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IMPLEMENTATION OF 3D PRINTING TECHNOLOGY TO SUPPORT INNOVATIVE AND CREATIVE LEARNING FOR STUDENTS AND TEACHERS OF SMAN 1 SIDAYU GRESIK

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Abstract

Background. Integrating three-dimensional (3D) printing technology into secondary education offers opportunities to enhance digital literacy, experiential learning, and innovative teaching practices. However, limited access to digital fabrication equipment and insufficient technical competencies among teachers and students remain challenges to its implementation.

Aims. This community service program aimed to introduce 3D printing technology, strengthen participants' understanding of digital fabrication, and promote its potential application in creative and project-based learning at SMAN 1 Sidayu, Gresik, Indonesia.

Methods. The program employed a participatory, practice-oriented approach comprising four stages: preparation, implementation, evaluation, and sustainability support. Activities included interactive lectures, technology demonstrations, guided 3D modeling exercises, and practical instruction in preparing digital designs for printing. Program outcomes were evaluated using pre-test and post-test assessments involving 35 participants and a satisfaction questionnaire completed by 31 respondents.

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Result. The findings revealed an increase in mean knowledge scores from 48.63 to 54.71, representing a gain of approximately 6.08 points. Individual performance improved for 54.3% of participants, remained unchanged for 31.4%, and declined for 14.3%. Furthermore, 93.5% of respondents rated the overall program as Very Good, while facilities and instructional quality received Very Good ratings of 91.6% and 89.5%, respectively. Participants nevertheless identified the need for longer practical sessions, more opportunities for independent printing, and improved instructional pacing. A 3D printer was donated to the school to support ongoing technology-based learning activities.
Conclusion. These findings suggest that structured training combined with equipment provision can support initial technological understanding and create opportunities for integrating digital fabrication into secondary education. However, sustained mentoring, teacher capacity development, and longitudinal evaluation are necessary to establish the program's long-term educational impact.

Keywords: 3D printing technology; digital fabrication; innovative learning; digital literacy; project-based learning; community engagement.

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INTRODUCTION

The development of digital technology has created a need for learning approaches that not only deliver information but also give students opportunities to explore, design, and produce their own work. Technology in education can support the development of digital knowledge and skills; however, its implementation must align with learning objectives, teachers' readiness, and students' needs. UNESCO emphasizes that educational technology should consider relevance, equitable access, effectiveness, and sustainability to genuinely support improvements in learning quality (Global Education Monitoring Report Team, 2023). A systematic review by Novak et al. also shows that 3D printing has been used to support interdisciplinary learning, produce learning media, and encourage creativity and innovation (Novak, E., et al., 2021).

One technology with the potential to support active learning is 3D printing, or three-dimensional printing. This technology is a form of additive manufacturing, a process in which objects are created by adding material layer by layer based on a digital model. In education, 3D printing can be used to introduce manufacturing processes to students and teachers, support the delivery of learning materials, and produce physical objects that facilitate learning. Ford and Minshall identified various applications of 3D printing in education, including supporting teaching, producing objects for learning activities, and developing technology-based educational activities (Ford, S., & Minshall, T., 2019). A study by Salazar et al. showed that the use of 3D-printed anatomical models can improve students'

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understanding of complex anatomical structures, indicating that printed physical objects can help visualize concepts that are difficult to understand (Salazar, D., et al., 2022).

3D printing can also be integrated into design activities, problem-solving, and project-based learning. Students can develop ideas into digital models, adjust dimensions, examine shapes, and then prepare files for printing. This process connects theoretical concepts with the design and production of tangible products. Research by Stern et al. showed that additive manufacturing education through product design and printing activities can provide collaborative learning experiences and encourage the application of knowledge to solve problems (Stern, A. et al., 2019). Lin et al. also reported that STEM projects based on 3D printing and iterative modeling can support secondary school students' imagination and interest in technology and engineering (Lin, K.-Y. et al., 2023).

