pelatihan robotika sebagai kegiatan pengabdian kepada masyarakat. Penelitian ini melibatkan 29 peserta pelatihan: 15 peserta dari kelas XI dan 7 peserta dari kelas X dan XII. Pengajaran dilakukan dengan menggunakan kombinasi instruksi didaktik, diskusi interaktif, dan praktik langsung. Para peserta diberikan ujian tertulis untuk menilai tingkat kemampuan mereka sebelum dan setelah program pelatihan. Hasil pelatihan menunjukkan adanya peningkatan yang signifikan dalam rata-rata kemampuan STEM peserta pelatihan, dengan peningkatan sebesar 38,15%. Selain itu, serangkaian kegiatan telah dilaksanakan secara efektif, yang menghasilkan tingkat kepuasan peserta pelatihan melebihi 50% yang berkaitan dengan materi pelatihan, pengajar, dan peralatan pembelajaran. Hanya 17% dari peserta pelatihan yang menyatakan ketidakpuasannya terhadap waktu yang dialokasikan, terutama durasi pelaksanaan praktikum.

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INTRODUCTION

STEM is an educational framework integrating several subjects, namely science, technology, engineering, and mathematics, into a cohesive entity, and many developing countries have extensively adopted this STEM-based education (Sartika, 2019). In recent years, there has been a notable rise in research endeavors of integrating STEM-based education within the educational landscape of Indonesia, particularly from 2015 onwards (Farwati et al., 2021). A notable surge was observed throughout 2019-2020, resulting in a cumulative rise of around 74.1% compared to preceding years. This phenomenon indicates that there has been a significant uptake and implementation of STEM-based education in Indonesia. Nevertheless, based on the data acquired, the implementation of STEM-based education remains predominantly focused in Province East Java and West Java. A significant proportion, precisely 44%, of provinces, including the Kepulauan Riau province, have yet to adopt STEM-focused educational approaches.

The teacher's vision and comprehension bolster the facilitation of STEM-based education. However, a study of 117 scientific instructors found a lack of adequate understanding of STEM-based education among teachers in Indonesia (Nugroho et al., 2019). Furthermore, the insufficiency of suitable facilities and infrastructure impeded the successful execution of STEM education. In the present context, educators assert that STEM-based education can address the essential proficiencies required in the contemporary day, such as the ability to engage in creative and critical thinking, problem-solving, effective communication, and collaborative aptitudes. The assertion is supported by Hafni et al. (2020) and Permanasari et al. (2021) findings. Hafni et al. (2020) showed that STEM-based education could enhance students' problem-solving and critical-thinking abilities. Permanasari et al. (2021) assert that implementing STEM-based education can effectively stimulate students' ideation, mainly when they engage in project-based learning. The utilization of interactive learning technologies can facilitate the introduction of STEM subjects. Robots are a viable educational tool for STEM-focused instruction (Ponce et al., 2022).

Extensive study has been conducted on utilizing robots as educational tools for STEM-based learning, yielding compelling findings. As an illustration, the STEM-oriented educational robot AGROBOT-II, presented by Prayogo et al. (2020), and SpaceR, developed by Nata et al. (2021). Furthermore, Politeknik Negeri Batam (Polibatam) has also designed a STEM-based educational robot kit for high-school students in the Batam region, recognizing the benefits of robots as a medium for learning in STEM-based education. The robot kit that has been designed is additionally furnished with instructional resources that assist educators in facilitating the learning process. In addition to instructional resources, the robot will be engaged in a competition after the session to enhance the students' incentive to study. Chung et al. (2014) found that competition has the potential to stimulate and enhance students' motivation to learn. The educational robot that has been devised does not yield immediate advantages to the population, particularly the local people residing in Batam. The utilization of robots within the Polibatam Robotics Engineering Technology (RET) Study Program is now confined to providing support in students' learning process in the semester's preliminary stages. Community service initiatives were implemented to enhance the study's overall impact and value. This initiative pertains to the adolescent population attending secondary education institutions in the Batam region.

