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STEM-robotic: Enhancing teachers' competence in implementing STEM and coding

Falenthino Sampouw[1], Andi Fajeriani Wyrasti[2], Faisal[3], Irfan Irnandi[4], Benidiktus Tanujaya[5], Jeinne Mumu[6], Maryo Sopater Istia[7], Haryanto[8], Riris Indarwati[9], Sisilia Almandha[10], Dewi Brilliana Putri[11]
[1,2,3,4,5,6,7,8,9,10,11] Universitas Papua, Manokwari, Indonesia
f.sampouw@unipa.ac.id[1], a.wyrasti@unipa.ac.id[2], f.faisal@unipa.ac.id[3], i.irnandi@unipa.ac.id[4], b.tanujaya@unipa.ac.id[5], j.mumu@unipa.ac.id[6], m.istia@unipa.ac.id[7], h.haryanto@unipa.ac.id[8], ririsindarwati531@gmail.com[9], sisiliaalmandha70458@gmail.com[10], dp3818626@gmail.com[11]

ABSTRACT

The STEM-Robotics training at YPPK St. Thomas Aquino Junior High School in Kaimana, West Papua, was conducted to address teachers' low understanding of STEM and coding concepts and the suboptimal utilization of robotics facilities in schools. This program aims to improve teachers' understanding of STEM learning, coding competency, and attitudes toward the implementation of STEM-Coding. The program was implemented using a service-learning approach involving 28 teachers, 4 lecturers, and 3 students across five stages: needs identification, collaborative planning, practice-based implementation, critical reflection, and evaluation. Data were collected using a validated questionnaire and analyzed descriptively. The training results showed that teachers' understanding of STEM learning reached 52% in the moderate category and 48% in the high category. Teachers' understanding of coding reached 4% in the moderate category and 96% in the high category. In comparison, positive attitudes toward STEM-Coding learning reached 11% in the moderate category and 89% in the high category. Overall, all program success indicators were met, with more than 85% of teachers in the moderate-to-high category across all measured aspects. This program is effective in improving teacher competency and supporting the development of technology-based learning in areas with limited access to education.

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ABSTRAK

Pelatihan STEM-Robotics di SMP YPPK St. Thomas Aquino Kaimana, Papua Barat, dilaksanakan untuk mengatasi rendahnya pemahaman guru terhadap konsep STEM dan coding serta belum optimalnya pemanfaatan fasilitas robotik di sekolah. Program ini bertujuan untuk meningkatkan pemahaman guru tentang pembelajaran STEM, kompetensi coding, serta sikap terhadap implementasi STEM-Coding. Program dilaksanakan menggunakan pendekatan service learning yang melibatkan 28 guru, 4 dosen, dan 3 mahasiswa melalui lima tahapan, yaitu identifikasi kebutuhan, perencanaan kolaboratif, pelaksanaan berbasis praktik, refleksi kritis, dan evaluasi. Data dikumpulkan menggunakan kuesioner yang telah divalidasi dan dianalisis secara deskriptif. Hasil pelatihan menunjukkan bahwa pemahaman guru terhadap pembelajaran STEM mencapai 52% pada kategori sedang dan 48% pada kategori tinggi. Pemahaman guru terhadap coding mencapai 4% pada kategori sedang dan 96% pada kategori tinggi, sedangkan sikap positif terhadap pembelajaran STEM-Coding mencapai 11% pada kategori sedang dan 89% pada kategori tinggi. Secara keseluruhan, seluruh indikator keberhasilan program tercapai dengan lebih dari 85% guru berada pada kategori sedang hingga tinggi pada seluruh aspek yang diukur. Program ini efektif dalam meningkatkan kompetensi guru dan mendukung pengembangan pembelajaran berbasis teknologi di wilayah dengan keterbatasan akses pendidikan.

Kata Kunci: *koding; kompetensi guru; STEM; STEM-Robotics*

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INTRODUCTION

The implementation of the Science, Technology, Engineering, and Mathematics (STEM) approach in education has demonstrated significant potential to foster and enhance 21st-century skills (Arlinwibowo et al., 2021; Puspandari et al., 2025). The integration of STEM into the learning process has been shown to improve students' problem-solving abilities, critical thinking skills, and creativity (Anita et al., 2021; Tiryaki & Adıgüzel, 2021; Vistara et al., 2022). In addition, STEM-based learning has also been found to enhance students' self-efficacy (Kusyanto et al., 2022; Nu'man et al., 2021; Tiryaki & Adıgüzel, 2021). Despite these positive potentials, the implementation of STEM learning still faces several challenges. Previous studies have revealed that teachers experience difficulties in designing STEM-based instruction, primarily due to limited foundational understanding of STEM concepts and insufficient knowledge of the technological and engineering aspects involved in the learning process (Nu'man et al., 2021; Sukarman & Retnawati, 2022).

