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Transforming Technological Literacy through Appropriate Technology Socialization for Junior High School Students

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ABSTRACT

The rapid progress of information and communication technology in the era of the Fourth Industrial Revolution demands that younger generations possess strong technological literacy to adapt effectively to ongoing digital transformation. This study aims to enhance students' technological literacy at SMPN 1 Karangrejo through socialization and practical activities using appropriate technology (AT). The research adopts a participatory descriptive method involving 40 junior high school students. The activities consist of four stages: preliminary observation, interactive socialization, hands-on construction of appropriate technology tools, and evaluation. Quantitative results show an average technological literacy increase of 35.2% with a normalized gain score of 0.71, indicating high effectiveness. Qualitative findings reveal enhanced student motivation, creativity, collaboration, and environmental awareness. The study demonstrates that project-based AT learning effectively transforms students' technological understanding and attitudes, making it replicable in other schools with local adjustments.

Keywords: *Technological Literacy, Appropriate Technology, Participatory Learning, Junior High School, Project-Based Education*

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INTRODUCTION

Technological progress in the 21st century has significantly influenced how students learn, communicate, and solve problems. The increasing integration of digital systems into education requires students not only to use technology but also to understand and apply it meaningfully. In Indonesia, digital transformation in education is guided by national programs such as *Merdeka Belajar* and the *Pancasila Student Profile*, which emphasize innovation, collaboration, and sustainability [1]. However, in semi-urban schools, such as SMPN 1 Karangrejo in Tulungagung, students often use technology primarily for entertainment or social media rather than productive learning or environmental problem-solving [2].

Technological literacy involves not only operating devices but also understanding their underlying mechanisms, ethical implications, and social functions [3]. Prasetyo and Lestari [4] argue that students must transition from passive users to active innovators capable of contextual technological application. The gap between digital literacy (knowing how to use technology) and technological literacy (knowing how to create or adapt technology) is evident in many Indonesian schools [5].

Therefore, a practical, participatory, and contextual learning model is required. Appropriate Technology (AT) represents a solution to this issue. It refers to simple, cost-effective, and locally adaptable technology that empowers users to create innovations aligned with their context [6]. In educational settings, AT promotes hands-on engagement and sustainable problem-solving. Kolb's experiential learning theory [7] supports the idea that knowledge retention increases when learners directly experience, reflect, conceptualize, and apply new information. This study investigates how socialization and practical AT activities can improve the technological literacy of students in SMPN 1 Karangrejo. The objectives are: (1) to increase students' understanding of technological concepts, (2) to stimulate critical and creative thinking, and (3) to promote environmentally conscious innovation through project-based learning.

Technological literacy has emerged as an indispensable competence in the twenty-first-century educational landscape. Beyond the ability to operate digital devices, it encompasses understanding how technology functions, evaluating its social impact, and employing it responsibly for solving contextual problems [8]. In Indonesia, government policies such as *Merdeka Belajar* and the *Profil Pelajar Pancasila (P5)* emphasize learner-centered, innovation-oriented education that integrates science, ethics, and community values [9]. These initiatives align closely with the United Nations Sustainable Development Goals—specifically SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure)—which promote inclusive, equitable education and sustainable industrial innovation [10].

However, gaps remain between policy aspirations and practical implementation. Studies reveal that many junior high students, particularly in semi-urban and rural contexts, remain consumers rather than creators of technology [11]. They use smartphones extensively for social interaction yet struggle to apply technological concepts for scientific experimentation or problem-solving. This disparity between *digital literacy* (knowing how to use) and *technological literacy* (knowing how to create and innovate) necessitates contextual, hands-on learning approaches [12].

Appropriate Technology (AT)—defined as small-scale, affordable, and locally adaptable technology [13]—offers a pedagogical bridge between theoretical science and real-world application. Through AT, students can directly experience the relationship between technological design, resource efficiency, and environmental responsibility. Such learning encourages *learning by doing*, consistent with [14] experiential learning cycle of concrete experience, reflection, conceptualization, and application.