Multiple entities have implemented community service initiatives, enhancing students' competencies within educational institutions. For instance, Irawan et al. (2023) offers training programs to enhance proficiency in BOS (Bantuan Operasional Sekolah) fund management and reporting abilities. On the one hand, the training about soft skills was conducted by Juwito et al. (2022) and Kusumaningrum and Sulistyaningsih (2021). Juwito et al. (2022) offer educational programs to enhance students' personal branding and public speaking abilities. In her work, Kusumaningrum and Sulistyaningsih (2021) offer insights into the concepts of Pancasila and nationalism within the context of the digital era. Furthermore, Surahmat et al. (2023) conducted service activities within the realm of robotics, employing robots derived from research to serve as tourism assistants in various tourist destinations.

The primary objective of this community service initiative is to enhance the STEM proficiencies of students enrolled in a selected educational institution located in Batam. The endeavor consisted of providing robotics education to enhance STEM competencies among high school students, specifically focusing on traditional Pondok Pesantren (Islamic boarding schools). The instruction took place at the Pondok Pesantren Granada, among the Islamic boarding schools in Batam. The selection process was initiated in response to the request made by educators at the institution, who expressed a desire to incorporate STEM education into their curriculum to benefit their students. In addition, the selection of the community service site was based on the school's ongoing deficiency in supporting educational infrastructure. Provisions are made in the form of robot kits, educational materials, and evaluative test items to facilitate the training endeavors and assess the progress in students' comprehension pre-training and post-training. In addition to engaging in various activities, we administered questionnaires about disseminating instructional content to assess trainee's satisfaction with the training sessions.

This present study will delineate the various aspects of community service, organizing the explanations into distinct sections. The materials and methodologies employed in the service program will be examined later. Subsequently, the discourse examines the outcomes of the service actions, which will be closed in the conclusion section.

METHOD

The initiation of community service activities includes the first preparation of educational resources, encompassing robot kits, instructional materials, assessment items, and surveys. In addition, the training program incorporates a robot kit as an educational tool for trainees to engage in hands-on exercises. After completing the learning activities, an assessment was conducted to evaluate the student's abilities. This assessment involved administering pre-prepared test questions and assessing the student's satisfaction levels upon completing the activities.

The Angry Froggie Robot Kit

A wide array of media platforms can be employed to impart knowledge about STEM subjects to kids. For instance, the educational platform Noftiana et al. (2019) employs Scratch media to introduce and elucidate several physics ideas. Moreover, didactic tools as a practical medium are also highly prevalent. Muslim et al. (2018) use the Electric Motor Control (EMC) didactic package as a pedagogical tool to impart knowledge about electrical power systems. The motor didactic equipment has the potential to be enhanced with an embedded controller device, which can facilitate the learning process for additional students who are interested in acquiring knowledge about embedded system-based control systems, as suggested by Matsuzaki et al. (2019).

The provided training incorporated a hands-on component involving a robotic kit named "Angry Froggie", designed by robotics researchers affiliated with Polibatam. The visual representation and structural characteristics of the Angry Froggie device are depicted in Figure 1. Figure 1. (a) depicts the CAD design of the Angry Froggie, whereas Figure 1. (b) displays the constructed robot prototype. The comprehensive specs of the Angry Froggie utilized in training exercises are presented in Table 1. The Angry Froggie resembles several well-known robot kits, specifically BEAM and LEGO. The primary objective behind the design of these robots was to serve as an educational tool. However, the BEAM system, established by Boya-Lara et al. (2022), is primarily designed to cater to the needs of engineering students. In contrast, the LEGO set presented by Addido et al. (2023) emphasizes enhancing students' comprehension of Newtonian physics. In contrast to the pair mentioned above of robots, the Angry Froggie we developed was purposefully meant to serve as an educational tool tailored for high school pupils. The featured information for educational purposes primarily focuses on subjects linked to STEM.

(a) (b)

Figure 1. Visualization of (a) CAD design of Angry Froggie, and (b) prototype of Angry Froggie.

Table 1. Specifications of "Angry Froggie".