Furthermore, implementing STEM-based learning also encounters challenges in selecting appropriate assessment techniques to evaluate the learning process. These findings are consistent with interview results conducted with the principal of Saint Thomas Aquino Junior High School in Kaimana, who stated that no teachers at the school had implemented the STEM approach in their classroom instruction due to their limited understanding of fundamental STEM concepts. In addition, teachers had not yet participated in any STEM-related training programs, either organized by the school or by the Kaimana Regency Education Office. STEM learning can be implemented through various instructional media and project-based activities, such as eco-enzyme and waste-recycling projects, as well as other contextual learning experiences. One alternative activity that can be integrated into STEM learning is robotics.

However, the use of robotics as a project within STEM-based learning remains relatively limited, particularly in Kaimana Regency, where robotics activities in educational settings have rarely, if ever, been introduced (Maqruf et al., 2024; Nehru et al., 2023). The integration of robotics projects into STEM learning provides numerous educational benefits (Chung et al., 2014). This is because robotic construction activities inherently involve coding processes (Latip et al., 2020). Consequently, such learning experiences directly require coding competencies and introduce teachers to various coding applications for educational practice. One of the major challenges in STEM-Robotics learning is the availability of facilities, including computers and robotic equipment. Survey results indicated that Saint Thomas Aquino Junior High School in Kaimana possesses adequate computer facilities, and teachers are already familiar with their use.

In addition to having a computer laboratory, the school also owns a set of robotic equipment. According to the school principal, the robotic equipment was procured to support learning resources and exploratory robotics activities within the school. Furthermore, the principal expressed the school's intention to establish an extracurricular robotics program. However, this initiative has not yet been implemented because no teachers currently possess sufficient competence to use the robotic equipment effectively. The limited use of robotic equipment at Saint Thomas Aquino Junior High School in Kaimana is primarily due to teachers' limited knowledge of STEM implementation and coding. The school, which is managed by the Catholic Education Foundation under the Diocese of Manokwari-Sorong, remains subject to the educational policies implemented by the Kaimana regional government.

The local government also regulates educational funding at the school. For approximately the past ten years, the Kaimana regional government has implemented a free education program, meaning that all early childhood, elementary, junior high, and senior high/vocational schools, both public and private, are prohibited from charging students educational fees. Educational expenses covered by the regional

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government include student uniforms and textbooks, while honorary teachers' salaries are funded through local government contracts. Consequently, schools are not permitted to collect additional educational fees. Under these conditions, operational funding largely depends on the School Operational Assistance Fund (BOS) program. Although some funding exists for teacher professional development, such support at the school remains highly limited.

Moreover, Kaimana's geographical location limits access to professional training programs because transportation to and from the region requires substantial financial resources. In addition, Kaimana Regency does not yet have teacher training institutions or higher education institutions specializing in teacher education, further limiting access to professional development opportunities. As a result, teachers primarily rely on training programs organized by the Kaimana Education Office. Considering the school's strong potential in human resources and available facilities, which are not aligned with adequate access to professional knowledge and training, interventions aimed at teacher professional development and instructional improvement are urgently needed at SMP YPPK St. Thomas Aquino Kaimana. Therefore, implementing a STEM-Robotics training program is considered essential for enhancing teachers' understanding of STEM concepts and improving their coding competencies.

Literature Review

STEM Learning

STEM learning is an interdisciplinary pedagogical approach that integrates science, technology, engineering, and mathematics through meaningful problem-solving, design-based inquiry, experimentation, and the application of concepts to real-life situations. Rather than treating the four disciplines as separate school subjects, STEM learning positions students as active problem solvers who investigate phenomena, design solutions, test prototypes, analyze data, and communicate their reasoning through collaborative activities (Kelley & Knowles, 2016). In classroom practice, STEM activities commonly include project-based learning, engineering design challenges, scientific investigation, mathematical modeling, technology-assisted experimentation, and contextual problem-solving that connects school knowledge with community needs. Previous studies have shown that STEM learning can strengthen students' critical thinking, creativity, collaboration, communication, scientific literacy, and problem-solving competence, especially when learning tasks are authentic and require students to connect concepts across disciplines (English, 2016; Li et al., 2020).