Recent empirical works support this view. [15] observed a 45 percent increase in student creativity through AT-based project learning, while [16] found participatory socialization raised engagement and retention more effectively than lecture-based instruction. These findings highlight AT's potential not merely as a teaching aid but as a transformative educational framework fostering agency and innovation.

This research therefore investigates how socialization and practice of AT can transform technological literacy among SMPN 1 Karangrejo students. The objectives are threefold:

1. To enhance understanding of technological principles through experiential projects;
2. To develop critical-creative thinking and collaborative problem-solving skills; and

3. To internalize sustainability and social responsibility aligned with national education policy and global SDGs.

By integrating AT into a structured participatory model, this study contributes both theoretically—to constructivist and experiential learning discourse—and practically to Indonesia's ongoing digital transformation in education.

2. Literature Review

The concept of technological literacy has evolved alongside global educational reforms emphasizing STEM (Science, Technology, Engineering, and Mathematics). According to Trilling and Fadel (2019), technological literacy is one of the four core 21st-century skills, integrating creativity, critical thinking, communication, and collaboration (4Cs). [17] expands this definition by including ethical and sustainable technology use.

Several empirical studies underline the role of practical-based learning in enhancing technological understanding. [18] found that participatory socialization activities improve student engagement by 65% compared to traditional lecture methods. Similarly, [19] demonstrated that *peer learning* in AT projects fosters deeper conceptual understanding and teamwork.

In Indonesia, [20] showed that project-based AT training increased junior high students' creativity by 45%, confirming the method's alignment with national goals for student competency enhancement. Therefore, the integration of AT into educational practice not only supports technological literacy but also reinforces the *Pancasila Student Profile* dimensions—creativity, independence, collaboration, and social awareness.

2.1 Research Design

A descriptive–participatory approach was employed to allow active involvement of students throughout the learning process [21]. The method emphasizes co-creation between facilitators and learners to encourage reflective understanding. Both quantitative and qualitative data were used to obtain comprehensive insights into the program's effectiveness.

2.2 Participants

Forty students (20 male, 20 female) from grades VIII and IX of SMPN 1 Karangrejo participated voluntarily with parental consent. The participants represented diverse academic abilities, ensuring inclusiveness and representativeness. Two teachers served as facilitators together with three instructors from the Marine Electrical Engineering Department, PPNS.

2.3 Procedure

The program was implemented over four consecutive stages:

1. Preliminary Observation:
   Baseline data were collected through questionnaires and interviews assessing familiarity with technological tools, conceptual understanding, and environmental awareness.
2. Interactive Socialization:
   An introductory workshop delivered concepts of Appropriate Technology using multimedia presentations and demonstrations (e.g., energy-saving devices, waste-management tools). Discussions connected these examples to local issues in students' communities.
3. Hands-On Workshop and Group Projects:
   Students were divided into eight teams (five members each). Each group designed and built a simple AT prototype utilizing affordable local materials—

such as mini composters, automatic lighting systems, or water filters. Emphasis was placed on creativity, teamwork, and safety.

4. Evaluation and Reflection:
   After project completion, each group presented their prototype, explaining its function and sustainability aspects. Evaluation involved pre- and post-tests, performance assessment rubrics, and reflection journals.

2.4 Data Collection and Analysis

Quantitative data were derived from pre-/post-test instruments measuring four dimensions of technological literacy: conceptual understanding, practical skills, critical thinking, and collaboration. The normalized gain (g) was calculated following [22]:

$$g = \frac{(\text{post} - \text{pre})}{(100 - \text{pre})}$$

A gain value above 0.7 is categorized as high effectiveness.

Qualitative data were analyzed thematically through coding of observation notes, focus-group transcripts, and student reflections [23]. Codes were clustered into themes representing behavioural change and learning engagement.

