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IoT Implementation for Control and Monitoring of Production to Enhance the Quality of Chain-Link Wire Mesh at UMKM Bengkel Hikmah Teknologi, Blang Crum Village, Lhokseumawe City

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ABSTRACT

This community service activity was carried out with the aim of assisting the UMKM Bengkel Hikmah Teknologi in Blang Crum Village, Lhokseumawe City, in improving the quality and quantity of chain-link fence (kawat harmonika) production through the implementation of Internet of Things (IoT)-based technology. The main problems faced by the partner include low product precision, relatively slow production processes, and high operational costs due to manual systems. To address these issues, the community service team designed and implemented an IoT-based automatic control system capable of regulating wire length, tension, and alignment with high precision, while also providing real-time production monitoring through a web-based interface. The stages of the activity included partner needs analysis, system design, device installation and integration, operator training, and system performance evaluation. The results showed significant improvements, including product quality consistency reaching up to 90%, production speed increased by 50%, and labor efficiency improved by 50%. In addition to generating economic benefits through profit growth for the partner, this activity also fosters the development of a technology-based creative industry and contributes to the achievement of Sustainable Development Goal (SDG) number 9 on industry, innovation, and infrastructure.

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INTRODUCTION

UMKM Bengkel Hikmah Teknologi, located in Blang Crum Village, Muara Dua Subdistrict, Lhokseumawe City, Aceh, as shown in Figure 1, is a micro-enterprise engaged in the production of chain link wire (kawat harmonika). Established in 2020 and independently managed by its owner, this business holds significant potential in meeting community needs for wire mesh products, particularly for fencing, construction, and security purposes. However, the workshop faces several critical challenges in its production management.

One of the main obstacles is that the production process is still largely manual and only carried out when incoming orders are received. This condition prevents the business from producing in larger quantities or preparing stock for wider distribution, such as through hardware stores or online marketplaces. The limited production capacity is primarily due to the suboptimal performance of the existing machinery, both in terms of production speed and product quality, which remains inconsistent and less precise. Furthermore, the absence of an integrated control and monitoring system makes it difficult to track and evaluate production processes comprehensively, thus reducing efficiency and the overall quality of the final product.

From a regional perspective, Blang Crum Village has relatively good accessibility and a high potential for UMKM development. Nevertheless, technological intervention is still required for local enterprises to remain competitive in broader markets. Therefore, the implementation of Internet of Things (IoT)-based technology to automate production control and monitoring is essential. Such an approach is expected to accelerate production processes, improve product quality, and create opportunities for business expansion on a larger scale.

FIGURE 1. Condition of UMKM Bengkel Hikmah Teknologi located in Blang Crum Village, Muara Dua Subdistrict, Lhokseumawe City, Aceh, as the production site of chain link wire

The production of chain link wire in Lhokseumawe City and its surrounding areas is still relatively limited, both in terms of the number of businesses and production capacity. This condition actually presents a highly promising business opportunity to be developed, considering the increasing demand for chain link wire, particularly for residential fences, commercial buildings, public facilities, and construction projects. Chain link wire is widely recognized as a building material with significant functions in terms of security and aesthetics, offering advantages in durability and flexibility of use. Amid

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the continuous growth of infrastructure development in Aceh, including Lhokseumawe City, the demand for chain link wire is expected to keep rising. However, the limited number of local producers often forces consumers to purchase from outside the region, resulting in higher prices and longer delivery times. This indicates that the local market remains wide open and requires more businesses capable of meeting these needs efficiently and sustainably.

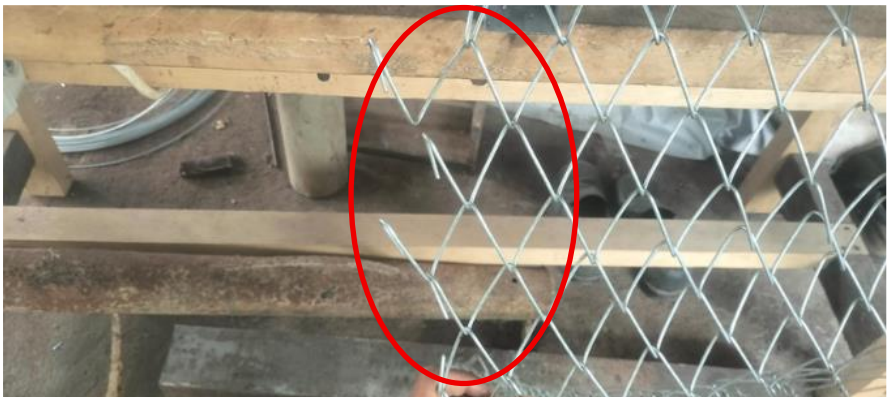

FIGURE 2. Shows the production results of chain link wire that are still imprecise, which leads to material waste.