In Indonesia, STEM education has also been increasingly discussed as a promising approach to support 21st-century learning, although its implementation still depends on teachers' understanding, access to learning resources, school infrastructure, and professional development opportunities (Ilma et al., 2023; Permanasari et al., 2021). Therefore, teachers' competence is a central factor in the successful implementation of STEM. Teachers are expected not only to master subject matter but also to design interdisciplinary learning scenarios, facilitate inquiry and engineering design processes, use technology meaningfully, guide collaboration, conduct formative assessment, and connect STEM projects with students' local contexts. Recent studies on STEM teacher competence emphasize that professional development should help teachers move from merely understanding STEM as a concept to planning, implementing, evaluating, and reflecting on integrated STEM instruction in authentic classroom settings (Margot & Kettler, 2019; Purmanna et al., 2025).

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STEM and Coding in Robotics Activity

Coding in school learning can be understood as the process of creating, testing, revising, and applying algorithmic instructions to solve problems, produce digital artifacts, or control technological systems. In the Indonesian context, coding has gained stronger policy relevance through the national direction for Coding and Artificial Intelligence learning, which emphasizes computational thinking, digital literacy, programming algorithms, data analysis, and ethical use of technology across basic and secondary education. The 2025 subject guide for Coding and Artificial Intelligence states that the subject is intended to help teachers understand learning outcomes, plan instruction, and develop technology-based learning that is contextual, student-centered, and responsive to school characteristics; it also identifies coding and AI learning outcomes across phases C, D, E, and F, with emphasis on computational thinking, digital literacy, algorithms, programming, data analysis, and AI ethics.

This policy direction creates strong potential to integrate coding with STEM-based robotics activities in schools, because robotics provides a concrete and engaging context in which students can simultaneously apply scientific concepts, mathematical reasoning, engineering design, and computational logic. In robotic activities, students do not only "write code"; they identify problems, design mechanical structures, connect sensors and actuators, develop algorithms, upload programs, observe robot behavior, debug errors, and refine their designs based on evidence. Such activities make abstract STEM concepts visible and manipulable, for example, when students use distance sensors to understand measurement, motor speed to explore ratio and proportionality, or line-following robots to connect logic, data input, control systems, and iterative design.

International studies indicate that educational robotics can support computational thinking, problem solving, motivation, collaboration, and STEM attitudes when activities are designed as structured, inquiry-oriented, and reflective learning experiences (Ching & Hsu, 2023; Zhang et al., 2021). Indonesian studies and community-based programs also suggest that STEM, coding, and robotics training can improve teachers' readiness, perceptions, and practical skills for implementing technology-rich STEM learning. However, challenges remain regarding infrastructure, teacher confidence, learning time, and sustainable mentoring (Purmanna et al., 2025). Therefore, future research and development in Indonesia may focus on locally relevant robotic learning modules, low-cost robotics kits, unplugged-to-plugged coding pathways, teacher professional development models, assessment instruments for computational thinking and STEM competence, and inclusive robotics activities that can be implemented in diverse school contexts, including schools with limited digital facilities.

METHODS

The community service program was implemented at Saint Thomas Aquino Junior High School in Kaimana, West Papua. This school is one of the private secondary schools in Kaimana Regency that demonstrates considerable potential for implementing STEM- and coding-based learning. The school's robotic equipment supports this potential; however, these resources have not yet been fully utilized. The community service program involved all teachers across various subject areas, for a total of 28 participants. In addition, the program engaged four lecturers who served as facilitators or trainers, as well as three university students who acted as assistants during the activities.

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The implementation of this community service program adopted a service-learning approach. This approach was selected because it effectively integrates learning experiences with meaningful community engagement, enabling teachers as participants not only to acquire new knowledge but also to internalize it through direct practice relevant to their classroom contexts. The stages of the program implementation, in accordance with the service-learning framework, included identifying the community's learning needs, collaboratively planning activities, conducting practice-based learning, engaging in critical reflection on the experiences gained, and conducting evaluations to enhance participants' competencies. An overview of the implementation of this community service program is presented in **Figure 1**.

