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Enhancing technology literacy through the design and implementation of an IoT Module for extracurricular activity

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ABSTRACT

Limited access to technology-based learning facilities remains a challenge for border-area schools in improving students' digital literacy. This community service program aimed to implement an Internet of Things (IoT)-based technology literacy module as an appropriate technology solution for extracurricular activities at SMA Negeri 2 Sekayam, West Kalimantan. The program addressed two main partner problems: the absence of a dedicated IoT learning resource and the limited readiness of teachers and students to conduct IoT-based learning. The activity involved 10 teacher representatives and 20 twelfth-grade students and was carried out through needs identification, module and kit development, teacher training, student IoT introduction, and evaluation. The outputs consisted of one IoT module, one supporting kit using ESP32, LED, buzzer, and relay components, and a structured extracurricular learning scenario. Quantitative evaluation using pre-test and post-test questionnaires showed that the teacher satisfaction index increased from 40.0 to 78.3 percent, while the student index increased from 37.5 to 85.0 percent. These results indicate that the program provided practical learning resources and improved the partner's readiness to continue technology-based extracurricular learning.

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1. INTRODUCTION

Community service (PkM) is a concrete form of university contribution to improving the quality of education in local communities (Diwyarthi et al., 2024; Hesti & Markos, 2024; Haryono et al., 2024; Thamimi et al., 2025). Community service initiatives encourage the academic community to provide innovative solutions to various challenges faced by schools, particularly in the development of technological competence, which is a major focus of the Deep Learning Indonesia (DL-ID) curriculum (Addam, 2025; Darmayanti et al., 2025). This curriculum emphasizes the development of 21st-century skills, including digital literacy, critical thinking, creativity, and technology-based problem-solving abilities (Dilekçi & Karatay, 2023; Erol, 2021; Nadawina et al., 2025; Solahudin, 2024).

SMA Negeri 2 Sekayam is a public senior high school located on Jalan Raya Lintas Sekayam KM. 07, Kenaman Village, Sekayam District, Sanggau Regency, West Kalimantan. The school is situated in the

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Indonesia-Malaysia border area, relatively far from the provincial capital and major higher education centers. As a result, direct access to technology enrichment programs, laboratory assistance, and regular mentoring from universities is more limited than in urban schools. Therefore, community service activities in this context need to provide not only short-term socialization but also practical learning resources that can still be used by the partner after the program ends.

The preliminary assessment conducted by the implementation team showed that SMA Negeri 2 Sekayam did not yet have a dedicated IoT module or a simple IoT kit for extracurricular activities. The partner also needed teacher mentoring because the teachers expected to guide technology-based extracurricular activities were not yet familiar with basic IoT concepts and simple component interfacing. This condition was reflected in the baseline evaluation, in which the teacher index before training was 40.0 percent, while the student index before the introduction activity was 37.5 percent. These values indicate that the main partner problem was not only the absence of equipment but also the limited readiness to use technology-based resources independently.

Technology literacy is increasingly important for secondary school students since the ability to understand, use, and create technology-based solutions is closely related to critical thinking, creativity, problem solving, and digital competence. In science and technology learning, IoT provides a practical context as it connects sensors, electronic components, microcontrollers, communication networks, and real-world applications. For border-area schools, a simple IoT module can serve as an appropriate technology solution because it is relatively affordable, can be demonstrated using basic components, and can be integrated into extracurricular activities without requiring a complete advanced laboratory.

Previous community service programs have shown that IoT-based training can effectively improve students' technological literacy and practical skills. For example, IoT training at SMK Dinamika Kota Tegal reported that 99 percent of participants understood IoT technology after the activity (Budihartono et al., 2022), while a similar program at SMK Kristen Immanuel Pontianak showed that 63 percent of students improved their pre-test and post-test scores (Rochadiani & Santoso, 2023). Another vocational workshop covering basic electronics, digital systems, microcontrollers, and IoT projects increased the average student score from 54.7 to 81.3 (Rohmah, 2022). Practice-based mentoring programs at SMA Kolese De Britto and SMA Islam Sultan Agung 3 Semarang also showed that IoT modules, device demonstrations, and mini-project activities could improve students' understanding, digital literacy, and ability to complete simple IoT projects (Haryono et al., 2025; Mulyono et al., 2024). In addition, an IoT module and training program at SMAN 3 Pekanbaru supported the implementation of the P5 project in the Merdeka Curriculum and resulted in 100 percent of participants reporting improved IoT knowledge and skills (Wahyuni et al., 2024). These findings indicate that IoT-based community service programs are relevant and effective for strengthening technology literacy. However, similar programs remain limited in border-area schools with restricted facilities. Therefore, the present program was designed to introduce a simple IoT module at SMA Negeri 2 Sekayam as a practical solution to support technology-based extracurricular activities.