In the production process of chain link wire at UMKM Bengkel Hikmah Teknologi, issues related to inaccuracy are often encountered, particularly in terms of wire dimension precision. Figure 2 shows that the weaving results are not uniform, with several sections exceeding the standard size, requiring manual re-cutting. This condition directly affects production efficiency as it leads to material waste. The unused wire cuttings become production waste, which not only increases raw material costs but also adds extra workload for operators. Furthermore, inaccuracies in wire dimensions and joints can compromise the overall quality of the product, both in terms of strength and appearance, ultimately reducing consumer trust in the final output. This problem generally occurs because the production system is still carried out manually and lacks automatic control technology that can ensure uniformity of wire dimensions according to the desired design or specifications. To address this issue, the implementation of Internet of Things (IoT)-based technology for real-time monitoring and precision control of production is essential. Such technology enables the production machine to automatically measure and regulate wire length and tension, thereby reducing human error and minimizing material waste. With this technology, not only will product quality improve, but also the efficiency of raw material utilization, which will ultimately have a positive impact on business profitability and product competitiveness in the market.

FIGURE 3. A partner employee engaged in the production process of chain-link wire at UMKM Bengkel Hikmah Teknologi

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In Figure 3, the operator is shown carrying out the manual production of chain-link wire at UMKM Bengkel Hikmah Teknologi. This process requires a high level of accuracy and skill, as the operator must ensure that the wire is woven with a precise and consistent pattern. The operator is also responsible for adjusting the length, tension, and position of the wire to match the desired size and shape. Such activities are not only time-consuming but also physically demanding, especially when production is carried out in large quantities. Dependence on manual skills without the support of automated tools makes the production process less efficient and prone to errors, both in terms of measurement, pattern, and outcome. Moreover, productivity heavily relies on the operator's capabilities and physical condition, which can lead to inconsistent results and uneven product quality.

This figure clearly illustrates that the production process is still highly dependent on direct human intervention, which represents one of the main reasons why technological intervention is needed to enhance efficiency and accuracy in production. The implementation of Internet of Things (IoT)-based technology can serve as an ideal solution to support the operator's work, for instance, by providing an automatic control system capable of monitoring and regulating the production process in real time. In this way, the operator continues to play an important role but is assisted by a system that improves precision, accelerates production time, and reduces the likelihood of errors in the chain-link wire production process.

Local enterprises such as Bengkel Hikmah Teknologi in Blang Crum Village hold significant potential to play a strategic role in fulfilling this market demand. With the support of technology, increased production capacity, and a more structured management system, this enterprise can become a pioneering local producer of competitive chain-link wire. Furthermore, the development of this business has the potential to create new job opportunities for the surrounding community and stimulate local economic growth. The adoption of IoT-based technology in the production process can become a key added value that strengthens product competitiveness in terms of quality, efficiency, and the ability to meet large-scale demand. Therefore, this opportunity needs to be optimally utilized through proper empowerment and assistance.

The objective of the Community Service Program entitled "Implementation of IoT-Based Production Control and Monitoring Technology to Improve Quality and Increase the Production Capacity of Chain-Link Wire Manufacturing at UMKM Bengkel Hikmah Teknologi, Blang Crum Village, Lhokseumawe City" is to empower local entrepreneurs through the application of innovative and appropriate technology to enhance efficiency, accuracy, and production capacity of chain-link wire. This activity directly supports the achievement of the Sustainable Development Goals (SDGs), particularly Goal 8 (Decent Work and Economic Growth) and Goal 9 (Industry, Innovation, and Infrastructure). In addition, the program is aligned with the Higher Education Key Performance Indicators (IKU), particularly IKU 3 (lecturers working outside campus), IKU 5 (research outputs utilized by society), and IKU 2 (students gaining off-campus experiences). Within the context of Asta Cita, this program supports Goal 6, namely "Enhancing the productivity of the people and competitiveness in international markets" by strengthening local economic potential through technology-based approaches. Furthermore, this activity is in line with the focus areas of the National Research Master Plan (RIRN), particularly Engineering and Industrial Technology, as well as Information and Communication Technology, through the integration of IoT in the MSME sector. The main issues addressed concern the suboptimal production and business management processes due to reliance on manual methods, lack of precision, and minimal systematic documentation. With the implementation of IoT-based production control and monitoring technology, a more efficient, modern, and competitive system is expected to be established, thereby sustainably enhancing the competitiveness of local MSMEs.