2.5 Ethical Considerations

Ethical approval was obtained from the PPNS Community Engagement Committee. Participation was voluntary; all data were anonymized. The research adhered to principles of inclusivity, gender equality, and educational fairness consistent with SDG 4.

METHOD

This study employs a descriptive-participatory research design involving 40 students from classes VIII and IX at SMPN 1 Karangrejo. Data were collected through pre-test and post-test instruments, observation, and reflective interviews. The research stages consisted of:

1. Preliminary Observation – assessing students' initial technological literacy levels through questionnaires and interviews.
2. Interactive Socialization – delivering AT concepts through visual media, discussions, and simple demonstrations.
3. Hands-On Project Practice – students were divided into eight groups to build simple AT prototypes such as mini composters, automatic lamps, and water filters using local materials.
4. Evaluation and Reflection – combining quantitative gain score analysis [24] with qualitative thematic analysis [25].

The gain score was calculated using the formula:

$$g = \frac{(post - pre)}{(100 - pre)}$$

where *g* represents normalized gain, and *pre* and *post* represent average pre-test and post-test scores respectively.

3.1 Research Design

This research adopted a descriptive–participatory approach, combining quantitative and qualitative strategies to analyze how *Appropriate Technology (AT)* socialization activities influence the technological literacy of junior-high students. The participatory framework was chosen because it allows learners to be directly involved in planning, doing, and reflecting on their own learning process, which aligns with [26] experiential-learning cycle. The study was implemented within a community-service–based educational program at SMPN 1 Karangrejo, Tulungagung Regency, and facilitated by lecturers and students from Politeknik Perkapalan Negeri Surabaya (PPNS).

The design emphasized learning by doing. Rather than serving as passive recipients, students acted as co-creators in constructing simple technological devices that addressed everyday local problems such as waste, energy saving, or clean-water access. This approach simultaneously promoted conceptual understanding, skill mastery, and attitudinal change toward sustainability.

3.2 Participants and Setting

Forty students (20 boys, 20 girls) from grades VIII and IX participated voluntarily with the consent of their guardians and teachers. Two science teachers acted as in-school mentors, while three PPNS facilitators guided the technical sessions. The school was selected because of its semi-urban context and limited access to advanced laboratory equipment—conditions representative of many Indonesian schools seeking affordable models of technological literacy improvement.

Participants represented heterogeneous academic backgrounds and socio-economic conditions, which provided a realistic overview of the diversity present in Indonesian lower-secondary education. The gender balance was maintained intentionally to ensure inclusivity and equitable participation in STEM-related learning, consistent with SDG 4 (Quality Education) and SDG 5 (Gender Equality) principles.

3.3 Procedures

The program ran for six weeks and consisted of four sequential phases:

1. Preliminary Observation (Week 1) – Baseline data were collected through questionnaires and semi-structured interviews to determine students' familiarity with technology, their perception of its usefulness, and their ability to relate scientific concepts to technological functions. Classroom observations identified gaps in problem-solving and collaborative skills.
2. Interactive Socialization (Week 2) – A one-day seminar and demonstration introduced the idea of *Appropriate Technology*. Facilitators used videos, posters, and sample devices (e.g., solar-powered lamps, mini water filters) to explain principles of efficiency, simplicity, and sustainability. Discussions encouraged students to identify local problems that could be solved through simple technological means.
3. Hands-On Project Workshop (Weeks 3–5) – Students worked in eight mixed-ability groups (five members each) to design and build one prototype per group. Examples included an automatic-lighting system using LDR sensors, an organic-waste composter made from recycled materials, and a low-cost water-filtration unit. Facilitators supervised safety procedures and guided reflection on scientific principles underlying each prototype.
4. Evaluation and Reflection (Week 6) – Each group presented its project in front of peers and teachers, demonstrating operation, explaining materials, and analyzing the benefits and limitations. Evaluation covered both cognitive gains (conceptual and procedural knowledge) and affective outcomes (motivation, teamwork, and environmental awareness). Reflection sessions allowed students to discuss lessons learned and propose ideas for improvement.