Based on these previous community service programs, this program aimed to implement an IoT-based technology literacy module as appropriate technology for extracurricular activities at SMA Negeri 2 Sekayam. Specifically, the program aimed to provide a simple IoT module and kit, improve teacher readiness to guide IoT practice, improve students' understanding and motivation toward technology, and establish a sustainable foundation for technology-based extracurricular activities in a border-area school. To address these needs, the PkM activity was designed by introducing a simple IoT module that students could use in extracurricular activities. Teachers were also provided with training and guidance

so that they could independently mentor students and develop sustainable extracurricular activities aligned with technological developments. Through direct and practical application, this activity was expected to foster students' interest and motivation to engage more actively with technology. Through the implementation of this PkM program, SMA Negeri 2 Sekayam was expected to obtain technology-based facilities and extracurricular learning resources that can support the development of students who are competitive, creative, and adaptive to the digital era.

2. METHODS

Partner, Location, and Target Participants

The partner of this community service program was SMA Negeri 2 Sekayam, located in Sekayam District, Sanggau Regency, West Kalimantan Province, as shown in Figure 1. The main onsite activity was conducted in the school ICT laboratory on 29 August 2025. The target participants consisted of 10 teacher representatives who were trained to become extracurricular mentors and 20 twelfth-grade students who participated in the IoT introduction and demonstration session.



Figure 1. Location and distance map of SMA Negeri 2 Sekayam

IoT-Based Technology Literacy Concept and Success Indicators

The appropriate technology implemented in this program was IoT-based technology literacy, consisted of a learning module, basic electronic components, microcontroller-based devices, and simple learning scenarios for extracurricular activities. The module introduced the concept of IoT, the functions of LED, buzzer, and relay components, and basic applications using ESP32 and Raspberry Pi. The results of implementation were assessed using the indicators shown in Table 1.

Table 1. Success indicators of the IoT-based technology literacy implementation

Problems	Implemented Scenarios	Indicators
No dedicated IoT resource for extracurricular activities	Printed IoT module and supporting kit	At least one module and one kit are available for school use
Limited teacher readiness to guide IoT practice	Teacher training and demonstration	Teacher post-test index reaches at least 75 percent
Limited student understanding of IoT and basic components	Student introduction and hands-on demonstration	Student post-test index reaches at least 75 percent
Lack of structured technology-based extracurricular scenario	Step-by-step activities using simple components	The school receives a structured learning scenario for continued extracurricular use

Implementation Stages and Schedule

The program was implemented using a participatory approach involving the community service team, teacher representatives, and students. The implementation stages were adjusted to the partner's conditions so that the activities could be conducted with simple equipment and continued by teachers after the onsite program. The detailed stages are presented in Table 2, while the implementation flow is shown in Figure 2.