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METHOD

The implementation method of this community service activity applies an applied technology engineering approach with systematic stages designed to address the challenges faced by UMKM Bengkel Hikmah Teknologi in producing chain-link wire mesh. The process begins with observation and needs analysis, carried out through field visits, interviews, and direct measurement of the production process. Collected data include product dimensions, daily production volume, average production speed per meter, and the precision level of the woven results. This quantitative information becomes the foundation for formulating solutions that are aligned with actual field conditions.

Following this stage, the team develops a prototype of an Internet of Things (IoT)-based automatic control system utilizing an ESP32 microcontroller integrated with sensors and actuators to regulate wire length, tension, and alignment. Initial trials are conducted with at least three replications on 10-meter production runs to test system stability and accuracy. Once the prototype demonstrates feasibility, the system is installed and tested on a full scale using the partner's production machine. During this process, new production data are gathered to evaluate improvements in production speed, labor efficiency, and product quality compared to conditions before implementation.

To ensure effective technology transfer, comprehensive training is provided to UMKM operators through lectures, question and answer sessions, and group discussions. Lectures introduce the fundamental concepts of IoT, system operating principles, and step-by-step guidance on system operation. The question and answer sessions enable participants to clarify their understanding, while group discussions focus on identifying field-related challenges and formulating practical solutions. The training program concludes with a system evaluation, based on indicators such as enhanced product precision, reduced production time, and improved workforce efficiency, thereby ensuring that the system can be optimized to meet the partner's long-term needs.

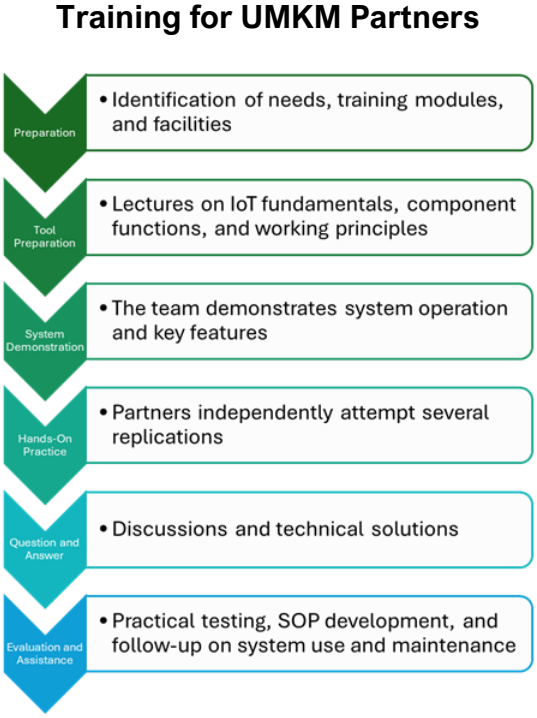

FIGURE 4. Flowchart of the UMKM training stages in the community service activity

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- Preparation – Identification of training needs according to the partner's condition. Development of training modules covering the basic theory of IoT, component functions, and machine operating procedures. Provision of training facilities such as laptops, projectors, printed modules, and IoT devices ready for use.
- Theoretical Introduction – Delivery of material through lectures to explain the basic concepts of the Internet of Things, the benefits of automation in small industries, and the working principles of the control system. Explanation of the function of each component, including sensors, actuators, and the ESP32 microcontroller.
- System Demonstration – The team demonstrates how the IoT system installed on the production machine works. The focus is on setting wire length, tension, and real-time production monitoring.
- Hands-On Practice – Partners are involved in independently operating the system under the team's guidance. Multiple replications are conducted to ensure partners become familiar with operating the system from start to finish until the product is produced.
- Question and Answer Session and Discussion – An interactive session to accommodate questions from partners. The discussion focuses on technical challenges and practical solutions that can be applied daily.
- Evaluation and Mentoring – Evaluation of the partner's understanding through simple practice tests. The team provides further assistance, including the preparation of written guidelines (SOP) for the use and maintenance of the system.

