Jurnal Pemberdayaan Masyarakat
Volume 5 Issue 2 Year 2026 | Pages 425–442
ykgm.org

E-ISSN 2962-8091
DOI: https://doi.org/10.46843/jpm.v5i2.703

Empowering Digital Literacy through Computational Thinking, AI, and Renewable Energy in a Water-Scarce School

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ABSTRACT

Ongoing advances in digital technology require teachers to adapt and develop their technological competence continuously. However, a gap in technological understanding remains between teachers in rural and urban areas, particularly in Indonesia. SMA Negeri 1 Sukanagara, as the only public high school in its region, faces challenges related to water scarcity and limited access to energy, which affect both learning activities and the school community's basic needs. This community service program aims to enhance teachers' digital literacy through training in Computational Thinking (CT), Artificial Intelligence (AI), and Renewable Energy prior to the implementation of a smart rainwater-harvesting system at the school. The methods used included a survey, training sessions, and evaluation using a problem-based approach combined with pre-test and post-test assessments. A problem-based learning approach confirmed that the CT training had helped teachers to develop more structured problem-solving skills. Results of the test also show that AI and Renewable Energy training improved participants' understanding by an average of 17.08% and 14.28%, respectively, compared to their initial scores. These improvements demonstrate the potential of training programs like these to enhance teachers' understanding and better prepare them for implementing emerging technologies in schools.

ARTICLE INFORMATION

Keywords:
digital literacy; rural schools; teacher training; technology; water scarcity

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Article info: Submitted: 2025-12-05 | Revised: 2026-02-28 | Accepted: 2026-03-11 | Published: 2026-05-21
Recommended citation: Hardhienata, M. K. D., Wulandari., Tobing, S., Schauf, A., Rahmani, S., Siantar, G. A. L., Ahmad, H. F., Asfarian, A., Padmanagara, T. P., Syuhada, E. R., Suminto, S., & Mutmainah, I. (2026). Empowering Digital Literacy through Computational Thinking, AI, and Renewable Energy in a Water-Scarce School. *Jurnal Pemberdayaan Masyarakat, 5*(2), 425-442.

INTRODUCTION

Rapid technological advancements are currently driving transformation and disruption across virtually all sectors, especially education. These advancements not only encourage teachers to develop adequate digital literacy but also to keep up with students' learning pace as they adapt to technology. According to a report from the World Economic Forum (2025), technological literacy, Artificial Intelligence (AI), and environmental stewardship are among the ten skills projected to grow in

importance in the years to come. Educators will need to master these skills to adapt to the accelerating technological transformation in education, not only for themselves but also to help guide students as they too adapt to these changes.

On the other hand, the rapid development of technology and the spread of information have created a significant gap in the understanding and utilization of technology between urban and rural communities. This gap is influenced by various factors, including socio-economic conditions, the availability of supporting technological infrastructure, and limited access to adequate resources (Simmonds et al., 2019). To reduce these gaps in understanding and technological competence among teachers in rural, remote, or disaster-prone areas, various initiatives to improve technology literacy have been implemented. These activities have included training in Computational Thinking (CT) (Simmonds et al., 2019; Cian & Brasili, 2025; Chasannudin et al., 2022), Artificial Intelligence (AI) (Mangione et al., 2025; Patty et al., 2025), and Renewable Energy (Sutradhar et al., 2024; Myori et al., 2025), each using materials designed to strengthen teachers' capacities in facing the challenges posed by digital transformation and the application of green technology in educational environments.

Several previous studies have shown that CT training for teachers in rural areas improves their thinking skills, equips them to solve problems more systematically, and increases their confidence in integrating CT concepts into their lesson plans. In Chile, Simmonds et al. (2019) conducted a project-based training program using Scratch, a programming language and educational web interface targeted at young or beginner-level coding students, which successfully strengthened teacher competency and served as the basis for subsequent programs that developed digital education policies in remote areas. Cian and Brasili (2025) implemented a community-based training approach that encouraged teachers in rural areas to understand and apply CT concepts in science projects. In rural Wyoming, USA, Croff (2017) conducted teacher training using a game- and simulation-based approach that was proven to improve critical thinking and problem-solving skills and to increase student interest in Science, Technology, Engineering, and Mathematics (STEM).

Various CT-themed teacher training programs have also been conducted in Indonesia. Supatmiwati et al. (2023) trained madrasah teachers in Lombok to integrate CT concepts into various subjects. Chasannudin et al. (2022) found that, after using Scratch to train teachers in Pati, Central Java, 67% of the course participants understood the materials and were able to create simple CT-based games. Hermawan et al. (2022) demonstrated that CT training can significantly improve teachers' higher-order thinking skills through trials conducted in Islamic schools in Depok, West Java. Working in North Luwu Regency in South Sulawesi, Babo et al. (2023) used the `Bebras Challenge`, an activity consisting of introductory tasks designed to engage computational thinking and informatics skills, to introduce CT concepts to teachers, who then taught them to students. In line with this study, Apriani et al. (2022) trained elementary school teachers in West Lombok in CT through a workshop. Taken together, these studies support the notion that even brief encounters with Computational Thinking through focused training activities can improve teachers' competence in systematically understanding and solving problems in a structured way. Furthermore, the training can help teachers integrate CT concepts into their future lesson plans, even when teaching non-STEM subjects.