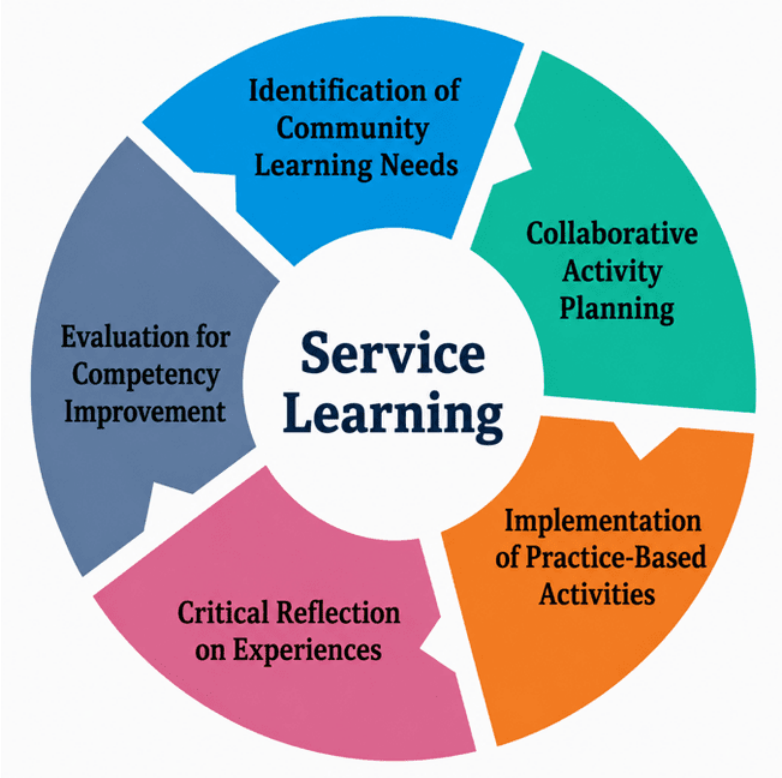

Figure 1. Service Learning Process
Source: Adapted from Mutambara (2023)

During the stage of identifying the community's learning needs, the program team mapped the actual problems and educational needs faced by Saint Thomas Aquino Junior High School. This process involved observations, interviews, and group discussions to ensure that the designed activities were aligned with the school's contextual needs. The subsequent stage involved collaborative planning for activities, in which lecturers and university students worked together to design the program and prepare the necessary instructional and robotic equipment. At this stage, the learning objectives, implementation strategies, division of responsibilities, resource allocation, and indicators of success were also determined. The third stage involved implementing practice-based activities, during which the team of lecturers and students conducted direct training sessions at the school. These activities were highly applicable and provided participants with authentic learning experiences.

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Following the implementation phase, a critical reflection process was conducted. Reflection activities were carried out through discussions, allowing participants to reconstruct their practical experiences into deeper conceptual understanding. The final stage involved an evaluation aimed at improving participants' competencies. The evaluation encompassed two dimensions: the assessment of teachers' learning achievements and the program's broader impact on the school community. The evaluation results were used to assess the program's effectiveness, identify existing limitations, and inform improvements to future community service activities. This community service program focused on three main intended outcomes: teachers' understanding of STEM learning, teachers' understanding of coding, and teachers' positive attitudes toward STEM-Coding learning.

These three aspects were measured using a five-point Likert-scale questionnaire that two experts had validated. The questionnaire was administered during the evaluation stage to assess the program's effectiveness and success. The criteria for determining the success of the program were established as follows: 1) at least 85% of teachers achieving a minimum of the moderate category in their understanding of STEM learning concepts; 2) at least 85% of teachers achieving a minimum of the moderate category in their understanding of coding; and 3) at least 85% of teachers achieving a minimum of the moderate category in demonstrating positive attitudes toward the implementation of STEM-Coding learning in classroom practices. The collected data were categorized into low, moderate, and high levels based on score intervals derived from the ideal mean and standard deviation.

RESULTS AND DISCUSSION

Results

Identification of Community Learning Needs

The process of identifying community learning needs was conducted through telephone interviews and discussions involving the principal of SMP YPPK St. Thomas Aquino Kaimana. The discussions focused on three main topics: the school's condition, teachers' competencies, and the implementation of STEM learning in classroom practices. Discussions regarding the school's condition examined its profile, educational facilities, and institutional management. The topic of teachers' competencies examined the implementation of classroom instruction and the ways teachers engaged in professional development activities. Meanwhile, the discussion on the implementation of STEM learning examined teachers' initial understanding of STEM education and the extent to which STEM-based learning had been applied in classroom settings.