Specifications	Value
Dimension	13cm×12cm
Power Source	4.5 VDC Battery
Robot controller	Microcontroller ESP8266
Robot actuator	2×DC Motor with wheel
Robot sensor	HC-SR04 ultrasound sensor Three-channel infrared sensor Remote control receiver
Capabilities	Avoiding obstacles Following line Controlling by remote Generating music

During the training sessions, trainees must assemble Angry Froggie parts, establish connections between electronic components, and code the Angry Froggie controller. The Angry Froggie possesses several programmable capabilities, encompassing line following, obstacle avoidance, remote control adherence, and emission of sounds with distinct tonal qualities. Several of these features are absent in the robot kits mentioned above. In addition, the enraged amphibian Angry Froggie is outfitted with an ESP32 microcontroller with Wi-Fi and Bluetooth capabilities. Utilizing these two communication features enables the Angry Froggie to be programmed remotely, eliminating the need for physical cable connections.

Teaching Method and Materials

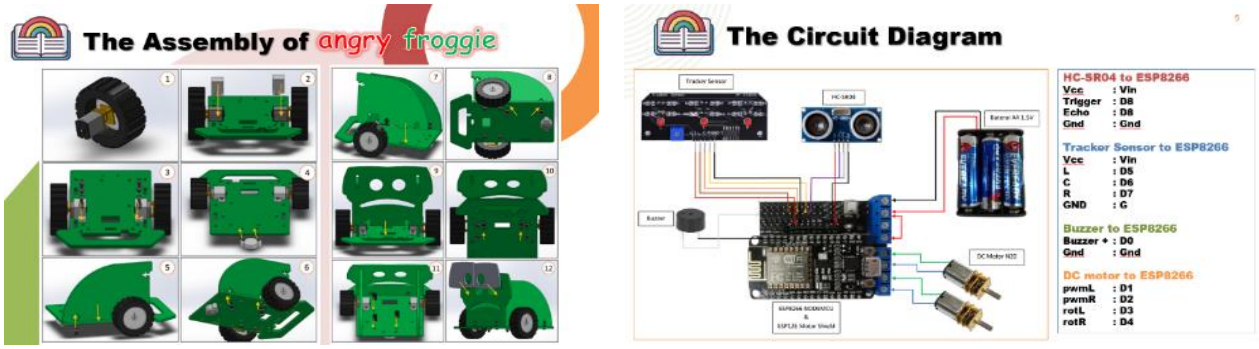
The Angry Froggie kit has educational resources specifically tailored for high school students and those new to robotics. Furthermore, this particular content possesses the potential to serve as a valuable instructional resource for educators seeking guidance on the intricacies of the learning process. The provided content encompasses elucidations regarding the constituent elements of robots, the many stages involved in robot assembly, the stages involved in installing electronic components, and the fundamental principles of robot programming.

The initial content provided to the trainee pertains to Angry Froggie's fundamental components and operational capabilities. The pedagogical approach employed for the dissemination of this content involves the utilization of lectures and discussions. Initially, the trainer elucidated the subject matter by employing the presentation slide, as depicted in Figure 2, where Figure 2 (a) and Figure 2 (b) depict the components comprising the Angry Froggie kit, including the body, sensors, and electronics circuits, both situated at the front and the back of the robot. The Angry Froggie body was constructed using acrylic material, with a specific design facilitating convenient assembly and disassembly. It was propelled by a pair of wheels attached to a direct current (DC) actuator. The sensors integrated into the Angry Froggie include a distance sensor for distance measurement and a 3-channel infrared sensor for line detection. Alongside incorporating sensors, the Angry Froggie was equipped with an electronics controller known as the NodeMCU ESP8266, which served as its principal controller. The controller mentioned above is also linked to the DC motor controller. The educational approach involves acquainting trainees with the names and functions of robot elements, facilitating their comprehension of fundamental aspects of robot components. The lecture segment focused on STEM's science and technology element, elucidating the operational principles of DC motors, motor drivers, sensors, and microcontrollers to the trainee.

(a) (b)

Figure 2. "Angry Froggie" (a) isometric view, and (b) view from the back.