Nevertheless, implementing 3D printing in schools requires adequate technical introduction and guidance. Teachers and students need to understand the printer's working principles, component functions, filament characteristics, the use of design and slicing software, and operational safety. A review by Tejera et al. emphasizes that integrating 3D modeling and printing into teacher education can support practical skills and experience, but still faces challenges related to limited resources, time, and integration into teaching and learning (Tejera, M. et al., 2025). In addition, using FFF/FDM printers requires attention to particle and chemical emissions, which are affected by filament type and printing temperature (Stefaniak, A. B., et al., 2021; Li, J. F., & Glassford, E. K., 2025). Successful technology integration is also influenced by resource readiness, teacher competence, equipment availability, and the technology's suitability for learning needs (Global Education Monitoring Report Team, 2023; Ford, S., & Minshall, T., 2019; Salazar, D. et al., 2022).

In response to these needs, the Faculty of Science and Technology, Universitas Airlangga, organized a community service program entitled "Implementation of 3D Printing Technology to Support Innovative and Creative Learning for Students and Teachers of SMAN 1 Sidayu Gresik." The program, attended by approximately 30 participants, aimed to introduce the working principles and components of 3D printing, provide an understanding of its applications in learning, and guide participants in creating simple designs and preparing print files. Through this program, which also included learning evaluation and the donation of a 3D printer to the school, participants' technological literacy and digital design skills were expected to improve, while opportunities for project-based learning at SMAN 1 Sidayu Gresik could be expanded.

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METHOD

The community service program entitled "Implementation of 3D Printing Technology to Support Innovative and Creative Learning for Students and Teachers of SMAN 1 Sidayu Gresik" was carried out in four main stages: preparation, implementation, evaluation, and program sustainability, as illustrated in Figure 1. These stages were systematically designed so the program would not focus solely on introducing the technology, but would also give participants practical experience and encourage the use of 3D printing in school learning activities. The use of 3D printing in education may include introducing the technology to students and educators, producing objects to support learning, and developing practice-based educational activities (Ford, S., & Minshall, T., 2019 ; Novak, E., et al., 2021 ; Tejera, M., et al., 2025).

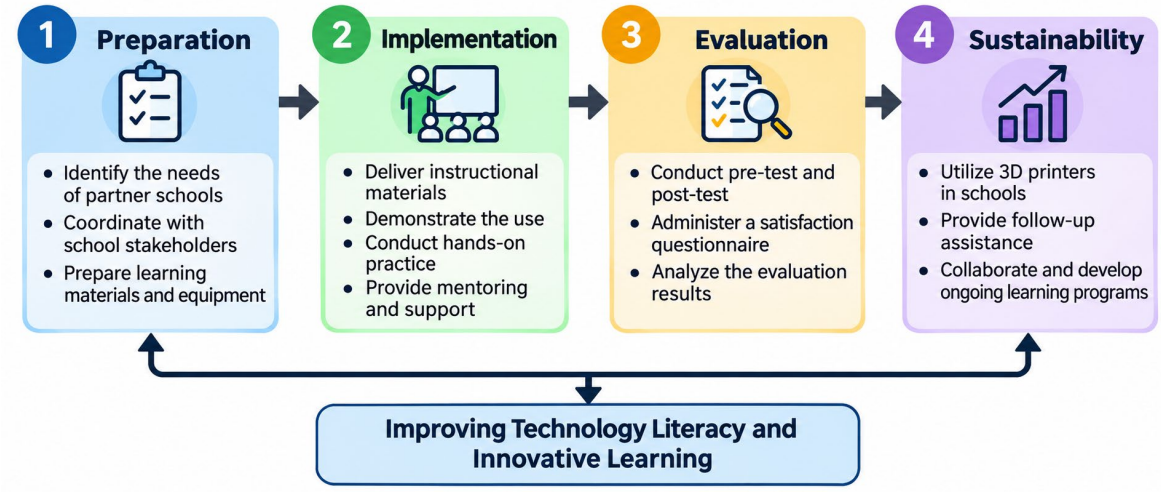


Figure 1. Diagram of the activity implementation stages

Preparation Stage

The preparation stage began with identifying the partner school's needs and coordinating between the community service team from the Faculty of Science and Technology, Universitas Airlangga, and SMAN 1 Sidayu Gresik. The team coordinated to align program objectives, training materials, participants' needs, and the school's available facilities. The team then prepared training materials covering an introduction to 3D printing technology, the printer's working principles and components, types of materials or filaments, and its use in supporting innovative and creative learning.