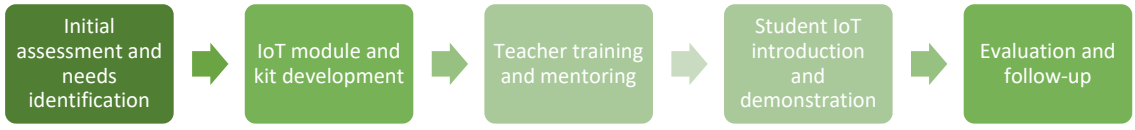


Figure 2. Block diagram of community service implementation procedure

Table 2. Implementation stages and schedule

Stage	Activity	Objective	Participants	Time & Output
1	Initial coordination and needs identification	Identify partner problems, available facilities, and activity readiness	Community service team and school representatives	Month I; partner needs and activity agreement
2	Design of IoT module and kit	Prepare appropriate technology in the form of a simple IoT package	Community service team	Month II-III; module draft and kit
3	Delivery of module and kit	Provide practical learning resources for the school	Community service team and partner school	August 29, 2025; printed module and kit received by school
4	Teacher training	Improve teacher readiness to guide IoT extracurricular practice	10 teacher representatives	August 29, 2025; teacher workshop and demonstration
5	Student IoT introduction	Improve students' understanding and motivation toward IoT	20 twelfth-grade students	August 29, 2025; IoT introduction and kit demonstration
6	Evaluation and follow-up	Measure before-after changes and prepare sustainability recommendations	Teachers, students, and community service team	August 29, 2025; pre-test/post-test results and follow-up plan

Evaluation Method

Evaluation was conducted using pre-test and post-test questionnaires with a 1 to 4 Likert scale. The teacher instrument consisted of six items measuring basic IoT knowledge, understanding of component functions, ability to use the module, confidence in guiding students, motivation to develop technology-based extracurricular activities, and willingness to apply the knowledge in school learning. The student instrument consisted of six items measuring basic IoT knowledge, understanding of LED, buzzer, and relay functions, ease of understanding the module, usefulness of the equipment demonstration, motivation to learn technology, and interest in technology-based extracurricular activities. The Satisfaction Index (SI) was calculated using Equation 1 (Eq. 1).

$$SI = \frac{Actual\ Score}{Ideal\ Score} \times 100\% \quad \text{.....} \quad (1)$$

The percentage improvement for each questionnaire item was calculated using Equation 2 (Eq. 2).

$$Improvement\ (\%) = \frac{Post\ test - Pre\ test}{Pre\ test} \times 100\% \quad \text{(2)}$$

For the teacher evaluation, the ideal score was 240, obtained from 10 respondents multiplied by 6 items and a maximum score of 4. For the student evaluation, the ideal score was 480, obtained from 20 respondents multiplied by 6 items and a maximum score of 4.

3. RESULTS AND DISCUSSION

Results

Preliminary coordination and partner needs

The coordination was carried out through direct meetings between the implementation team and SMA Negeri 2 Sekayam. Began with a survey of the school's conditions, the needs identified including; the availability of classrooms or laboratories, supporting facilities such as electricity and internet access, and students' readiness to participate in the activities. Further surveys were also conducted to ensure that the program could be designed according to the school context, so that the prepared module and equipment would be well-suited and could be used optimally. The identified needs and implemented responses are summarized in Table 3.

Table 3. Partner needs, implemented outputs, and evidence of change

Initial Conditions	Implemented Outputs	Evidence after Program
No dedicated IoT module for extracurricular learning	Basic Training Module on IoT	Printed module available
No simple IoT kit for hands-on demonstration	IoT kit using ESP32/Raspberry Pi and basic components	Kit available for demonstrations on LED, buzzer, relay, and simple IoT applications
Teachers had limited readiness to guide IoT practice	Teacher workshop and demonstration	Teacher SI increased from 40.0 percent to 78.3 percent
Students had limited initial understanding of IoT	Student introduction and hands-on demonstration	Student SI increased from 37.5 percent to 90.8 percent

Based on the survey results, the program was scheduled for 29 August 2025 and implemented within the school areas, using the ICT laboratory as the most suitable space to accommodate both students and equipment. During the coordination meeting, the program objectives were also agreed upon, namely to provide a simple introduction to IoT for students and a short training session for teacher mentors. In addition to the schedule, the activity flow and technical requirements to be prepared by both the implementation team and the school were also discussed.

Design and development of the IoT module and kit

The implementation team prepared a simple IoT-based module designed to match the abilities of high school students. The module included an introduction to basic IoT concepts, examples of IoT applications, and practical steps that could be carried out in extracurricular activities. The kit included affordable and familiar devices, such as ESP32, Raspberry Pi, LED, buzzer, relay, jumper cables, and other supporting components. It was designed by considering the students' level of understanding and the school's limited facilities.