After explaining the various components of the Angry Froggie and their respective functionalities, the training session will proceed with a practice component involving hands-on assembly. During the workshop, the trainer provided a concise overview of the many processes of assembling Angry Froggie, accompanied by presentation slides visually represented in Figure 3 (a). Initially, trainees receive instruction on the engineering components of robotics, encompassing the assembly of fasteners and the electronics integration of the robot. The presented slide includes a numerical code assigned to each stage of the robot assembly, positioned at the upper right corner of the picture, to reduce problems in installation. The assembly procedure commenced with affixing the Angry Froggie wheels onto the chassis, culminating in the attachment of the ultrasonic sensor holder, which serves as the visual apparatus of the robot. Subsequently, the implementation of the electronic system may commence. In electronics components installation, circuit designs are presented visually, as depicted in Figure 3 (b), as instructional aids for trainees. Trainees are mandated to engage in collaborative, hands-on exercises, including the assembly of robots. Consequently, the session provides an opportunity to develop and enhance the student's communication and collaboration skills.

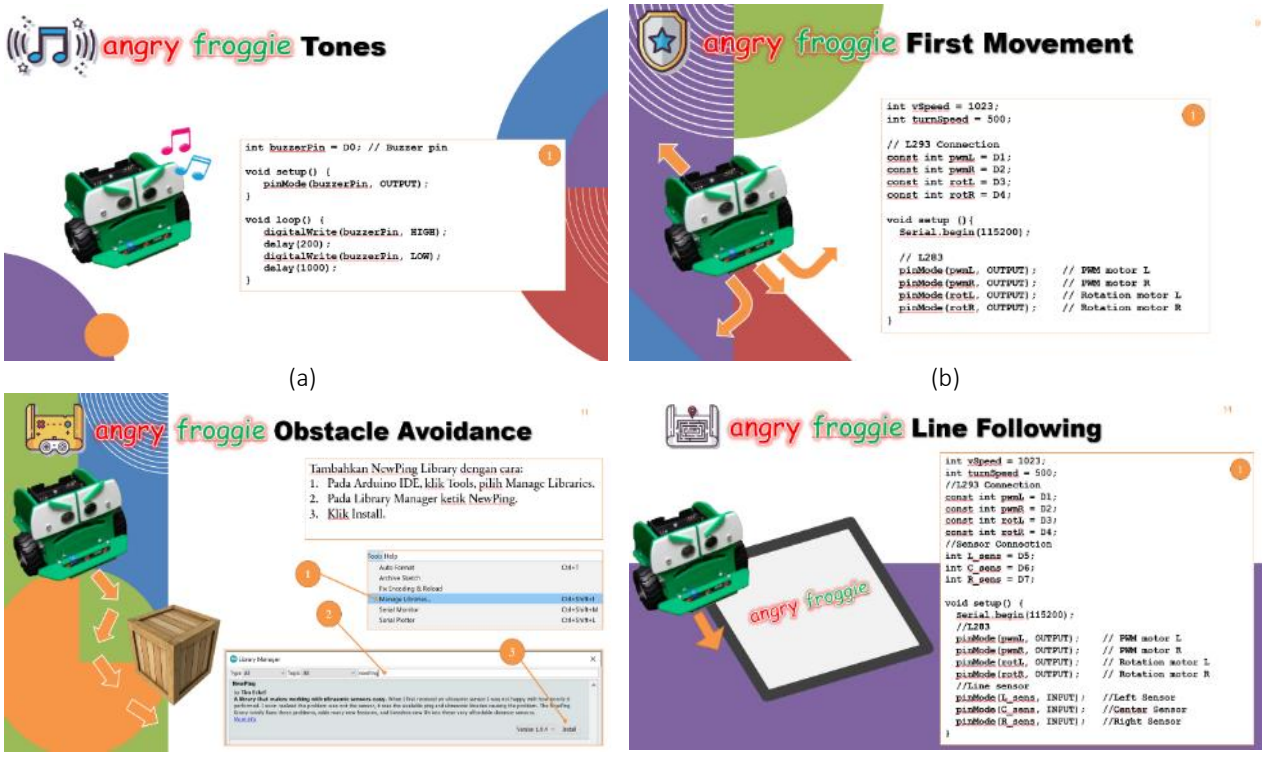


(a) (b)

Figure 3. Angry Froggie assembly process on (a) mechanics components, and (b) electronics components.