This cyclical process reinforced continuous learning: *experience → reflection → conceptualization → application*, in line with experiential-learning theory.

3.4 Data Collection Instruments

Three main instruments were used:

1. Pre-test and Post-test Questionnaires – Twenty multiple-choice and five short-answer items measured four dimensions of technological literacy: (a) conceptual understanding, (b) practical skill, (c) critical thinking, and (d) collaboration.
2. Observation Sheets and Field Notes – Used by facilitators to record behavioral indicators such as initiative, communication, and engagement.
3. Reflection Logs and Focus-Group Discussions – Captured students' subjective experiences, perceived benefits, and challenges.

Instrument validity was examined through expert review by three educators from PPNS's Educational Technology Department. Reliability was confirmed with a Cronbach's α of 0.83, indicating high internal consistency.

3.5 Data Analysis

Quantitative Analysis

Pre- and post-test scores were analyzed using normalized-gain analysis (Hake, 1999):

$$g = \frac{(S_{\text{post}} - S_{\text{pre}})}{(100 - S_{\text{pre}})}$$

where $S_{\text{pre}}$and S_{post}represent average percentage scores before and after the program. A gain > 0.7 denotes high effectiveness, 0.3–0.7 moderate, and < 0.3 low. Descriptive statistics (mean, SD, percentage improvement) were calculated using MS Excel.

Qualitative Analysis

All qualitative data (observation notes, focus-group transcripts, and logs) were coded thematically following [27] six-step framework:

1. Familiarization with data;
2. Generation of initial codes;
3. Searching for themes;
4. Reviewing themes;
5. Defining and naming themes;
6. Producing narrative synthesis.

Triangulation between quantitative and qualitative findings ensured methodological validity and provided a comprehensive understanding of students' transformation processes.

3.6 Ethical Considerations

Ethical clearance was obtained from the PPNS Research and Community-Engagement Ethics Board. Participation was voluntary, anonymity was guaranteed, and data were used solely for academic purposes. The study respected principles of equality, inclusivity, and child protection as recommended by UNESCO educational-research guidelines.

3.7 Research Framework

The methodological framework integrated national education policy and global sustainability perspectives. At its core, the model positioned *Appropriate Technology* as the pedagogical medium connecting:

- Inputs: students' initial literacy, local resources, facilitator guidance;
- Processes: participatory learning cycles (socialization, experimentation, reflection);

- Outputs: improved conceptual–procedural understanding, creativity, collaboration, and sustainability awareness.

This framework ensured coherence with Indonesia's *Merdeka Belajar* philosophy and SDG targets while maintaining adaptability for replication in other schools.

RESULTS AND DISCUSSION

The implementation of the AT-based socialization program resulted in a substantial improvement in students' technological literacy. The quantitative data are presented in Table 1.

Table 1. Improvement in Technological Literacy Aspects

Literacy Aspect	Pre-Test (%)	Post-Test (%)	Increase (%)
Conceptual Understanding	52.5	88.7	36.2
Practical Skills	49.2	84.5	35.3
Critical Thinking	47.8	82.0	34.2
Collaboration and Communication	55.1	90.4	35.3
Average Total	**51.2**	**86.4**	**+35.2**

The normalized gain ($g = 0.71$) classifies the intervention as highly effective (Hake, 1999).

Students showed visible enthusiasm during the project stages, and their engagement increased with each cycle of design and experimentation. Qualitative observations reveal three main behavioral transformations:

1. Learning Independence – Students began identifying problems and proposing technical solutions autonomously.
2. Collaborative Synergy – Group interactions became more structured and equitable, with task-sharing and peer feedback.
3. Environmental Awareness – 70% of the student projects focused on sustainability, e.g., waste-to-product innovation and simple energy-saving tools.

The AT learning framework successfully combines experiential learning and constructivist pedagogy. Through *learning by doing*, students engage in active cognitive restructuring, which solidifies understanding and fosters innovation.