Figure 3. The coordination between the school and the Community Service team representatives
Figure 4. Simple IoT kit

The design process began by selecting the most relevant and applicable materials. One of the selected topics was the introduction and interfacing of basic electronic components such as LEDs, buzzers, and relays. This material was chosen so that students could more easily understand basic electronics concepts while also seeing simple IoT applications in everyday life. The module was arranged step by step, beginning with a brief theoretical explanation, component specifications, circuit illustrations, and practical examples that could be applied directly using simple devices. The simple IoT kit is shown in Figure 4.

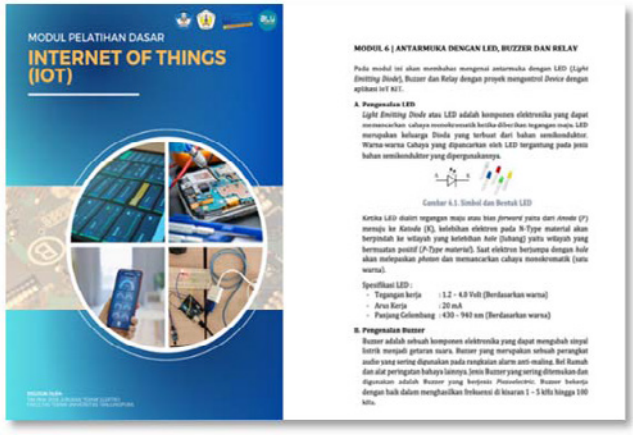


Figure 5. Module and example of the materials presented in the module

In the development stage, the team emphasized simple language and clear visual aids. Each topic was supported with images, circuit symbols, and concise explanations to help students understand the material without requiring a strong technical background. In addition, the module contained basic component specifications and step-by-step practice guidelines. The outcome of this stage was a module titled "Basic Training Module on Internet of Things (IoT)", which contained introductory IoT material and several simple practices using the provided equipment, as shown in Figure 5. This module was then printed and delivered to the school together with the simple IoT kits during the teacher and student training sessions.

Teacher training activity

The program then continued with teacher training, which was conducted in the form of a short and interactive workshop. This training was attended by 10 teacher representatives from the school. The materials delivered included an introduction to IoT, instructions on how to use the module, and simple practice sessions with the provided equipment. Before the session began, teachers completed a pre-test to assess their initial understanding of basic electronic components and IoT. The pre-test results showed that most teachers were not yet familiar with IoT terminology.



Figure 7. Teacher training activity
Figure 8. Teachers' enthusiasm in asking questions during the activity

The training then focused on understanding the module content, using the kit, and applying simple components such as LEDs, buzzers, and relays. This session was conducted as a short but interactive workshop accompanied by live demonstrations. Teachers appeared enthusiastic and actively asked questions to deepen their understanding. After the training was completed, the teachers completed a post-test, and the results showed a significant improvement in their understanding. Based on the training outcomes, the teacher mentors showed strong enthusiasm and stated that the activity helped them gain new insights and knowledge that they had not previously acquired.

Evaluation of teacher training

A total of 10 extracurricular teacher mentors participated in the activity. The evaluation of the teacher training at SMA Negeri 2 Sekayam was conducted using a questionnaire instrument based on a 1 to 4 Likert scale, consisting of six questions as shown in Table 4. The questionnaire was designed to measure the teachers' level of knowledge, understanding, motivation, and readiness to implement IoT in classroom learning and extracurricular activities.

The data were processed in several stages. First, the scores for each question item were summed and divided by the number of respondents to obtain the average score per question. Second, the total score of all respondents was summed to obtain the actual total score, while the ideal score was obtained by multiplying the number of respondents, the number of questions, and the maximum score.

