

Empowering Island Communities through STEM-Based Antenna Fabrication Training for Vocational Students in the Riau Archipelago

(Pemberdayaan Masyarakat Kepulauan melalui Pelatihan Fabrikasi Antena Berbasis STEM untuk Siswa Vokasi di Kepulauan Riau)

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ABSTRACT

The Riau Archipelago faces persistent challenges in wireless connectivity, highlighting the need to strengthen local technological capacity. This community engagement program aimed to improve vocational students' knowledge and practical skills in antenna technology through STEM-based training. Thirty students from Computer and Network Engineering and Telecommunication Access Network programs participated in theoretical instruction, Yagi and microstrip antenna fabrication, and performance measurement activities. Program effectiveness was evaluated using pre-test and post-test assessments and a participant satisfaction survey. The average score increased from 46.7 to 84.7, with a normalized gain of 0.71, indicating substantial improvement in conceptual understanding. Participants also reported high satisfaction with the relevance and usefulness of the training. These findings demonstrate that STEM-based antenna fabrication training can strengthen vocational students' technical competencies and support local capacity development for digital connectivity in island communities.

Keywords:

antenna fabrication; community empowerment; digital connectivity; vocational education; wireless communication.

ABSTRAK

Kepulauan Riau menghadapi tantangan konektivitas nirkabel yang membutuhkan penguatan kapasitas teknologi masyarakat lokal. Program pengabdian ini bertujuan meningkatkan pengetahuan dan keterampilan praktis siswa vokasi dalam teknologi antena melalui pelatihan berbasis STEM. Sebanyak 30 siswa dari bidang Teknik Komputer dan Jaringan serta Jaringan Akses Telekomunikasi mengikuti pembelajaran teori, fabrikasi antena Yagi dan mikrostrip, serta pengukuran kinerja antena. Efektivitas program dievaluasi melalui pre-test, post-test, dan survei kepuasan peserta. Skor rata-rata meningkat dari 46,7 menjadi 84,7 dengan normalized gain sebesar 0,71, yang menunjukkan peningkatan pemahaman konseptual yang substansial. Peserta juga menunjukkan tingkat kepuasan yang tinggi terhadap relevansi dan manfaat pelatihan. Hasil ini menunjukkan bahwa pelatihan fabrikasi antena berbasis STEM dapat memperkuat kompetensi teknis siswa vokasi sekaligus mendukung pengembangan kapasitas lokal untuk konektivitas digital masyarakat kepulauan..

Kata kunci:

fabrikasi antena; komunikasi nirkabel; konektivitas digital; pemberdayaan masyarakat; pendidikan kejuruan.

Introduction

Reliable wireless communication plays a crucial role in supporting economic activity, education, and social development, particularly in regions with geographically fragmented landscapes. The Riau Archipelago, consisting of thousands of islands dispersed across maritime zones, faces persistent challenges in ensuring equitable digital

access due to limited infrastructure, high deployment costs, and the physical barriers created by sea separation (Aqorau, 2025; Nurman et al., 2025; Rusfa et al., 2023). These structural constraints often result in inconsistent signal coverage, reduced internet reliability, and limited opportunities for community participation in the digital ecosystem. Improving local human resource capacity in communication technology is therefore essential for strengthening digital resilience in island communities (Amalia et al., 2025; Darmawan et al., 2023; Hidayat et al., 2023). Several solutions to this problem have been studied, resulting in several recommendations, including: expanding satellite-based internet networks, partnering with the private sector to provide devices, community-based teacher training, and empowering communities to utilize technology. The government certainly has a strategic role in designing integrated, regional-based policies to ensure the continued success of digital education. Achieving equitable education quality in Indonesia requires a solid and well-thought-out strategy. (Harahap et al., 2025)

Indonesia has experienced several extraordinary circumstances that have impacted learning processes. During the COVID-19 pandemic, educational institutions were encouraged to implement distance learning to suppress disease transmission. Meanwhile, numerous limitations in technological infrastructure have caused distance learning to experience numerous obstacles and even lead to learning loss. According to a report from UNICEF Indonesia (2021), at the peak of school closures, more than 35% of students in rural areas were unable to participate in distance learning due to infrastructure and economic constraints, compared to 8% in metropolitan areas. Despite emergency measures implemented to mitigate learning loss, persistent structural challenges that hinder access to education in rural and island areas remain largely unresolved (Riady et al., 2025). Several other circumstances also force schools to adopt distance learning policies, such as when haze triggers poor air quality due to forest fires that occur almost every year in Indonesia (Perwithosuci et al., 2025; Wijaya & Arymurthy, 2024). This encourages community empowerment so that they have the ability to implement technological engineering that supports the quality of information technology while not conflicting with existing regulations.