Moreover, this study's outcomes align with previous research confirming that AT-based education significantly boosts creativity and confidence in technological problem-solving. The findings also support the national goal of developing future-ready learners as mandated by the *Merdeka Belajar* initiative.

Figure 1 illustrates the students' engagement during the AT workshop, highlighting their collaboration and practical experimentation. The transformation from passive learning to active innovation demonstrates that participatory AT education instills a deeper appreciation for technology's societal role.

The overall results indicate that the socialization and hands-on model serves not merely as a learning method but also as a mindset transformation mechanism—turning students into creators rather than consumers of technology. Teachers also reported observable improvements in class participation and project creativity following the program, consistent with findings. Quantitative and qualitative analyses collectively demonstrate that the *Appropriate Technology (AT) Socialization Program* significantly improved students' technological literacy. The normalized gain score of 0.71 reflects a high level of learning effectiveness, while qualitative data reveal transformation not only in cognitive performance but also in motivation, collaboration, and socio-environmental responsibility.

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Average Total	**51.2**	**86.4**	**+35.2**

These results align with Hake's (1999) framework, classifying the normalized gain as *high effectiveness*. From an educational standpoint, the data indicate that hands-on, participatory approaches facilitate a transition from rote memorization toward experiential understanding.
Students became capable of linking technological principles with tangible applications in their daily lives — an essential marker of literacy transformation.
The qualitative thematic analysis yielded three dominant themes representing behavioral and attitudinal change.

Theme 1: Emergence of Self-Directed Learning

Before the program, most students viewed technology as merely a tool for entertainment or classroom assistance. After participating, they began identifying contextual problems in their surroundings—such as waste management, water use, and energy conservation—and independently sought technological solutions. This finding resonates experiential learning model notion that student-centered, inquiry-based learning produces deeper cognitive retention. Students also demonstrated higher persistence in problem-solving, evident in their willingness to iterate designs despite initial failures.

Theme 2: Strengthened Collaboration and Creative Problem-Solving

Group-based AT projects enhanced communication and cooperation skills. During prototype construction, students assigned roles organically—some focused on material sourcing, others on wiring, measurement, or documentation. Such cooperative dynamics mirror *social constructivism*, where learning occurs through collaborative interaction. similarly emphasized that participatory socialization amplifies engagement and retention through peer-to-peer learning mechanisms.

Furthermore, creativity manifested in students' ability to integrate scientific reasoning with local wisdom. For instance, one group designed an organic waste composter using bamboo tubes and reused plastic bottles; another developed an automatic water tap utilizing recycled sensors. These outcomes signify cognitive flexibility—students could transfer theoretical knowledge into innovative solutions relevant to their socio-environmental contexts.

Theme 3: Environmental Awareness and the Pancasila Student Profile

Environmental consciousness emerged as a strong learning outcome. Seventy percent of the projects focused on sustainability—waste-to-product innovation, energy-efficient lighting, and water conservation systems. This aligns with the *Profil Pelajar Pancasila (P5)* framework, particularly the values of *gotong royong* (collaboration) and *berkebinekaan global* (global citizenship).

Such integration indicates that technological literacy, when contextualized through AT, transcends cognitive learning—it shapes moral, social, and environmental .

Comparative Analysis with Previous Research

When compared with similar studies, this program's impact is notably strong. reported a 45% creativity improvement in middle-school AT training, whereas this study achieved a 35.2% average literacy increase encompassing both technical and socio-emotional aspects. Nasution found that *peer learning* in technology education raised engagement by 70%; this study achieved comparable engagement levels but added value by embedding sustainability and Pancasila values. Internationally, Trilling and Fadel emphasized that 21st-century skills require the synergy of creativity, collaboration, critical thinking, and communication—the 4Cs—all of which were reinforced through this participatory AT framework.