The teacher questionnaire results are presented in Table 5. Prior to the training, the average scores ranged from 1.5 to 2.2, with an overall average of 1.8, indicated that the teachers' understanding of basic IoT concepts, the functions of simple components, and the use of IoT modules was still limited. After the training, a clear improvement was observed. The average score for each question increased to a range of 2.9 to 3.6, with an overall average of 3.25. The highest improvement occurred in Q1, which measured basic IoT knowledge, at 93 percent. This was followed by Q2, which measured understanding

of component functions, and Q3, which measured the ability to use simple IoT modules, each with an 88 percent increase. The lowest improvement was found in Q6, which measured willingness to apply the knowledge in teaching activities, at 64 percent, although this still showed meaningful progress. Overall, the satisfaction index increased from 40 percent in the pre-test to 78.3 percent in the post-test. Thus, the training activity resulted in an overall improvement of 38.3 percent.

Table 4. List of teacher questionnaire questions

Code	Questions
Q1	Do you know the basic concept of the Internet of Things (IoT)?
Q2	Do you understand the functions of basic components (LED, buzzer, relay) in an IoT circuit?
Q3	Are you able to use a simple IoT module for extracurricular activities?
Q4	Do you feel confident in guiding students in simple IoT practices?
Q5	Has this activity increased your motivation to develop technology-based extracurricular activities?
Q6	Are you willing to apply the knowledge gained in school learning activities?

Table 5. Teacher questionnaire results

Question	Average Pre-Test	Average Post-Test	Improvement (%)
Q1	1.5	2.9	+93
Q2	1.7	3.2	+88
Q3	1.6	3.0	+88
Q4	1.8	3.2	+78
Q5	2.1	3.6	+71
Q6	2.2	3.6	+64
Total Actual Score	**96**	**188**	
SI (%)	**40%**	**78%**	**+38**

IoT introduction activity for students

After the series of teacher training sessions was completed, the program continued with an introduction to IoT for students, as shown in Figure 9. This activity was attended by 20 twelfth-grade students of SMA Negeri 2 Sekayam. Before the material was delivered, students were given a pre-test to measure their initial understanding of basic technology concepts and simple electronic components such as LEDs, buzzers, and relays. The pre-test results indicated that most students did not yet have sufficient understanding of the relationship between these components and the concept of the Internet of Things (IoT).



Figure 9. IoT introduction activity for students
Figure 10. Demonstration of the IoT kit to students

During the introduction session, students were introduced to basic IoT concepts and several examples of their applications in daily life, such as environmental monitoring systems, automated lighting, and simple alarm systems, as shown in Figure 10. The explanations were delivered in simple language and supported by live demonstrations using the IoT kits that had previously been provided to the school. This approach was used to make the material easier to understand and to help students connect it with their everyday experiences.

The activity proceeded interactively, with many students actively asking questions and trying to understand the IoT applications being demonstrated. This enthusiasm indicated that the program successfully stimulated students' curiosity and interest in technology.



Figure 11. Students' enthusiasm in asking questions

At the end of the session, students completed a post-test using the same questions as the pre-test. The results showed a significant improvement in understanding, with most students able to explain the functions of basic components and identify examples of simple IoT applications.

Results of students' iot introduction

The program continued with an Internet of Things (IoT) introduction session for students. A total of 20 twelfth-grade students of SMA Negeri 2 Sekayam participated in this activity. Students completed a pre-test to measure their initial knowledge of basic IoT concepts and simple components. After the introduction session and IoT kit demonstration, students completed a post-test using the same instrument.

The data were processed using the same method applied to the teacher evaluation. The list of student questionnaire questions is presented in Table 6, while the average pre-test scores, post-test scores, and percentage increases are shown in Table 7. Prior to the activity, students' average scores ranged from 1.3 to 1.7, with an overall average of 1.5, indicated students' initial understanding of IoT was very limited. After participating in the activity, the average scores increased to a range of 3.1 to 3.6, with an overall average of 3.4. The highest increase was observed in Q1, which measured basic IoT knowledge, at 133 percent. This was followed by Q2, which measured understanding of basic component functions, at 129 percent, and Q3, which measured ease of understanding the module, at 125 percent. The lowest increase was recorded in Q6, which measured interest in participating in technology-based extracurricular activities, at 84 percent, although this still represented meaningful improvement.

Taken together, the total actual score before the activity was 180, which increased to 408 after the activity. With an ideal score of 480, obtained from 20 respondents multiplied by 6 questions and a maximum score of 4, the students' satisfaction index was 37.5 percent in the pre-test and 85.0 percent in the post-test. Thus, there was an improvement in the satisfaction index of 47.5 percent.