Based on the initial interviews and discussions with the principal of SMP YPPK St. Thomas Aquino Kaimana, several important findings emerged that became the foundation for implementing the community service program. The school is located in Kaimana Regency, West Papua, specifically on Lettu Idrus Street, Kaimana Subdistrict, Kaimana District. Established in 2004, the school has adequate facilities to support teaching and learning, including a well-equipped library and sufficient computers. In addition, the school owns one set of robotic equipment; however, it has not yet been used. The robotic equipment was originally purchased following a promotional activity conducted at the school.

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The primary reason the available robotic equipment had not been utilized was the absence of teachers capable of operating it. Furthermore, the geographical location of Saint Thomas Aquino Junior High School in Kaimana limits access to professional training programs. Access to and from the region entails considerable transportation costs, which constrain teachers' opportunities to participate in external professional development activities. In addition, Kaimana Regency does not yet have teacher training institutions or higher education institutions specializing in teacher education, thereby limiting teachers' access to competency development programs. Consequently, teachers largely depend on training programs organized by the Kaimana Education Office.

The interviews also revealed that teachers' classroom instruction was relatively varied. Teachers were already familiar with and had applied several instructional strategies, such as problem-based learning, discovery learning, inquiry learning, and team games tournaments. However, project-based learning approaches were still rarely implemented. Similarly, although teachers had previously heard about STEM learning, they had not yet fully understood the conceptual foundations of STEM education or how STEM-based instruction could be effectively implemented in classroom practices.

Collaborative Activity Planning

Based on the identified community learning needs, specific problems, proposed solutions, and targeted outcomes were systematically mapped. This mapping served as the foundation for designing the community service program and is presented in Table 1 below.

Table 1. Specification of Problems, Solutions, and Targeted Outcomes

No	Problems	Solution	Target
1	Limited understanding of STEM learning concepts led to a lack of STEM implementation among teachers.	Enhancing teachers' understanding of STEM learning concepts and their implementation through training activities.	At least 85% of teachers demonstrate adequate understanding of STEM concepts and their implementation.
2	Teachers lacked competencies in robotic coding, resulting in the robotic equipment remaining unused.	1. Introducing coding applications compatible with the available robotic equipment; 2. Improving teachers' coding competencies.	At least 85% of teachers can perform coding activities with Studuino.
3	No previous training, workshops, or professional development programs related to STEM-Coding Robotics had been conducted for teachers at Saint Thomas Aquino Junior High School in Kaimana.	Conducting STEM-Coding Robotics training at the school.	At least 80% of teachers demonstrate positive attitudes toward implementing STEM-Robotics learning in classroom practice.

Source: Authors' analysis 2025

At this stage, a range of preparations was carried out, from program planning and coordination among team members to technical preparation. The community service team held four coordination meetings to discuss detailed activity planning, the division of roles and responsibilities, and the preparation of modules and instructional materials for use during program implementation.

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(a) (b)

Figure 2. Preparation and Equipment Inspection Activities: (a) module development and (b) robotic equipment inspection
Source: Community Service Documentation, 2025

Prior to implementing the training activities, the community service team conducted various technical and academic preparations to enhance the program's effectiveness. These activities included developing instructional modules, preparing learning materials, and inspecting the functionality of the robotic equipment used during the training sessions. **Figure 2** presents several preparation activities carried out to ensure that the STEM-Robotic program could be implemented optimally and in accordance with the participants' learning needs. The preparation process was conducted to ensure the availability of properly functioning equipment and to support the effectiveness of the community service activities implemented.

Implementation of Practice-Based Activities

This stage began with a socialization session conducted with the partner institution, namely SMP YPPK St. Thomas Aquino Kaimana. During this session, the community service team explained the program's primary objectives in detail. The program was planned to be implemented over five days, with teachers as the main participants and several students participating in the STEM-Robotics trial activities. At the end of the program, the team also planned to donate one unit of robotic equipment along with a set of instructional guidebooks to the school. The implementation of the practice-based training activities began with the delivery of materials on STEM learning, coding, and the integration of STEM-Robotics activities through coding. The training employed various instructional methods, including lectures, discussions, simulations, assignments, and intensive mentoring.

All teachers and several student representatives from Saint Thomas Aquino Junior High School in Kaimana attended the STEM and robotics coding training. On the first day, the training focused on introducing the fundamental principles of STEM learning, providing inspiration for interdisciplinary project ideas, and assigning independent tasks to participants. During the implementation stage, participants were actively engaged in various STEM and robotics coding activities designed to strengthen their understanding of coding, logical reasoning, and problem-solving skills. The activities gradually progressed from introductory programming exercises to more complex robotic applications using the Studuino platform. As shown in **Figure 3**, teachers participated in hands-on coding practices, robotic simulations, and robotic car testing activities that encouraged collaborative learning and authentic STEM experiences.