Technical preparation included checking the 3D printer, laptops or computers, filament, design and slicing software, three-dimensional model files, and supporting

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equipment for demonstrations and practice. The team also prepared evaluation instruments, including pre-test and post-test questions and a participant satisfaction questionnaire. This preparation ensured the activities would meet their objectives and that the technology introduced would be relevant to learning needs. UNESCO (Global Education Monitoring Report Team, 2023) emphasizes that technology use in education should consider its suitability for learning needs, user readiness, and sustainability. Teacher readiness and training support are also important factors in implementing 3D modeling and printing technology (Tejera, M. et al., 2025).

Implementation Stage

The implementation stage began with an opening session and remarks from the school and representatives of the community service team. Participants then took a pre-test to assess their initial understanding of 3D printing technology. This was followed by presentations on the definition of 3D printing, its working principles, the printer's main components, the materials or filaments used, and operational safety. The next topic covered potential applications of 3D printing technology as a learning medium, particularly in supporting design activities, producing teaching aids, and developing simple products in the school environment.

After the presentation, participants attended a demonstration of the hardware and software required for the three-dimensional printing process. The demonstration was followed by practical sessions and guidance in creating simple designs and preparing files for printing. In general, the practical stages included creating or modifying a digital model, exporting it in STL format, configuring it using slicing software, and preparing the print file for the printer being used. This practice-based approach gave participants the opportunity to connect conceptual knowledge with designing and producing physical objects. Ford and Minshall (2019) explain that 3D printing can be used in education to introduce additive manufacturing technology while producing artifacts that support the learning process. Design- and print-based learning experiences can also encourage learning through direct practice (learning by doing) (Greenhalgh, S., 2016; Özeren, Ö., et al., 2023).

During demonstrations and practical sessions, participants were instructed to follow equipment operating procedures, stay away from the high-temperature nozzle and build plate, and use the printer in an area with adequate air circulation. These safety considerations are important because the FFF/FDM process can generate ultrafine particles and volatile

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organic compounds, depending on the material and printing conditions (Stefaniak, A. B., 2021; Li, J. F., & Glassford, E. K., 2025).

Evaluation Stage

The evaluation stage assessed whether the program objectives were achieved, particularly improvements in participants' understanding and their assessment of the training. Knowledge was evaluated by comparing the pre-test and post-test results. The results of both tests were used to identify changes in participants' understanding after attending the presentations and practical sessions. The data were analyzed by comparing mean scores before and after the activities to present changes in learning outcomes quantitatively.

In addition to knowledge evaluation, the study collected feedback through a participant satisfaction questionnaire. The aspects evaluated included the relevance of the materials to participants' needs, the clarity of the instructors' presentations, the adequacy of facilities and infrastructure, opportunities for hands-on practice, and the benefits of the activities for learning at school. The evaluation results helped identify what worked well and what needed improvement for future activities. This evaluation approach aligns with the principle of evidence-based educational technology use, which requires assessing technology effectiveness and its suitability for learning objectives (Global Education Monitoring Report Team, 2023; Novak, E. et al., 2021).

Sustainability Stage

The sustainability stage focused on using 3D printing technology after the training was completed. One form of sustainability support in this program was donating a 3D printer to the partner school so the equipment could be used in learning activities. Its use could be developed through the production of teaching aids, three-dimensional models for science and mathematics lessons, and simple prototypes created as part of student assignments or projects.

Program sustainability could also be strengthened through continued mentoring, supporting learning materials, teacher capacity development, and collaboration between the school and the community service team. Teachers can integrate three-dimensional design and printing activities into project-based learning so that students gain experience in

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designing, testing, and refining products. Developing three-dimensional design and printing skills across disciplines can strengthen the integration of science, technology, engineering, arts, and mathematics learning (Harron, J. R., et al., 2022; Tejera, M. et al., 2025; Lin, K.-Y. et al., 2023).

Overall, these four stages are interrelated and supported by continuous monitoring and evaluation. The evaluation results provide a basis for improving activity implementation and planning subsequent programs. Through this approach, the community service program is expected to improve technological literacy, digital design skills, and the implementation of innovative learning at SMAN 1 Sidayu Gresik.