The most recent instructional session delivered by the trainer focused on fundamental robot programming. The teaching materials incorporated a crucial program in this instructional session. The objective was to develop a fundamental comprehension of programming and algorithms, encompassing STEM's technological and mathematical aspects. During this programming instructional session, the instructor will utilize Arduino as an Integrated Development Environment (IDE) for program creation. Arduino is commonly employed as an instructional tool in the STEM domain because of its widespread usage as an Integrated Development Environment (IDE), as evidenced by the research undertaken by Pech and Novak (2020) and Prihatiningrum et al. (2022).

The instructional resources utilized for programming are depicted in Figure 4. In Figure 4 (a), a pedagogical activity is depicted wherein the robot generates auditory stimuli. This instructional material introduced trainees to fundamental programming, including debugging and transferring source code onto the Angry Froggie. The programming of the basic Angry Froggie movement was implemented following the depicted procedure in Figure 4 (b). During this instructional session, trainees were introduced to the fundamental principle of robot locomotion, which involves the rotation of two DC motors. Subsequently, the trainees get acquainted with sensor coding and fundamental algorithms through the provided instructional material. The sensors and primary algorithmic material are depicted in Figure 4 (c). In this instructional material, trainees were required to use ultrasonic sensor readings to program Angry Froggie to navigate obstacles effectively. In addition, the previous course encompassed the coding for the line follower, as depicted in Figure 4 (d) of the presentation slides. In the last session, trainees must develop a program for Angry Froggie to track a line three-channel infrared.



(a) (b)

(c) (d)

Figure 4. Coding lesson for (a) generating tone, (b) rotating the motors, (c) avoiding objects, and (d) following the track.

Evaluation Methods

Pre-assessment and post-assessment were administered to the trainees of the training program in order to assess the efficacy of the training program. The pre-assessment and post-assessment comprise a set of 10 questions related to the STEM field, with both assessments featuring identical question content. Trainees must ensure the completion of the examination within a time frame of 20 minutes. The pre-assessment administration occurred before the training commenced, while the post-assessment was administered after the completion of the program. The pre-assessment and post-assessment were employed to assess the trainee's acquired knowledge after the training. In conjunction with administering pre-assessment and post-assessment, trainees in the training program were also provided with a feedback form after finishing the training program. The present feedback form encompasses the feedback provided by trainees regarding many aspects of the training program, including their answers to the presenters, material, training duration, equipment, and any further ideas on the training activities.

Training Participants

Specific STEM education programs prioritize the instruction and development of high school pupils. Specialized training programs exclusively cater to female pupils (Lou et al., 2014; Olmedo-Torre et al., 2018). In this program, we targeted participants from Islamic Boarding School students. A total of 29 students were present from the Pondok Pesantren Granada as trainees. **Error! Reference source not found.** illustrates the allocation of participation through a pie chart. It can be observed that most individuals who took part in the training exercise were enrolled in the XI grade. Approximately 15 individuals were reached, seven belonging to grades X and XII. During the classroom period, the trainees were assigned to ten separate groups by randomly distributing the participants within each group. An assistant trainer, a freshman in the RET Study Program at Polibatam, accompanied every group.

Figure 5. Trainees Distribution.

RESULTS AND DISCUSSION

This part describes the outcomes and comments derived from the robotics training session. Initially, the outcomes of executing the conducted operations are delineated. Next, we shall elucidate the outcomes associated with the augmentation of knowledge acquisition among the individuals undergoing training. The concluding section provides an overview of the satisfaction of the conducted activities. The subsequent sub-section comprehensively explains the results obtained and their subsequent discussion.