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Figure 3. STEM-Robotic Coding Activities: (a) application and robotic introduction, (b) LED coding activity, (c) pedestrian traffic light coding, and (d) robotic car testing
Source: Community Service Documentation, 2025

The second day of the training focused on installing the Studuino application, introductory coding concepts, and the robotic components used to operate the ARTEC robotic system (**Figure 3(a)**). The installation process was completed, as indicated by the studio application's ability to detect responses from the robotic device, as evidenced by the blinking green LED indicator. The Studuino application is based on Scratch programming and utilizes a drag-and-drop interface. The second-day training also involved operating the Studuino application through simple coding exercises, particularly programming the LED lights to turn on and off (**Figure 3(b)**). Participants were expected to create code to control the LED lights at specified time intervals. At this stage, all participants completed the simple coding tasks and managed to activate the LEDs. However, several challenges were observed during the training. Some participants were not yet familiar with Scratch-based applications that use drag-and-drop programming, which required additional adaptation and practice. In addition, several participants had difficulty translating their ideas for activating LEDs into logical programming sequences or algorithms within the application.

Consequently, the facilitators provided intensive guidance and scaffolding to help participants better understand how to transform conceptual ideas into algorithmic structures. On the third day, the training continued with coding activities focused on developing a pedestrian traffic light simulation (**Figure 3(c)**). At this stage, the complexity of algorithm construction was gradually increased. Participants were introduced to simplified coding logic using conditional statements such as "if-then" structures. Through this activity, both teachers and students were encouraged to strengthen their logical reasoning skills as expressed through algorithmic thinking. The fourth day of the training continued the robotic coding activities, focusing on operating DC motors and constructing robotic vehicles. During this session, participants were expected to program robots equipped with two DC motors. Teachers and students were also instructed to design and build robots that would later be tested in a competitive activity (**Figure 3(d)**).

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Participants were challenged to regulate the speed and directional accuracy of their robots to ensure stable straight-line movement.

Critical Reflection on Experiences

During the critical reflection stage, teachers, as participants, were asked to provide direct reflections based on their experiences during the training activities. A summary of the teachers' reflections is presented in the following table.

Table 2. Summary of Teachers' Reflections

No	Before Participating in the Training	Summary of Teachers' Reflections
1	Limited understanding of STEM learning	- After participating in the training, teachers realized that STEM learning can be highly contextual and engaging when implemented in classroom practices. - Teachers recognized that STEM learning supports holistic learning principles because it integrates multiple disciplines within a single learning experience. - Teachers also realized that STEM learning requires collaboration, which aligns with the cocurricular curriculum implemented at the school.
2	Limited understanding of coding	- Teachers realized that coding is not limited to informatics or engineering fields but can be learned and taught at all educational levels. - Teachers recognized that coding does not necessarily require sophisticated applications or high-performance computers but can be implemented through simple classroom activities. - Teachers also understood that coding activities involve not only writing commands or algorithms, but also developing logical, critical, and creative thinking skills.
3	Attitudes toward STEM-Coding learning	- Teachers realized that STEM-Coding learning through robotic activities supported by simple applications is accessible, engaging, and enjoyable. - Despite limited facilities, teachers expressed interest in implementing STEM-Coding learning in their classrooms and believed that students would respond positively to such activities. - Teachers also expressed expectations for similar future training programs to enhance their knowledge and competencies further.

Source: Authors' analysis 2025

Based on **Table 2**, the STEM-Coding training program had a significant positive impact on teachers' understanding and attitudes. Prior to the training, teachers demonstrated a limited understanding of STEM and coding concepts and showed relatively low enthusiasm for their implementation in classroom practice. However, after participating in the program, teachers recognized that STEM learning is contextual, enjoyable, and capable of supporting holistic and interdisciplinary learning experiences. They also realized that coding is not exclusively associated with informatics disciplines, but can be taught in simple ways across all educational levels to foster logical reasoning and creativity. Furthermore, teachers became more confident and motivated to implement STEM-Coding learning in their classrooms despite existing facility limitations, as they perceived strong potential to increase students' interest and engagement in learning activities.