RESULTS AND DISCUSSION

Initial Condition of UMKM Bengkel Hikmah Teknologi

UMKM Bengkel Hikmah Teknologi, located in Blang Crum Village, Lhokseumawe City, is a local business engaged in the production of chain-link wire mesh. This product has considerable economic value as it is widely used for various purposes, such as land boundary fencing, temporary construction walls, animal cages, as well as home and plantation security systems.

Before the implementation of this community service activity, the UMKM was still facing several challenges, including:

- Production remains semi-manual:

  The chain-link wire mesh machine owned by the partner has not yet been equipped with an automatic monitoring system, requiring the operator to manually check the weaving process.

- Low production capacity:

  The average production is only around 15 m² per day. This figure is still far below market demand, which can reach 20–25 m² per day.

- Inconsistent product quality:

  Instability in machine speed and wire tension often causes irregular weaving patterns.

- Raw material waste:

  Wire is often wasted due to delays in detecting technical issues such as wire breakage or machine

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jams.

- Stagnant income:

  With limited capacity, the UMKM's average monthly income is only around IDR 5–6 million.

Table 1 presents the initial production conditions at UMKM Bengkel Hikmah Teknologi before the implementation of the IoT-based control and monitoring technology. The data show that production capacity was still limited to an average of 30 rolls per month, with product quality lacking uniformity, where the precision level only reached around 70%. This condition was influenced by the use of a manual system, which required considerable time for measuring wire length, adjusting tension, and arranging the chain-link pattern. In addition, production speed was relatively slow, with an average of 8 hours needed to produce one roll of chain-link wire mesh, resulting in a high workload for operators. This situation negatively impacted labor efficiency and increased operational costs due to high energy and time consumption. From a financial perspective, the partner could only generate profits of approximately IDR 6,000,000 per month, which is still relatively low compared to the large market potential in Lhokseumawe and the surrounding areas. These conditions highlight fundamental problems related to productivity, product precision, and cost efficiency, thus requiring modern technology-based solutions to enhance business competitiveness and expand market access.

TABLE 1. Initial Production Conditions of UMKM Bengkel Hikmah Teknologi

Production Aspect	Initial Condition (Before IoT)
Daily Production Capacity	± 15 m²/day
Working Hours	8 hours/day
Product Quality	Inconsistent, frequent weaving defects
Material Efficiency	± 80% (20% wasted due to machine errors)
Monitoring System	Manually, operators must check routinely
Monthly Income	Rp 6,000,000

IoT Technology Intervention

Considering these conditions, the community service team from Politeknik Negeri Lhokseumawe (PNL) offered a solution through the implementation of IoT-based control and monitoring technology on the chain-link wire machine. This intervention was carried out through several strategic steps:

- Installation of sensors to detect machine rotation speed, the number of wire coils, and wire tension during the production process.
- Integration of the ESP32 microcontroller as the control center for processing sensor data.
- Development of a web server–based monitoring dashboard, enabling operators to monitor machine conditions in real time using either laptops or smartphones.
- Implementation of an automatic notification system that alerts operators in case of issues such as wire breakage or non-standard weaving patterns.
- Training operators to understand the usage, maintenance, and troubleshooting of the new system.

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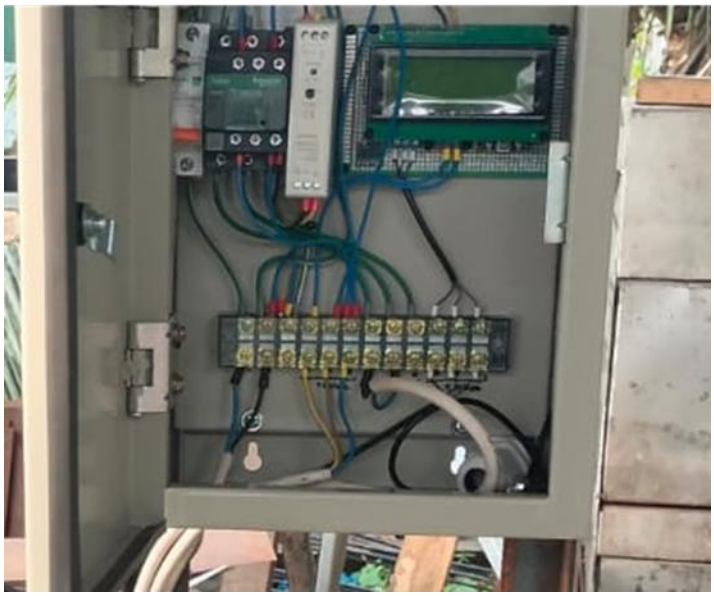