DISCUSSION

Implementation of the Community Service Program

The community service program, themed "Implementation of 3D Printing Technology to Support Innovative and Creative Learning for Students and Teachers of SMAN 1 Sidayu Gresik," was held on Friday, October 9, 2026, at SMAN 1 Sidayu, Gresik Regency, East Java. This activity represented the Faculty of Science and Technology, Universitas Airlangga's contribution to introducing digital manufacturing technology to the secondary education environment. Through this program, students and teachers were expected to gain basic knowledge and initial experience in using 3D printing technology as an innovative and creative learning medium.

The series of activities began at 08:00–08:15 Western Indonesian Time (WIB) with the team's arrival, coordination with the school, and venue preparation. Participant registration took place from 08:15 to 08:30, followed by the opening session from 08:30 to 08:45. After remarks by the Principal of SMAN 1 Sidayu Gresik and the chair or coordinator of the community service program, the activity continued with the presentation of a memento and a prayer. This opening sequence was important for establishing coordination between the implementation team and the partner school and ensuring that the activities proceeded according to plan.

At 09:15–09:30, participants took a pre-test to assess their initial understanding of 3D printing technology. Next, from 09:30 to 10:00, participants received an introduction to 3D printing technology, covering its working principles, the machine's main components, materials or filaments, and safety aspects of its use. This material provided a conceptual

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foundation before participants attended an explanation of how 3D printing supports innovative and creative learning at school from 10:00 to 10:30.



Figure 2. Introduction to 3D printing technology and its use in innovative and creative learning.

The practical and mentoring sessions took place from 10:30 to 11:30 and continued from 13:00 to 13:30 after the break for rest, prayer, and lunch. During these sessions, participants were guided to create simple designs and prepare digital files for 3D printing. The activities then continued with a post-test, a live interactive quiz, and completion of the evaluation from 13:30 to 13:50. From 13:50 to 14:00, a 3D printer was donated to the school, and documentation continued, while the closing session was held from 14:00 to 14:10.

Improvement in Participants' Knowledge of 3D Printing Technology

One indicator of the program's success was the change in participants' understanding before and after the training. This was measured through a pre-test conducted from 09:15 to 09:30 and a post-test from 13:30 to 13:50. These two measurements were used to identify developments in participants' understanding of the working principles of 3D printing and the stages involved in producing three-dimensional objects.

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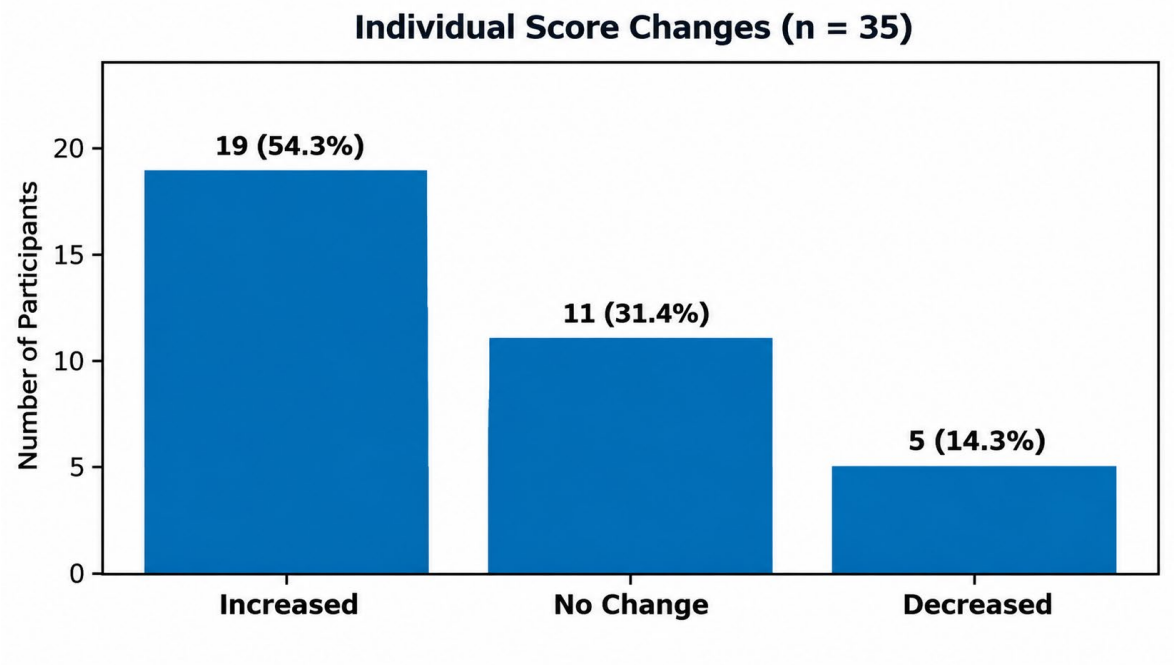


Figure 3. Distribution of individual score changes among participants who completed the pre-test and post-test.