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Evaluation for Competency Improvement

As the final stage of the community service program, an evaluation was conducted to assess the extent to which the activities' objectives had been achieved and their impact on improving teachers' competencies. The evaluation focused on three primary aspects: teachers' understanding of STEM learning, teachers' understanding of coding, and teachers' positive attitudes toward implementing STEM-Coding in classroom instruction. The evaluation instrument consisted of a five-point scale questionnaire that had been validated by experts and was administered to participants after the training program. The results of the evaluation of the program's achievement of objectives are presented in **Table 3**.

Table 3. Summary of the Evaluation Results on the Achievement of Program Objectives

Aspect	Category	Number of Participants	Percentage
Understanding STEM Education	Low	0	0%
	Moderate	14	52%
	High	13	48%
Understanding Coding Education	Low	0	0%
	Moderate	1	4%
	High	26	96%
A Positive Attitude toward STEM and Coding Education	Low	0	0%
	Moderate	3	11%
	High	24	89%

Source: Authors' analysis 2025

The evaluation of the STEM-Coding training program demonstrated that all indicators of program success were achieved at a highly satisfactory level (See: **Table 3**). Regarding teachers' understanding of STEM learning, 52% of teachers were categorized at the moderate level and 48% at the high level, with no participants classified in the low category. This indicates that 100% of the teachers achieved at least the moderate category, thereby meeting the success criterion requiring at least 85% of teachers to reach that level. Similarly, the results for teachers' understanding of coding were even higher, with 96% categorized at the high level and only 4% at the moderate level, meaning that all teachers also met the established success criteria. Regarding positive attitudes toward STEM-Coding learning, 89% of teachers were categorized at the high level and 11% at the moderate level, with no teachers classified in the low category. These findings indicate that all participants demonstrated positive attitudes toward implementing STEM-Coding learning, exceeding the target of at least 85% of teachers achieving a moderate category or above. Overall, the relationships among the categories across the three evaluated aspects indicate consistently high achievement, confirming that all program success indicators were fully met.

Discussion

The evaluation results indicate that the STEM-Robotic training program successfully improved teachers' understanding of STEM learning and coding, as well as their positive attitudes toward implementing STEM-Coding. All participants achieved at least a moderate category across the three evaluated aspects, demonstrating that the program effectively addressed the initial challenges identified during the needs

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assessment stage. These findings support previous studies emphasizing that STEM-oriented professional development programs can significantly strengthen teachers' pedagogical understanding, interdisciplinary perspectives, and readiness to implement technology-integrated learning (Margot & Kettler, 2019; Purmanna et al., 2025). The improvement in teachers' understanding of STEM concepts also reflects the importance of contextual and practice-oriented learning experiences, particularly when teachers are directly engaged in authentic problem-solving and collaborative activities. Integrated STEM learning becomes more meaningful when participants experience interdisciplinary connections through real-world applications, as implemented in the robotic projects during this training program (Kelley & Knowles, 2016).

Integrated STEM professional development programs help teachers develop interdisciplinary instructional perspectives and improve their confidence in implementing authentic STEM learning experiences in classroom settings (Dare et al., 2018; Li et al., 2020). Previous studies also revealed that teachers' readiness and confidence are essential factors influencing the successful implementation of STEM-oriented learning environments (Hewitt & Forcino, 2025). The high level of teachers' understanding of coding demonstrates that coding activities integrated with educational robotics can function as an accessible and effective medium for introducing computational thinking and algorithmic reasoning to teachers from diverse disciplinary backgrounds. This finding aligns with previous research showing that robotics-based coding activities enhance participants' logical thinking, problem-solving skills, and confidence in using technology (Ching & Hsu, 2023; Zhang et al., 2021). In this program, teachers were not only introduced to coding syntax. However, they were also engaged in designing logical sequences, controlling robotic systems, and solving practical programming challenges through the Studuino application. Such experiences are important because coding competencies are increasingly recognized as essential components of 21st-century education and digital literacy.

Furthermore, the use of Scratch-based drag-and-drop programming enabled teachers with limited prior technological experience to participate actively in coding activities, thereby reducing barriers to technology integration in STEM learning (Latip et al., 2020). Previous studies have also shown that robotics-based programming activities can improve computational thinking skills and support participants' understanding of algorithmic logic through interactive and experiential learning (Angeli & Valanides, 2020). These findings are also consistent with recent studies indicating that robotics and programming activities help participants concretize abstract STEM concepts while simultaneously developing higher-order thinking skills, including critical thinking and problem solving (Kurnia et al., 2025; Turhal et al., 2026). Furthermore, the programming and robotics activities provide authentic STEM experiences that strengthen learners' engagement and interdisciplinary understanding through hands-on exploration (Torres & Inga, 2025). The positive attitudes demonstrated by teachers toward STEM-Coding learning also represent an important outcome of the community service program. Teachers perceived STEM-Robotic learning as contextual, engaging, collaborative, and relevant to students' future competencies.