FIGURE 5. IoT-Based Control Module for the Chain-Link Wire Machine Implemented at the Partner UMKM

With the implementation of IoT technology, the production process at the partner's workshop became far more efficient and reliable. The integration of sensors, an ESP32 microcontroller, and a real-time web-based monitoring dashboard significantly reduced the risk of errors such as wire breakage and uneven weaving patterns. Operators could easily monitor machine performance, receive automatic notifications when problems occurred, and adjust settings without manual checks. This not only saved time but also minimized material waste. As a result, production capacity increased, product quality became more consistent, and overall operational efficiency improved, leading to higher productivity and profitability.

TABLE 2. Comparison of Production Before and After IoT Implementation

Production Aspect	Before IoT	After IoT	Improvement
Daily Production Capacity	± 15 m²/day	± 25 m²/day	+66%
Working Hours	8 hours/day	8 hours/day	Constant
Material Efficiency	± 80%	± 95%	+15%
Product Quality	Variable, frequent defects	Stable, more consistent	Significant improvement
Monitoring System	Manual	Real-time IoT-based	More efficient
Monthly Income	Rp. 9,000,000	Rp. 15,000,000	+66%

From the table, it is clear that the most significant improvements occurred in production capacity and income. Daily production, which was previously limited to only 15 m² per day, increased to 25 m² per day after the IoT system was implemented. Likewise, monthly income experienced a substantial rise, growing from Rp9,000,000 to Rp15,000,000, representing a 66% increase. This improvement demonstrates the positive impact of integrating IoT-based monitoring and control technology on productivity and efficiency. With more stable product quality and reduced material waste, the overall competitiveness of the business has also been significantly enhanced.

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FIGURE 6. The PKM team, assisted by students, is conducting configuration before testing

Figure 6 illustrates the PKM team, supported by students, actively engaged in the configuration process before testing the IoT-based control system on the harmonica wire machine. At this stage, the team ensures that all hardware components, such as sensors, ESP32 microcontrollers, and actuators, are properly connected and functioning. The students assist in setting up the system, uploading the program, and calibrating sensor readings to match the production requirements. This preparatory phase is crucial for minimizing potential errors during testing and ensuring that the machine can operate efficiently once the IoT system is fully implemented.

Economic Impact on the Partner

The increase in production has had a direct impact on the income of UMKM Bengkel Hikmah Teknologi. Previously, the business could only fulfill a limited number of orders due to low production capacity and inconsistent product quality. After the implementation of the IoT-based monitoring and control system, the workshop is now able to meet larger order volumes with greater consistency and efficiency. This improvement not only boosts monthly revenue but also enhances customer trust and satisfaction. In the long term, the partner gains stronger competitiveness, better market opportunities, and sustainable business growth within the local industry.

TABLE 3. Comparison of UMKM Income

Month	Before IoT (Rp)	After IoT (Rp)
Month 1	9,200,000	14,800,000
Month 2	8,900,000	15,100,000
Month 3	9,000,000	15,000,000
Average/month	9,000,000	15,000,000

Table 3 presents a comparison of UMKM Bengkel Hikmah Teknologi's income before and after the implementation of IoT over three months. Before the intervention, the monthly income fluctuated between Rp8,900,000 and Rp9,200,000, with an average of Rp9,000,000. After the IoT-based monitoring and control system was applied, income rose significantly, ranging from Rp14,800,000 to Rp15,100,000, with a monthly average of Rp15,000,000. This consistent growth reflects a 66% increase, driven by improved production efficiency and product quality. The data shows that IoT technology not only boosted productivity but also created tangible economic benefits for the business.

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Human Resource Competency Improvement

Beyond the direct impact on production capacity and income growth, this community service program has generated significant improvements in the human resource competencies of UMKM Bengkel Hikmah Teknologi, as summarized in Table 4. Before the intervention, operators relied solely on manual processes, including physically checking machine speed, wire tension, and mesh alignment. These methods demanded constant attention, were prone to human error, and often caused operator fatigue, limiting production efficiency and consistency.