In addition to CT training, a number of initiatives have been implemented to improve teacher competency in Artificial Intelligence (AI) in Indonesia and abroad. Adawiyah and Rindaningsih (2024) identified several common challenges faced by teachers in Indonesia, including limited infrastructure, limited technological skills, and a lack of understanding of new pedagogical issues arising from integrating AI into the learning process. Fortunately, recent literature indicates that AI training can be an effective way to address these digital competency gaps. Mangione et al. (2025) conducted Design Thinking training sessions in small and remote schools in Italy, prompting teachers to design AI-based learning scenarios through a collaborative, reflective approach. Meanwhile, Aprianto et al. (2025) and

Patty et al. (2025) have implemented AI training programs in semi-rural and remote areas of Indonesia, offering technical guidance and experiential learning approaches to help teachers explore generative AI tools. The results of these trainings have demonstrated improved teacher literacy in AI and pedagogical skills, as well as enhanced collaboration among teachers.

Alongside AI training initiatives like these, Renewable Energy training programs have also been widely conducted to help teachers understand and implement green technology. Sutradhar et al. (2024) developed STEM activity kits that were shipped to teachers and students in remote areas of Nebraska, USA, with interactive guidance through these activities, then provided remotely via online workshops. These workshops were shown to increase participants' knowledge and competence in renewable energy technology. In Indonesia, Myori et al. (2025) conducted training for vocational high school teachers in West Sumatra using solar power generator trainers as learning media; these also successfully improved teachers' understanding of solar-based technologies. Meanwhile, Wiyono et al. (2024) applied a Participatory Action Research (PAR) approach to train science teachers in South Sumatra in creating STEM-based renewable energy demonstration tools using local materials. Overall, practice-based and participatory training has proven very effective in improving energy literacy and pedagogical skills, while enhancing teachers' readiness to integrate renewable energy concepts into their own classrooms, especially in remote and resource-limited areas.

Although various digital literacy programs for teachers in CT, AI, and Renewable Energy have been successfully implemented, most present these topics as separate skill sets and focus primarily on improving teachers' classroom competency. Training approaches that present these three interrelated areas together as part of a unified whole and emphasize their importance when implementing technology more broadly in rural and disaster-prone areas of Indonesia remain very limited. The implementation of innovative technologies in Indonesia faces considerable barriers, including limited access to AI tools in rural and remote areas, a lack of comprehensive teacher training programs, and the absence of standardized curriculum models that could facilitate widespread adoption (Haetami, 2025). To address this gap, we first conducted initial surveys to pinpoint the most pressing problems faced by teachers in Sukanagara, Cianjur, West Java, whose experiences are likely representative of those in similar villages and disaster-prone areas. This was followed by a community service project conducted at SMA Negeri 1 Sukanagara, the only public high school in the area (Statistics Indonesia of Cianjur Regency, 2024), which, in addition to challenges related to technological literacy, also sometimes faces limited access to clean water. Although Sukanagara is rich in natural resources, SMAN 1 Sukanagara is located in Sukanagara Subdistrict, Cianjur, which is prone to natural disasters (Maryani et al., 2022). Cianjur regency, where SMAN 1 Sukanagara is located, has been classified as a high-risk disaster area from 2015 to 2024 according to the Indonesian disaster risk index, indicating its sustained vulnerability to multiple hazards such as floods and landslides (National Disaster Management Agency (BNPB), 2024). Educational infrastructure in the surrounding area remains limited, concentrating 1,102 students and 54 teachers at this single, relatively small local high school. Based on interviews with teachers at SMAN 1 Sukanagara, it came to light that the limited availability of clean water in the school often forces students to ask for clean water from nearby residents' wells, since drilled wells and supplies from the local water utility provider (*Perusahaan Daerah Air Minum* [PDAM]) are often insufficient to meet the school's growing needs. In addition to the problem of limited access to clean water, the rapid development of technology requires teachers in this region to actively update their own technological literacy, not only in order to handle their own increasing teaching loads, but also to keep up with the learning styles and rhythms of students who are increasingly adopting technology outside the classroom, including when completing schoolwork.

To address the above issues, this study aimed to engage high school teachers at SMAN 1 Sukanagara by evaluating their prior understanding of CT, AI, and Renewable Energy, and then to

improve their technological literacy through a brief but intensive training session covering these topics. This training was intended as a first step to reinforce teachers' technological literacy before proceeding with the phased implementation of an AI-based intelligent system, namely a smart rainwater harvesting system, designed to increase the school community's access to clean water and renewable energy. Finally, several post-training evaluations were conducted to assess the impact of the training on teachers' knowledge and readiness to implement technology in the school.