Training Activities

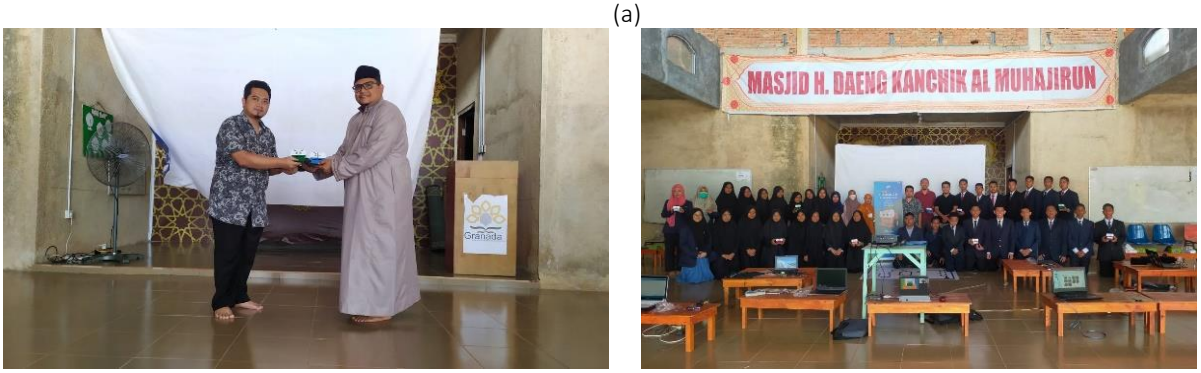
Batam City has implemented many programs aimed at enhancing STEM capabilities. The Project-Based Learning (PjBL) model was introduced for students in junior high school (SMP) (Storina, 2022). In addition, an assessment was conducted on the efficacy of educational resources on hydrocarbon content among high school students in Batam (Laila et al., 2022). Lastly, A training session on Arduino programming was administered to madrasah students in Batam City (Candra & Pangaribuan, 2023). Our activity is proposed for an Islamic Boarding School named Pondok Pesantren Granada. The Pondok Pesantren Granada, located in Kampung Jabi, Batam City, hosted robotics training classes on Saturday,

November 19, 2022. The gathering was attended by 29 students, three lecturers, and one lecturer from Pondok Pesantren Granada. The school's mosque room served as the venue for many activities. The activities commence at 9:00 a.m. and conclude at 4:00 p.m., with a designated interval from 12:00 to 13:00. The activity in question is visually represented in Figure 6 and Figure 7. The commencement of the activity was initiated by the head of the Pondok Pesantren Granada and trainer representatives from the Polibatam, as indicated in Figure 6 (a). Following the commencement of the inaugural ceremony, subsequent training activities were initiated. Figure 6 (b) illustrates an activity focused on delivering instructional information. Figure 7 (a) showcases a hands-on session centered on installing the Angry Froggie educational robot. Upon concluding all the training activities, the community service committee, trainer, and trainees assembled for a collective photograph, visually represented in Figure 7 (b).

(a) (b)

Figure 6. Training activities, (a) opening event, and (b) delivering the training.

(a)



(b)

Figure 7. Training activities, (a) hands-on practice, and (b) closing event.

Enhancing the Knowledge of Trainees

The findings from the pre-assessment and post-assessment inquiries demonstrated a noteworthy augmentation in the trainees' fundamental comprehension of the subject matter. According to the statistical data, trainees' mean score before their involvement in the training program was 59.66 points. In the interim, the mean score of trainees increased to 82.41 points after participating in the training program. The pupils had a significant exponential growth of around 22.76 points after participating in the training program. Based on the obtained results, it can be inferred that the exercise, as mentioned earlier, led to a significant enhancement of the trainees' capacity, with an observed rise of 38.15%.

The graphical representation of the enhancement in assessment score based on class level is depicted in Figure 8. The most significant improvement in comprehension was observed in the eleventh grade, exhibiting a cumulative gain of approximately 59.76%. Prior to the commencement of the training, the mean score attained by the trainee in class XI was recorded as 54.67. However, after they participated in the training, a notable increase in the average score was seen, reaching around 87.33. Although grades X and XII demonstrate a comparable enhancement in exam scores, the

percentage increase in grade X was approximately 18.60%, while class XII exhibited a slightly higher increase of approximately 18.75%.

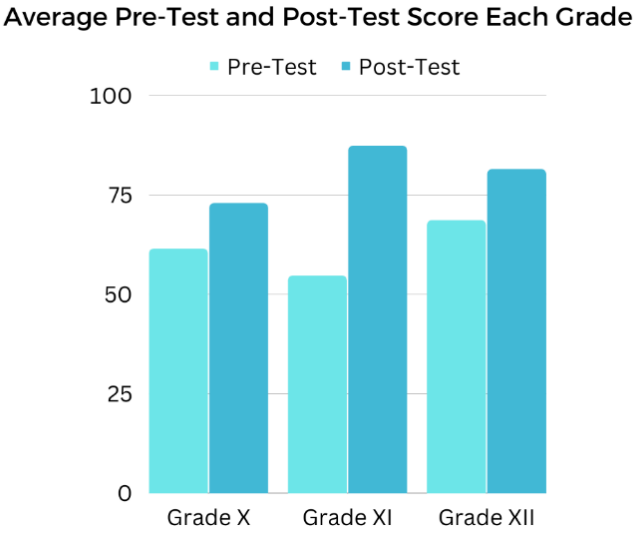


Figure 8. The mean score of pre-assessment and post-assessment of each grade.