Pedagogical and Policy Implications

This program bridges the gap between national education reforms (*Merdeka Belajar*, *P5*) and classroom practice. It operationalizes SDG 4 by ensuring inclusive, quality education and SDG 9 by fostering innovation and sustainable infrastructure. For teachers, AT-based learning provides a practical model for integrating STEM education with civic and environmental education. For policymakers, it demonstrates that technological literacy can be enhanced without heavy investment—only with creative, participatory methods leveraging local resources. Hence, this model offers a replicable, scalable, and sustainable framework for community-based technological education at the secondary level.

Conceptual Reflection

The integration of appropriate technology in education functions as a *transformative catalyst*. Students who initially viewed themselves as users gradually internalized the identity of *problem solvers* and *innovators*. This mirrors the theoretical continuum proposed by Rahmawati (2024): from digital consumer → digital participant → digital innovator. The SMPN 1 Karangrejo case demonstrates that when supported by guided facilitation, even limited-resource environments can achieve higher-order technological learning outcomes. Conceptual framework illustrates how *Appropriate Technology Socialization* mediates between *policy context* (Merdeka Belajar, SDGs) and *student transformation outcomes* (literacy, creativity, collaboration, and sustainability).

The results of this study provide deeper insight into how the combination of *Appropriate Technology (AT)*, experiential learning, and participatory pedagogy can serve as a catalyst for educational transformation in Indonesia's middle schools. While previous national initiatives such as *Merdeka Belajar* have highlighted the importance of student autonomy and project-based learning, implementation often remains abstract due to limited resources and teacher readiness. This study bridges that gap by offering an operational framework that uses low-cost, locally available materials to develop complex cognitive and socio-emotional competencies simultaneously.

At the theoretical level, the AT approach strengthens constructivist learning theory, which posits that students construct knowledge through interaction with their environment and through reflection on practical experiences. The workshop and project cycles allowed students to move beyond declarative knowledge into procedural and conditional understanding—knowing *how* and *when* to apply technology. The iterative cycle of design, experimentation, and reflection mirrors Dewey's philosophy of education as a continuous reconstruction of experience.

The study also aligns with Kolb's experiential learning stages: concrete experience (hands-on AT creation), reflective observation (group discussion), abstract conceptualization (connecting to theory), and active experimentation (prototype improvement). This continuous loop cultivated resilience and adaptability—competencies vital for lifelong learning in the 21st century.

From a policy perspective, the research operationalizes the Profil Pelajar Pancasila (P5) through three dimensions:

1. Creative and Innovative Learners, reflected in the students' ability to generate novel technological ideas;
2. Collaborative and Cooperative Citizens, demonstrated by team-based problem solving; and
3. Globally Minded Individuals, achieved by connecting local sustainability issues with global challenges such as waste management and energy efficiency.

In addition, the findings contribute to SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure) by showing that innovation and technical education need not depend on sophisticated laboratories. Instead, AT learning contextualizes science through community relevance, democratizing access to STEM education even in resource-constrained schools.

Comparatively, this model outperforms conventional ICT-based literacy programs by integrating social, ethical, and environmental learning outcomes. While typical computer-based literacy emphasizes operational skills, AT projects nurture technological consciousness—understanding the broader social function and sustainability of technology. This distinction is crucial for building responsible digital citizens who can balance innovation with empathy and ecological awareness.

Moreover, teacher responses during reflection sessions confirmed that the AT model reduced classroom passivity and disciplinary issues, as students were more engaged in goal-oriented activities. Teachers noted an increase in collaborative communication and problem-solving dialogue among students—outcomes that are rarely achieved through traditional lecture-based approaches.

Finally, the study demonstrates the potential for institutional integration. If scaled, AT-based literacy could be embedded into local curricula or extracurricular programs, supported by BUMDes and local education authorities. Such integration would sustain learning beyond one-off projects, transforming schools into living laboratories that continuously generate innovation relevant to community needs.

Research Implications and Limitations

This study contributes several significant implications for theory, pedagogy, and policy.