With the implementation of the IoT-based control and monitoring system, operators acquired essential digital skills and technological literacy. Structured training sessions enabled them to operate an IoT dashboard, interpret real-time data from sensors, and respond immediately to system notifications, such as wire breakage or irregular weaving patterns. Furthermore, they learned basic troubleshooting and maintenance of ESP32 microcontrollers and sensor devices, ensuring the long-term sustainability of the system.

Table 4 highlights measurable improvements across key competency areas, including machine operation, monitoring, troubleshooting, data literacy, and overall confidence. Operators have transitioned from manual machine operators to technologically skilled technicians, capable of independently managing advanced digital systems. This development not only improves productivity and efficiency but also strengthens the UMKM's readiness to adopt future technological innovations, expand production capacity, and compete more effectively in a growing market, ensuring sustainable growth and competitiveness.

TABLE 4. Improvement after implementing IoT technology in MSMEs

Competency Aspect	Before IoT Implementation	After IoT Implementation	Improvement Achieved
Machine Operation Skills	Manual operation, high risk of errors	Able to operate an IoT-based dashboard and controls	Improved technical capability
Monitoring & Control	Visual/manual checking only	Real-time digital monitoring with notifications	More accurate and efficient
Troubleshooting Ability	Limited, dependent on an external technician	Basic troubleshooting and system maintenance	Higher self-reliance
Data Literacy	No data recording or analysis	Able to read and interpret sensor-based data	Better decision-making support
Confidence & Adaptability	Less confident with new technology	Confident in handling modern IoT systems	Increased readiness for Industry 4.0

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(a)

(b)

FIGURE 7. The PKM team is providing training to the partner on operating the IoT-based production control module

Figure 7 illustrates the PKM team actively conducting a hands-on training session for the UMKM partner on how to operate the IoT-based production control module. During this session, operators were guided step by step on using the digital dashboard to monitor machine performance, adjust wire tension, control weaving speed, and detect abnormalities in real time. The training also emphasized interpreting sensor data, responding to system notifications, and performing basic troubleshooting. This interactive approach, combining demonstration and practical exercises, allowed the operators to gain confidence and develop the technical skills necessary for independent operation. By directly involving the partner in the system's operation, the training ensured that the IoT technology would be effectively utilized to enhance production efficiency, improve product quality, and reduce material waste, fostering sustainable improvements in both human resources and overall business performance.

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FIGURE 8. Group photo with the partner after the completion of the community service activity

The community service activity not only produced tangible outputs, such as increased production capacity and improved product quality, but also generated significant outcomes in human resource development. Local operators at UMKM Bengkel Hikmah Teknologi gained valuable skills in operating IoT-based control and monitoring systems, interpreting real-time sensor data, and performing basic troubleshooting. This capacity building enhanced their technical competence, confidence, and independence, transforming them from manual machine operators into technologically capable technicians. By empowering local human resources, the program ensured sustainable utilization of modern technology, improved operational efficiency, and strengthened the overall competitiveness of the UMKM in the regional market.

CONCLUSION

The community service activity entitled “Implementation of IoT-Based Production Control and Monitoring Technology to Improve Quality and Increase Production of Chain-Link Wire at UMKM Bengkel Hikmah Teknologi, Desa Blang Crum, Kota Lhokseumawe” successfully provided a concrete solution to the partner’s challenges. The implementation of an IoT-based automatic control system, capable of precisely regulating wire length, tension, and neatness, combined with real-time monitoring via a web-based interface, proved effective in improving product quality, achieving up to 90% uniformity. Moreover, production speed increased by 50%, with more efficient processing time per roll of wire, thereby reducing operator workload and lowering operational costs.

Economically, the partner experienced an increase in production capacity from an average of 30 rolls per month to 45 rolls per month, resulting in approximately a 40% rise in revenue. Furthermore, this activity strengthened the technology-based creative industry, expanded the partner’s understanding of the importance of innovation, and enhanced preparedness for the era of industrial digitalization. The success of this program not only improved the competitiveness of UMKM Bengkel Hikmah Teknologi but also contributed to achieving Sustainable Development Goal (SDG) 9, particularly in the areas of industry, innovation, and infrastructure. Consequently, this community service provides sustainable added value for both the partner and the wider community.

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