Based on an analysis of the 35 participants who completed both the pre-test and post-test, 19 participants (54.3%) showed an increase in scores, 11 participants (31.4%) obtained the same scores, and 5 participants (14.3%) experienced a decrease. These results show that more than half of the participants improved their test scores after participating in the community service program on 3D printing technology. This finding indicates a change in test performance after the training; however, it cannot be interpreted as evidence of a single causal effect because the activity did not use a control group.

The score increases among most participants indicate an improvement in understanding following the presentations and practical guidance. Meanwhile, participants whose scores remained unchanged showed no change in their test results, while the decrease in scores among some participants indicates that improvements were not uniform. These differences can inform the improvement of presentation methods and the provision of more intensive guidance in future activities. This is consistent with the systematic review by Novak et al. (2021), which emphasizes that the benefits of 3D printing in learning are influenced by instructional design and implementation, as well as the review by Tejera et al. (2025), which identifies limited time and the need for training support as challenges to integrating this technology.

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Digital Design Practice and Introduction to the 3D Printing Process



Figure 4. Practical activities and guidance for participants in learning about three-dimensional design and the 3D printing process.

Practical activities are an important part of the training because they give participants opportunities to experience the technology in direct application. The practical sessions were held in two periods, from 10:30 to 11:30 and from 13:00 to 13:30. During these sessions, participants received guidance in creating simple designs and preparing digital files for three-dimensional printing. The learning-by-doing approach can help participants understand the relationship between digital designs and physical outputs, as discussed in the application of 3D printing in design education (Greenhalgh, S., 2016; Özeren, Ö., et al., 2023).

In general, producing objects using 3D printing begins with designing a digital model, exporting it in STL format, configuring it with slicer software, and preparing the printing instruction file. In Fused Deposition Modeling (FDM) printers, slicer software converts the digital model into printing paths, which the machine then executes to build the object layer by layer using thermoplastic filament.



Figure 5. Explanation of the 3D printing process.

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The introduction to this workflow provided participants with an overview of how 3D printing integrates digital design skills, an understanding of shape and dimensions, software operation, and machine use. Thus, the activity not only introduced the equipment but also created opportunities to develop problem-solving skills and creativity through product design. Research by Huang and Wang (2022) reported that a 3D design curriculum can improve students' three-dimensional drawing skills and originality, while Lin et al. (2023) found that iterative modeling in STEM activities benefits secondary school students' imagination.

In school settings, this approach can be applied through simple project assignments, such as creating geometric models, physics teaching aids, product prototypes, or components for science demonstrations. Students can learn about the relationship between digital designs and physical outputs while evaluating objects that do not match the initial design. This contextual use of digital technology aligns with UNESCO's discussion (Global Education Monitoring Report Team, 2023) that technology in education should be directed toward learning needs and tangible benefits for students. The interdisciplinary integration of CAD and 3D printing can also support project-based STEAM learning (Harron, J. R., et al., 2022).

Successful practical work depends not only on the ability to operate the machine, but also on design accuracy, printing parameter settings, filament selection, and the implementation of safety procedures. Stefaniak et al. (2021) showed that nozzle temperature and filament type can affect particle and chemical emissions during FFF printing. Evaluations in several schools and universities have also found emissions of volatile organic compounds and ultrafine particles during 3D printer use; therefore, ventilation, printer placement, operating settings, and safety procedures need to be considered (Li, J. F., & Glassford, E. K., 2025). Accordingly, technical guidance and repeated practice are needed to help participants develop their skills more effectively while maintaining safety.