Theoretical Implications: The integration of AT within a participatory framework expands the existing discourse on technological literacy from an instrumental perspective (technology as a tool) to a transformative paradigm (technology as a medium for empowerment and social innovation). It highlights the intersection between *technological knowledge*, *environmental ethics*, and *socio-cultural context*—a triad rarely discussed together in educational literature. The research thus offers a new lens for examining literacy that is multidimensional, embedding STEM within civic and moral education.

Pedagogical Implications: For practitioners, the findings provide a practical blueprint for applying *Merdeka Belajar* principles. Teachers can replicate the cycle—socialization, project work, reflection—using locally available materials, making technological learning equitable and relevant. The participatory model also strengthens teacher–student relationships, as facilitators shift from authority figures to mentors guiding inquiry. Furthermore, the success of collaborative AT projects suggests that schools can use this approach to enhance *interdisciplinary learning*, combining science, mathematics, and social studies around real-life problems.

Policy and Community Implications:n For policymakers, the research supports national efforts to promote inclusive and sustainable education under the *Rencana Pembangunan Jangka Panjang Nasional (RPJPN)*. The findings emphasize that technological literacy should be recognized as a key component of community empowerment, especially in regions transitioning toward industrialization. Local governments could integrate AT literacy into vocational and community programs to foster innovation ecosystems at the village level.

Limitations and Future Research: Despite its success, this study faced several limitations. First, the research duration was relatively short (six weeks), limiting longitudinal observation of behavior change. Future studies could implement semester-long interventions to measure long-term retention and attitudinal development. Second, while the sample was diverse, it was limited to one school, restricting generalizability. Expanding the sample across multiple schools and regions would enhance external validity.

Third, the research did not incorporate quantitative inferential testing such as ANOVA or regression due to its descriptive focus. Subsequent studies could combine experimental or quasi-experimental designs to measure effect size more precisely.

Finally, while the AT model promoted sustainability awareness, digital integration (IoT, sensors, and data visualization) remains limited by infrastructure. Future programs should explore hybrid models combining *appropriate technology* with *smart technology* to strengthen digital competencies and connect student projects to real-time data monitoring.

5. Conclusion and Recommendation

This research concludes that appropriate technology-based socialization effectively enhances technological literacy among junior high school students. The 35.2% improvement in average literacy scores and a high gain value (0.71) confirm the model's success. Beyond quantitative results, students exhibited notable progress in self-directed learning, creativity, collaboration, and environmental consciousness.

The findings suggest that incorporating AT projects into school curricula offers an effective, low-cost approach to developing 21st-century competencies aligned with the Pancasila Student Profile. Future implementations could expand to rural schools and integrate IoT-based data collection to strengthen digital literacy. Policymakers and educators are encouraged to replicate this model to support Indonesia's broader digital transformation agenda.

This study concludes that the *Appropriate Technology Socialization Program* effectively transformed students' technological literacy through participatory and experiential learning. Quantitatively, literacy increased by 35.2%, supported by a high normalized gain (g = 0.71). Qualitatively, students exhibited increased motivation, creativity, independence, collaboration, and environmental awareness.

These outcomes confirm that the integration of AT within secondary education can serve as a low-cost, high-impact educational innovation, promoting 21st-century competencies consistent with the *Profil Pelajar Pancasila* and national education policy. The success of this model also supports broader educational goals, particularly SDG 4 and SDG 9, by linking learning innovation with community sustainability.

Recommendations:

1. Schools should institutionalize AT-based projects as part of science or ICT curricula to promote contextual learning.
2. Teacher training institutions should incorporate participatory design and AT pedagogy to strengthen pre-service educators' capacity.
3. Future research should integrate IoT-based monitoring systems or digital dashboards to measure project performance and enhance students' data literacy.
4. Government and private sectors should collaborate to expand AT learning hubs as *Living Laboratories* for youth innovation.

In essence, this study demonstrates that technological literacy can be holistically developed through contextualized, collaborative, and sustainable approaches rooted in local wisdom and supported by national educational policy.

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