Vocational schools play a strategic role in preparing technically skilled graduates who are capable of addressing practical challenges in their environment (Rahmadhani et al., 2022; Widayana, 2023). However, several studies highlight that vocational learning in telecommunication departments remains predominantly focused on cable-based communication systems such as copper networks and fiber-optic installations, with relatively limited exposure to wireless communication and antenna technology (Sukaridhoto et al., 2023; Taufik et al., 2023). This creates a competence gap, particularly as wireless communication has become the backbone of modern connectivity, especially in remote and maritime regions where wired infrastructure is difficult to deploy (Amalia et al., 2025; Nurman et al., 2025).

Introducing antenna concepts through hands-on fabrication and measurement activities

is an effective approach to strengthening students' conceptual understanding and practical skills. Practical experimentation has been shown to promote deeper comprehension of electromagnetic principles, enhance problem-solving abilities, and improve students' capacity to correlate theoretical knowledge with real-world applications (Chung & Mung, 2025; Gião et al., 2024). Antenna fabrication, including Yagi and microstrip designs, also encourages learners to analyze design parameters, understand radiation behavior, and evaluate performance using measurement tools—skills that are relevant both academically and professionally (Lee et al., 2024; Morales Bezeira & Silva Sprock, 2025).

Integrated learning frameworks that combine science, technology, engineering, and mathematics have demonstrated significant effectiveness in vocational and technical education. STEM-based learning encourages students to apply multidisciplinary reasoning, engage in engineering design processes, and develop analytical thinking through hands-on experimentation (Dochshanov & Tramonti, 2025; Narathon et al., 2024). Research in maritime and remote-area education contexts also shows that STEM approaches increase student engagement, strengthen technical self-efficacy, and foster early research awareness (Adhelacahya et al., 2023; Jones, 2025). In the context of the Riau Archipelago, using STEM as the foundation of antenna training is relevant for supporting local empowerment by equipping students with competencies directly related to regional communication challenges (Boxerman et al., 2025; Pasongli et al., 2026).

Based on this rationale, a community engagement program was developed to introduce vocational school students to antenna fabrication and performance testing as a strategy to enhance technological literacy and stimulate early research interest. The program was implemented through a structured sequence of theoretical instruction, engineering design activities, hands-on fabrication of Yagi and microstrip antennas, and performance measurement using appropriate instrumentation. Pre-test and post-test evaluation were administered to measure cognitive improvement, while a satisfaction survey captured participant perceptions of the training.

The program aims not only to improve student competence but also to contribute to the broader mission of empowering island communities through the development of local technical capacity. Strengthening wireless communication literacy at the vocational level is expected to support long-term digital resilience, promote innovation, and foster collaboration between higher education institutions and schools in addressing communication issues unique to maritime regions.

Methods

This community engagement program was designed as a structured training intervention aimed at

enhancing students' understanding of antenna concepts through an integrated approach combining scientific explanation, engineering design, hands-on fabrication, and performance measurement. The program adopted a learning-by-doing model to promote active participation, technical reasoning, and early research awareness among vocational school students.

Thirty students from the Computer and Network Engineering and Telecommunication Access Network departments at a state vocational school in Tanjungpinang participated in the program. Students were selected based on their enrollment in telecommunication-related subjects, ensuring that the training aligned with their existing curriculum. All participants completed the full training sequence and the associated assessments.

The program was implemented in two phases. Preparation activities—including module development, equipment testing, and facilitator orientation—were conducted at the Electronics and Instrumentation Laboratory of Universitas Maritim Raja Ali Haji. The main training was held in the Bintan Hall of the partner vocational school on 27–28 October 2025, spanning full-day sessions.

The training was explicitly structured using a science, technology, engineering, and mathematics framework to promote holistic competency development.

Students were introduced to fundamental concepts of electromagnetic waves, frequency, wavelength, radiation patterns, and factors affecting antenna performance. These concepts supported understanding of why antennas behave differently in real environments.

Participants operated technological tools relevant to antenna testing, including network measurement devices, signal analyzers, and wireless modems. They practiced interpreting measurement displays and troubleshooting issues that affect communication quality.