Levels of Satisfaction

The training satisfaction of trainees is depicted in Figure 9 through a pie chart. The above findings were derived from a survey administered to a cohort of 29 individuals undergoing training. The questionnaire responses were categorized into four sections: trainer capabilities, equipment, materials quality, and course duration. The questionnaire findings from the trainees are depicted in Figure 9. Based on the acquired data, it can be inferred that most trainees expressed satisfaction with the conducted activities.

Concerning the caliber of the content offered, around 59% of trainees indicated that the provided material was of exceptional quality. Furthermore, none of the trainees indicated that the material was deficient. In contrast, according to the speaker's perspective, a majority of 59% of the trainees expressed that the presenter effectively delivered the content. The remaining 41% of trainees indicated that the trainer effectively delivered the material. Approximately 65% of trainees indicated that the equipment provided was sufficient to implement the training program. However, concerning the amount of training, approximately 17% of the trainees expressed that the allocated time for training was inadequate. This finding was corroborated by four trainees who expressed dissatisfaction with the insufficient duration of the training program. In addition, it was noted by four trainees that the hands-on duration in this activity was insufficient. The results obtained from the questionnaire function as a standard against which the efficiency of the provided training can be evaluated, as well as a reference point for improving future community service initiatives.

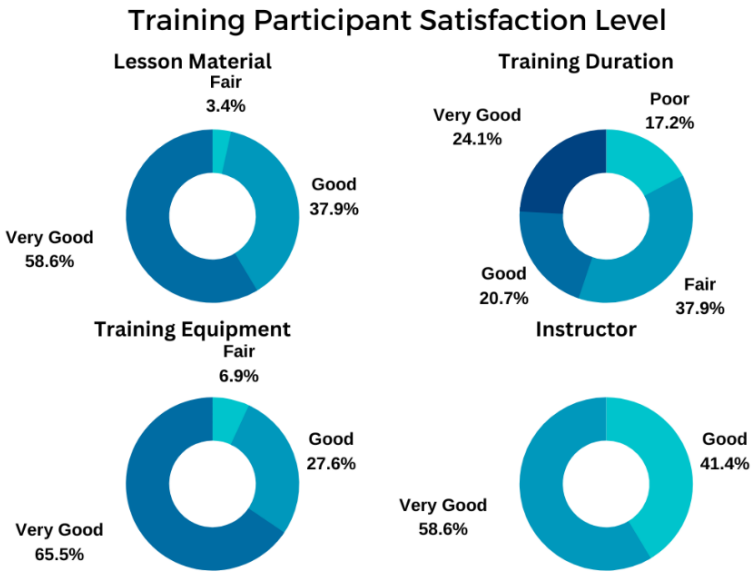


Figure 9. Training Satisfaction Level.

CONCLUSION

This study examines the implementation of a robotics training program at the Pondok Pesantren Granada to enhance students' comprehension of STEM subjects, specifically focusing on community service activities. Consequently, there was a notable enhancement of approximately 38.15% in the average trainees acquired knowledge as a direct outcome of community service activities. The data analysis revealed that the training activity significantly enhanced the trainee's science, technology, engineering, and mathematics (STEM) knowledge. Furthermore, the trainees expressed overall satisfaction with the conducted instruction, encompassing STEM and other areas of study. The data analysis determined that over 50% of trainees were satisfied with the training materials, presenters, and equipment quality. Nevertheless, a notable proportion of trainees, precisely 17% of the respondents, expressed dissatisfaction with the duration of the training they received, deeming it inadequate. In addition, some trainees expressed a need for further optimization of the time duration, particularly regarding the hands-on component. The service team will assess this questionnaire's answers and inform future enhancements in community service endeavors.

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