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3.4 Evaluation Results and Participant Responses

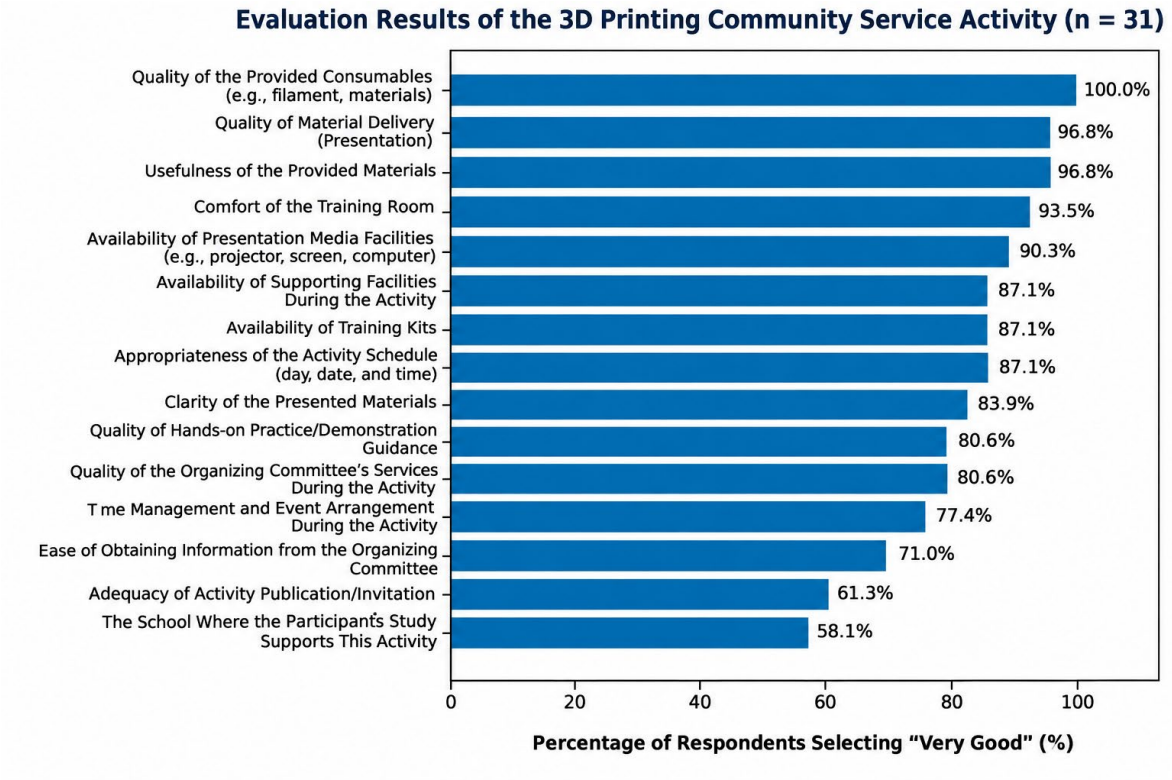


Figure 6. Percentage of respondents who gave a Very Good rating for each evaluation indicator.



Figure 7. Presentation of the evaluation results.

The evaluation results were obtained from 31 respondents. Across 15 assessment indicators, a total of 465 responses were collected, consisting of 388 responses (83.4%) rated Very Good, 76 responses (16.3%) rated Good, and 1 response (0.22%) rated Poor. Overall, this distribution indicates a positive response to the activity.

For the quality of materials and instructors, 111 of the 124 responses (89.5%) were rated Very Good. The indicators for the usefulness of the materials and the quality of presentation each received 30 Very Good ratings from 31 respondents (96.8%).

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Practical/demonstration guidance received 25 Very Good ratings (80.6%), indicating that the duration of practical sessions and opportunities to try the equipment could be improved.

For management and organization, 117 of the 155 responses (75.5%) were rated Very Good. Publicity/invitations received a Very Good rating from 61.3% (19 respondents), while 12 respondents rated this aspect Good. Scheduling and event management received 24 Very Good responses, 6 Good responses, and 1 Poor response. Open-ended comments also suggested extending the activity duration and delivering the material at a slower pace. Therefore, time management, publicity, and clarity of information should be prioritized for improvement.

For facilities, 142 of the 155 responses (91.6%) were rated Very Good. The quality of meals received a Very Good rating from all respondents (31 people), followed by room comfort (29 people; 93.5%) and the availability of presentation media (28 people; 90.3%). Meanwhile, the learning-environment support indicator received 18 Very Good ratings (58.1%) and 13 Good ratings (41.9%).