Students engaged in complete engineering design cycles, including analyzing antenna specifications, selecting materials, assembling Yagi and microstrip antennas, and optimizing them through iterative adjustments. Facilitators guided students in understanding how design decisions influence signal strength and directionality.

Mathematical reasoning was applied to calculate antenna dimensions based on frequency, interpret standing wave ratio values, analyze reflection coefficients, and compare measured performance against theoretical expectations. Simple computational exercises were integrated into each stage of fabrication and testing.

The program consisted of five sequential stages:

1. Introduction and Baseline Assessment

Participants completed a pre-test to measure initial understanding of antenna concepts, wireless communication fundamentals, and basic measurement principles.

2. Conceptual Instruction

Facilitators delivered interactive presentations on electromagnetic theory, antenna types, and factors affecting wireless performance. Demonstrations were used to build conceptual foundations before fabrication.

3. Antenna Fabrication Sessions

Students worked in groups to fabricate Yagi and microstrip antennas using training modules provided. They followed measured templates, assembled elements, and ensured material accuracy using simple tools.

4. Measurement and Testing

Completed antennas were evaluated using measurement instruments to observe return loss, standing wave ratio, and resonance characteristics. Students compared measurement results between antennas and analyzed performance differences.

5. Reflection and Post-Assessment

A post-test was administered at the end of the training to measure learning gains. Students also participated in reflection discussions to evaluate challenges, design improvements, and potential applications of antenna technology in island environments.

Three instruments were used in this study:

Pre-test and post-test assessments

Consisting of ten multiple-choice and short-answer questions to measure conceptual understanding before and after the training.

Participant satisfaction questionnaire

A five-point Likert-scale survey assessing perceptions of material relevance, instructor clarity, hands-on effectiveness, and perceived benefits.

Field observation notes

Qualitative observations recorded by facilitators on student engagement, practical challenges, and group collaboration.

Pre-test and post-test scores were analyzed quantitatively using descriptive statistics and normalized gain calculations to determine the extent of learning improvement. Questionnaire responses were converted into percentage satisfaction scores. Qualitative observations were triangulated with quantitative findings to provide

contextual insight into participant performance and program effectiveness.

Results

Figure 1 shows comparison of students’ pre-test and post-test scores during the STEM- based antenna assembly training. The results show a consistent increase in students’ performance, with post-test scores notably higher across all participants. This improvement indicates that the training effectively enhanced students’ conceptual understanding and practical skills related to antenna technology.

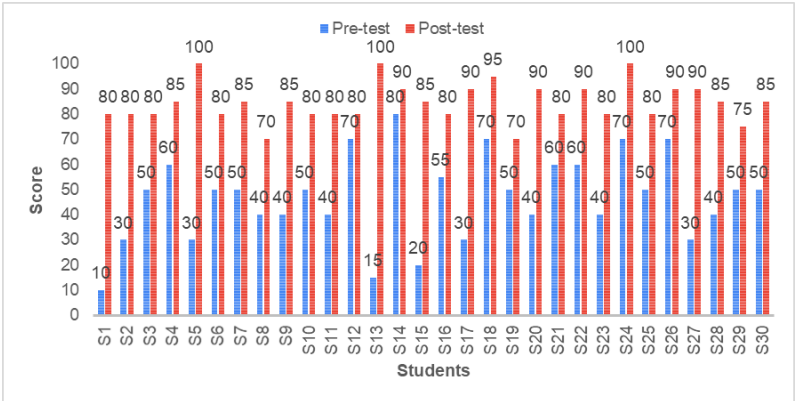


Figure 1. Comparison of Pre-test and Post-test Scores of Student Participants

Table 1 shows the average pre-test score was 46.7, with a minimum score of 10 and a maximum of 80. After the program, the average post-test score increased to 84.7, with a minimum of 70 and a maximum of 100. The normalized gain was calculated at 0.71, indicating substantial improvement from baseline.

Table 1. Summary of pre-test and post-test results

Indicator	Pre- test	Post- test
Mean score	46.7	84.7
Minimum score	10	70
Maximum score	80	100
Normalized gain	0.71	

The significant increase in post-test scores and the high normalized gain value indicate that the STEM-based antenna fabrication training effectively improved students’ conceptual understanding of wireless communication principles. This finding aligns with previous studies highlighting that hands-on and project-based learning approaches enhance comprehension of abstract engineering concepts by linking theory with real-world application (Morales Bezeira & Silva Sprock, 2025). Through antenna design, fabrication, and measurement activities, students were actively engaged in scientific reasoning and engineering problem-solving, which supports deeper learning and long-term knowledge retention (Dochshanov & Tramonti, 2025).