Positive attitudes toward technology-integrated learning are important because teachers' beliefs and perceptions strongly influence their willingness to adopt innovative instructional practices in classrooms (Margot & Kettler, 2019). In addition, positive attitudes toward STEM and coding can influence students' motivation, engagement, and academic achievement, particularly in subjects requiring logical reasoning and persistence (Sampouw et al., 2024). The reflection results further revealed that teachers became more confident in implementing STEM-Coding activities despite existing infrastructure and access limitations to professional development opportunities. This finding demonstrates that well-designed training programs can empower teachers in geographically isolated regions to become active agents of educational transformation. The improvement in teachers' attitudes toward STEM-Coding learning is also consistent

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with findings that educational robotics activities positively influence participants' motivation, engagement, and attitudes toward STEM learning environments (Nugent et al., 2010).

The positive changes in teachers' attitudes toward STEM-Coding learning also align with previous findings demonstrating that robotics and coding activities significantly improve motivation, attitudes, and engagement toward STEM-related learning environments (Gülen et al., 2025). Positive attitudes are particularly important because they influence teachers' willingness to continuously explore and adopt innovative technology-based instructional approaches in their classroom practices. The success of this community service program also highlights the importance of sustainable teacher professional development in regions with limited access to education, such as Kaimana, West Papua. Previous studies have shown that teachers in remote areas often experience restricted access to training, mentoring, and technological resources, which affects the implementation of innovative learning approaches (Ilma et al., 2023; Sukarman & Retnawati, 2022). Through the service-learning approach, this program not only transferred knowledge but also fostered collaborative and reflective learning experiences directly connected to the school's contextual needs (Aisy, 2024).

In geographically isolated educational contexts, sustained technology-based professional development programs are particularly important because they help reduce disparities in teachers' access to innovative pedagogical practices and strengthen teachers' readiness to implement STEM-oriented learning (Ilma et al., 2023; Margot & Kettler, 2019; Sukarman & Retnawati, 2022). In addition, recent studies on robotics-mediated STEM learning suggest that educational robotics can become an effective strategy for supporting transformative and collaborative learning environments, particularly when combined with reflective and inquiry-based pedagogical approaches (Trapero-González et al., 2024). This supports the implementation of the current program, in which teachers were encouraged not only to learn coding concepts but also to collaboratively design, test, and reflect on STEM-Robotics activities relevant to their school context. Therefore, the STEM-Robotic training program can serve as an alternative model for contextual, technology-based, and sustainable teacher professional development, particularly for schools located in geographically disadvantaged regions (Saputro et al., 2025; Siswanto et al., 2025).

CONCLUSION

Based on the results and discussion of the community service program implemented at Saint Thomas Aquino Junior High School in Kaimana, it can be concluded that the STEM-Coding training program successfully addressed the challenges related to teachers' limited understanding of STEM and coding concepts, as well as the underutilization of the robotic facilities available at the school. Through the service-learning approach, the program provided not only theoretical knowledge but also direct, practical experiences relevant to the school's instructional context. The training results demonstrated that teachers developed a stronger understanding of STEM learning and coding and exhibited positive attitudes toward their implementation in classroom practices. Teachers also recognized that STEM-Coding learning is contextual, engaging, and meaningful for students. The final evaluation indicated that all program success indicators were achieved at optimal levels, with more than 85% of teachers categorized at moderate to high levels across all measured aspects. These findings confirm that the training program was effective in enhancing teachers' competencies and creating opportunities to develop technology-based learning in regions with limited access to education. Future research may explore the long-term impact of STEM-Robotic training on teachers' classroom practices and students' learning outcomes, particularly in developing computational thinking, problem-solving skills, and STEM attitudes. Further studies may also investigate the effectiveness of locally contextualized robotics modules, sustainable mentoring models,

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and low-cost STEM-Coding implementations for schools in geographically isolated regions. In addition, broader investigations involving different school levels and educational contexts are needed to strengthen the scalability and sustainability of STEM-Robotic professional development programs in Indonesia.

AUTHOR'S NOTE

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