In the overall assessment of the activity, 29 respondents (93.5%) selected Very Good and 2 respondents (6.5%) selected Good. Open-ended responses expressed appreciation, describing the activity as enjoyable and useful. Suggestions included extending the activity, slowing the presentation pace, providing more opportunities to print products, and adding quizzes or interactive activities. Thus, the activity was received positively, while the duration of practical sessions and the pace of material delivery could be improved in future implementations.

3.5 Donation of a 3D Printer and Program Sustainability



Figure 8. Donation of a 3D printer to the partner school.

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Figure 9. Presentation of a memento to the partner school.

As part of efforts to support program sustainability, a 3D printer was donated to SMAN 1 Sidayu Gresik from 13:50 to 14:00. This donation was an important program output because the school received equipment that can be used to develop learning activities based on digital design and manufacturing.

The availability of a 3D printer at the school has the potential to expand the implementation of project-based learning. Teachers can develop assignments that integrate science, mathematics, technology, and creativity, while students can participate in designing, making, testing, and refining a product. Examples include producing physics teaching aids, geometric structure models, simple prototypes, and learning media tailored to subject-specific needs. Models for developing a 3D printing ecosystem in educational institutions emphasize the importance of integrating equipment, software, user training, and curriculum support to ensure that the facilities are used sustainably (Harron, J. R., et al., 2022).

To ensure that the benefits of the donation are sustained, machine-use management, regular maintenance, consumables management, and technical guidance for teachers and students are required. The school can also organize follow-up activities, such as three-dimensional design projects, slicer software training, and the development of simple products related to learning materials. Challenges involving resource availability, time allocation, teacher training, and curriculum integration have also been identified in studies of 3D printing education (Novak, E., et al., 2021 ; Tejera, M., et al., 2025). Therefore, program success should be measured not only by the completion of the training and equipment donation, but also by the use of the facilities in educational activities after the program has ended.

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Overall, this community service program provided the SMAN 1 Sidayu Gresik community with an introduction to 3D printing technology. The initial evaluation results showed improvements in participants' understanding and positive responses to the training. However, to ensure long-term impact, further evaluation is needed to measure machine utilization, the frequency of practical activities, participants' design skills, and the integration of 3D printing technology into school learning.

CONCLUSION

The community service program on the implementation of 3D printing technology at SMAN 1 Sidayu Gresik provided participants with an introduction and initial experience in understanding and using digital manufacturing technology to support innovative and creative learning. The pre-test and post-test evaluation of the 35 participants who completed both tests showed an increase in the mean score from 48.63 to 54.71, representing a gain of 6.09 points. A total of 54.3% of participants showed an increase in scores, while 31.4% obtained unchanged scores and 14.3% experienced a decrease.

The evaluation questionnaire results from 31 respondents also showed positive responses to the implementation of the activity. A total of 93.5% of respondents rated the overall activity as Very Good. The facilities aspect received a Very Good rating in 91.6% of responses, while the quality of materials and instructors reached 89.5%. Nevertheless, the evaluation indicated the need for improvements in scheduling, activity publicity, and practical guidance, including extending the duration to give participants more opportunities to develop designs and print products directly.

The donation of a 3D printer to the school is expected to support program sustainability through the development of teaching aids, simple prototypes, and technology-based learning projects. With this equipment, teachers and students are expected to gradually integrate 3D printing technology into learning activities. Continued mentoring and evaluation of machine utilization are needed to ensure that the program provides sustainable benefits for improving the quality of learning at school.

IMPLICATION

This program demonstrates a practical pathway for introducing digital manufacturing into secondary education through training, hands-on design activities, and access to equipment. For the academic community, it provides an example of university–school collaboration in

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applied technology education. For teachers and students, 3D printing can broaden opportunities for project-based and STEAM learning, strengthen digital design literacy, and support the development of teaching aids and prototypes. At a broader level, the activity contributes to the aims of SDG 4 (Quality Education) and SDG 9 (Industry, Innovation and Infrastructure) by promoting innovative learning and access to technology. It also supports the IMPACTA flagship program (Integrated Multi-Partner Action, Collaboration, and SDGs Acceleration) through collaboration between higher education and school partners. Long-term benefits will depend on sustained mentoring, maintenance, and curricular integration.

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