Figure 2 shows a pair of vocational students conducting continuity testing on one of the driven elements of their Yagi antenna using a digital multimeter. This step is essential to ensure that the conductive path is properly connected and free from unintended short circuits before the antenna undergoes performance measurement. Through careful probing of the feed point and element junctions, the students verify the integrity of electrical connections and confirm that assembly errors—such as soldering issues or loose joints—are minimized. This diagnostic activity forms a critical part of the engineering troubleshooting process, reinforcing practical competencies in electrical testing, precision handling of instruments, and quality assurance in antenna fabrication.



Figure 2. Participants assembling Yagi and conducting antenna performance measurements during the training session.

Figure 3 shows a student group presenting the performance results of their fabricated Yagi antenna using measurement data obtained from a NanoVNA device. During the presentation, students explain the observed standing wave ratio (SWR), resonance behavior, and signal response displayed on the screen, demonstrating their ability to interpret frequency-domain plots and relate them to antenna design parameters. This activity reflects the science and mathematics components of the STEM-based training, as students analyze empirical data, compare it with expected theoretical characteristics, and communicate their findings clearly to peers and facilitators. The presentation session strengthens students' analytical reasoning, scientific communication skills, and confidence in discussing practical wireless communication concepts.



Figure 3 Group of students presenting their antenna fabrication results and explaining measurement findings.

All participants completed the fabrication sessions for Yagi and microstrip antennas and were able to perform basic measurements using the testing instruments. Students actively took part in group work, antenna assembly, and measurement tasks. Several groups conducted repeated measurements to correct errors in resonance alignment.

Table 2 shows satisfaction questionnaire results indicate that the training was highly effective, with most aspects rated in the "Very Good" category. Participants reported clear understanding of the materials, improved knowledge of antennas and signals, and enhanced comprehension through hands-on practice. The trainers' performance and the relevance of the training to the students' vocational field were also rated very highly. Overall,

the participants expressed strong satisfaction and interest in future similar activities, demonstrating the positive impact of the program.

Table 2. Participant satisfaction results

No	Assessed Aspect	Percentage	Category
1	The training materials were delivered clearly and were easy to understand.	81%	Very Good
2	The training enhanced participants' knowledge of antennas and signals.	95%	Very Good
3	The antenna assembly practice strengthened participants' understanding of the theory.	84%	Very Good
4	The training tools and materials were easy to use and met safety standards.	78%	Good
5	The trainers and assistants provided effective explanations of the material.	95%	Very Good
6	The training motivated participants to further explore antenna technology.	84%	Very Good
7	The training materials were relevant to the participants' vocational field (Telecommunication Access Network Engineering).	95%	Very Good
8	The training schedule and duration were appropriate and sufficient.	84%	Very Good
9	Participants were interested in joining similar follow-up activities.	78%	Good
10	Overall, participants were satisfied with the implementation of the training.	90%	Very Good

Discussion

The substantial improvement in pre-test and post-test scores indicates that the training program effectively enhanced students' understanding of antenna concepts. The high normalized gain reflects meaningful conceptual development, demonstrating that hands-on and project-based learning approaches are effective in improving comprehension of abstract electromagnetic principles. By engaging students in designing, fabricating, and testing antennas, the program provided authentic engineering experiences that support deeper learning retention.

Several factors contributed to the success of this program. First, the use of a STEM-based approach enabled the integration of theoretical concepts with practical application, allowing students to directly observe the relationship between antenna design and measurement results. Second, the availability of hands-on activities, including antenna fabrication and measurement using real instruments, increased student engagement and motivation. Third, the involvement of facilitators and student assistants provided continuous guidance, which helped participants overcome technical difficulties during the learning process.

Despite the positive outcomes observed in this program, several limitations should be acknowledged. First, the number of participants was relatively limited, involving only 30 vocational students from a single institution, which may restrict the generalizability of the findings to broader educational contexts. Second, the duration of the training program was relatively short, which may not fully capture long-term retention of knowledge and the sustainability of students' technical skill development. Third, the study did not include a control group, making it difficult to compare the effectiveness of the STEM-based antenna training with other instructional approaches.