Table 6. List of student questionnaire questions

Code	Questions
Q1	Do you know what the Internet of Things (IoT) is?
Q2	Do you understand the functions of LED, buzzer, and relay after being introduced to them?
Q3	Is the module provided easy for you to understand?
Q4	Did the equipment demonstration help you understand the IoT material?
Q5	Has this activity motivated you to learn more about technology?
Q6	Are you interested in participating in technology-based extracurricular activities at school?

Table 7. Recapitulation of student questionnaire results

Question	Average Pre-Test	Average Post-Test	Improvement (%)
Q1	1.3	3.1	+133
Q2	1.4	3.2	+129
Q3	1.5	3.4	+125
Q4	1.5	3.5	+120
Q5	1.6	3.6	+113
Q6	1.7	3.6	+84
Total Actual Score	**180**	**408**	
SI (%)	**37.5%**	**85.0%**	**+47.5**

Discussion

The results indicate that the IoT-based technology literacy program addressed two main partner problems: the lack of practical IoT learning resources and the limited initial readiness of teachers and students. The tangible outputs of the program were the printed learning module, the IoT kit, and the extracurricular learning scenario. These outputs are important considering a community service program in a border-area school should leave usable resources for the partner, rather than only provide one-time training materials.

The increase in teacher SI from 40.0 percent to 78.3 percent suggests that the training improved teacher readiness to use the module and guide simple activities. This finding is in line with previous IoT community service activities. For example, Wahyuni et al. (2024) developed IoT modules and training to support technology-engineering project activities, while Mulyono et al. (2024) used ESP32-based training to strengthen digital literacy and talent development. The present program differs by focusing on a border-area school and positioning the module as an extracurricular resource that teachers can reuse after the program.

The increase in student SI from 37.5 percent to 85.0 percent also indicates that simple demonstrations using visible components can make IoT concepts easier to understand. Similar improvement patterns were reported in prior IoT workshops for students, such as the studies by Budihartono et al. (2022) and Rohmah (2022), in which practical workshop formats improved students' understanding. In the context of SMA Negeri 2 Sekayam, the use of LED, buzzer, and relay components was appropriate because these components are affordable, easy to observe, and suitable for introducing the relationship between hardware, control, and IoT applications.

The program also provides sustainability value for the partner, as the school received the module and kit, the teachers can now repeat or modify the scenario for future extracurricular sessions. However, the program was still limited to introductory-level IoT literacy. Further mentoring is needed to help the school develop more advanced projects, such as environmental monitoring, school facility automation, or locally relevant IoT applications for border-area communities.

4. CONCLUSION AND RECOMMENDATIONS

The community service program at SMA Negeri 2 Sekayam successfully implemented an IoT-based technology literacy module as a technology option for extracurricular activities in a border-area school in West Kalimantan. The program produced one printed IoT learning module and one supporting kit using ESP32, Raspberry Pi, LED, buzzer, and relay components. The program also improved partner's readiness and technology literacy, as shown by the increase in teacher SI from 40.0 percent to 78.3 percent and the increase in student SI from 37.5 percent to 85.0 percent. These results demonstrate that the activity not only increased knowledge and motivation but also provided tangible resources that can help the partner continue technology-based extracurricular learning after the community service program.

To ensure that this program is able to provide long-term benefits, several aspects should be considered. First, follow-up mentoring should be conducted periodically to help teachers gain more confidence in operating the IoT kit, modifying the learning module according to student needs, and guiding students independently during extracurricular activities. Second, the module is potentially expandable by adding more varied application scenarios, for example; temperature and humidity monitoring, simple school security alarms, automatic lighting systems, and environmental data logging, in order to add relevance to students' daily life. Third, the school should assign a regular extracurricular schedule and prepare a simple maintenance plan for the IoT kit so that the equipment is not only stored after the program, but can also be used continuously by students. Lastly, future community service programs should involve a larger number of students and include project-based evaluation, such as assessing students' ability to design and build a simple IoT prototype at the end of the activity.

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