The local context of island regions also played an important role in shaping the outcomes of this program. Students demonstrated strong interest in antenna applications due to their direct relevance to wireless connectivity challenges in geographically dispersed areas. This contextual relevance enhanced learning motivation, as participants were able to relate technical concepts to real-world problems experienced in their communities. Such context-based learning is particularly important in vocational education, where practical

relevance influences student engagement and knowledge retention.

The findings of this study are consistent with previous research highlighting the effectiveness of experiential learning and STEM integration in improving technical competence (Adhelacahya et al., 2023; Dochshanov & Tramonti, 2025). However, compared to prior studies that often focus on controlled classroom environments, this program emphasizes real-world application in a specific geographical context. The integration of antenna training with local connectivity issues provides added value by linking technical education with community needs, particularly in island-based regions where wireless communication plays a critical role (Lee et al., 2024; Narathon et al., 2024; Widayana, 2023).

The satisfaction survey results further support the effectiveness of the program, indicating that the training content was relevant and aligned with participant needs. Students not only demonstrated improved technical skills but also showed increased confidence in interpreting measurement results and solving practical problems. This aligns with studies suggesting that exposure to real measurement processes and iterative design activities enhances both technical skills and self-efficacy in vocational learners.

Overall, the program demonstrates that strengthening wireless communication literacy among vocational students can contribute to community empowerment in island regions. In areas where geographical conditions limit infrastructure development, local technical competence becomes essential. Through this training, students not only acquired fundamental antenna skills but also developed the confidence and awareness needed to contribute to future technological solutions.

At the end of the program, all students successfully presented their antenna fabrication results and demonstrated improved ability in interpreting measurement outputs. Several groups reported increased confidence in understanding signal behavior and expressed interest in further exploring antenna applications to address connectivity challenges in their communities. Future programs are therefore recommended to involve a larger and more diverse sample, extend the duration of intervention, and incorporate comparative or experimental designs to strengthen the validity and impact of the findings.

Conclusion

This community engagement program successfully met its objectives in strengthening vocational students' competence in antenna technology and enhancing their awareness of wireless communication challenges in island regions. The applied STEM-based training method—combining scientific explanation, engineering design, hands-on fabrication, and performance measurement—proved to be highly appropriate for addressing the skill gaps identified in the partner school, particularly the limited exposure to wireless communication concepts. The program produced measurable improvements in conceptual understanding, practical skills, and student confidence, and it effectively supported the development of problem-solving abilities relevant to the technological needs of the Riau Archipelago.

The activities generated significant benefits for the participants, including increased readiness to analyze signal problems, improved ability to interpret measurement data, and greater motivation to pursue technology-related inquiry. The training also contributed to community empowerment by cultivating local technical capacity that is essential for addressing digital connectivity issues in dispersed maritime regions. Furthermore, the active participation of students throughout the program indicates strong potential for adopting antenna-related innovation in their everyday environments.

To strengthen future community empowerment initiatives, it is recommended that similar programs be expanded to include advanced antenna design modules, collaborative mini-projects, and field-testing sessions in areas with weak signal conditions. Continued partnerships between universities and vocational schools will be important to sustain capacity-building efforts, support curriculum enrichment, and ensure that local communities remain equipped to respond to evolving connectivity challenges in the Riau Archipelago.

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Declarations

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT-4o to improve the language and readability of the manuscript. Following the use of this tool, the authors reviewed and edited the content as necessary and take full responsibility for the published content.

Authorship Contribution

Rusfa: Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing; Tonny Suhendra: Data Curation, Writing – Review & Editing; Mariyanti Elvi: Formal Analysis, Visualization; Ferly Oktavia: Validation, Investigation, Writing – Review & Editing.

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Conflict of Interest

The authors declare that they have no competing financial, professional, or personal interests related to this work. The funding source had no role in the program design, data collection and analysis, interpretation of the results, preparation of the manuscript, or decision to submit the article for publication. The authors also declare no affiliations that could be perceived as influencing the work.

Ethical Approval

This study used anonymous survey data to evaluate students' understanding and was considered exempt from formal institutional ethical review due to its minimal-risk nature. Ethical standards were maintained throughout the program. Informed consent was obtained from all participants prior to participation, and participants were informed of their right to withdraw at any time. All collected data were anonymized to protect participant privacy.

Data Availability Statement

All relevant data generated and analyzed during this study are included in this article.

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