METHOD

This study employed a mixed-methods participatory approach, integrating qualitative and quantitative methods (Creswell & Clark, 2018; Johnson & Christensen, 2019), and a participatory approach (Cornwall & Jewkes, 1995) by actively involving the school community in identifying challenges and collaboratively designing solutions. As a first step taken to help more precisely identify the problems faced on the ground by teachers at SMAN 1 Sukanagara, qualitative field surveys and interviews with teachers were conducted at SMAN 1 Sukanagara, Cianjur. Online participatory discussions were then held between the project team and school community members to help align perceptions of these problems, define shared priorities, and formulate appropriate solutions. This participatory approach aligns with research demonstrating that collaborative discussions among school community members can facilitate shared understanding and enable stakeholders to work together to identify and address educational challenges (Jin & Cutumitsu, 2023).

Next, a preliminary quantitative survey was conducted to assess teachers' prior understanding of basic concepts in Computational Thinking (CT), Artificial Intelligence (AI), and Renewable Energy. Based on the preliminary survey results, the team analyzed and designed training materials tailored to teachers' needs. The day-long training session was then conducted at SMAN 1 Sukanagara, engaging teachers from both social science and natural science fields. Each topical sub-session was introduced with an instructor-led presentation of the basic material. Participants were then divided into groups and prompted to complete interactive activities, providing teachers with an opportunity to practice their collaboration skills while engaging with the material.

The CT training sub-session applied problem-based learning methods. First, participants were given a "big picture" explanation of Computational Thinking, outlining its key concepts and emphasizing the urgency of CT competence for educators in the digital era, including those teaching in non-STEM fields. Participants were introduced to the four basic foundations of CT: (1) *decomposition*, (2) *pattern recognition*, (3) *abstraction*, and (4) *algorithms*, through real-life examples and simplified scenarios. In the final activity of the CT topical sub-session, participants were prompted with a challenge requiring them to apply these core CT concepts. Through a mock scenario that involved characters from WestJava's folklore and puppet theater traditions, participants were directed to identify problems and their important aspects (*abstraction*), break larger problems or systems down into smaller parts (*decomposition*), notice and describe relevant patterns that occur (*pattern recognition*), and to create a set of clear instructions for encoding/decoding relevant information in order to solve a task (*algorithms*).

In the AI sub-session, the activity began with a pre-test to measure participants' initial understanding. Next, instructional material was presented which covered the basic definition of Artificial Intelligence, outlined the four AI quadrants according to Russel and Norvig (2022), introduced *supervised* and *unsupervised* learning methods, contextualized *generative AI*, and introduced techniques for AI prompting based on Park and Choo's (2024) IDEA framework (*Include* essential parts; *Develop* with clear prompts; *Evaluate* outputs and refine prompts; and *Apply* with accountability) andLo's (2023) CLEAR guidelines (*Concise*, *Logical*, *Explicit*, *Adaptive*, and *Reflective*). Teachers were also briefed on issues related to AI ethics, including UNESCO guidelines for the use of

generative AI and the potential positive and negative impacts of AI. In a final segment, teachers were invited to practice creating effective prompts to generate classroom quiz questions for their chosen subjects. The session then concluded with a post-test.

The training continued with the Renewable Energy topical sub-session. Participants' levels of understanding before and after the training were measured using pre- and post-tests. Pre-test and post-test methodology has been widely validated in renewable energy education research as an effective approach to assess changes in teachers' knowledge and attitudes toward renewable energy resources (Onbaşılı, 2020). Following a pre-test, teachers were introduced to the basic definition of renewable energy and its various forms: hydro, wind, biomass, solar, ocean, and geothermal. Teachers were also introduced to interactive tools for calculating their own carbon footprints to illustrate the impacts of human activities on the environment, and were prompted to calculate, interpret, and compare their scores with fellow participants. The discussion then reviewed different ways participants could use renewable energy technologies, including solar photovoltaic (PV) as an alternative electricity source and rainwater harvesting systems for water storage. The roles of educators and youth in society's energy transition were emphasized. The presentation concluded with a hands-on demonstration of how solar energy is converted into electricity. Educational research has demonstrated that incorporating hands-on demonstrations and practical activities in renewable energy training significantly enhances participants' cognitive learning outcomes, with measurable improvements when assessed through pre-test and post-test methodologies (Risal et al., 2026). A question-and-answer segment and a post-test followed the Renewable Energy sub-session.

As mentioned earlier, both the AI and Renewable Energy topical sub-session, pre-test, and post-test instruments were used to evaluate changes in participants' understanding before and after the AI and Renewable Energy sub-sessions. This approach is widely used in educational studies to measure learning gains and training effectiveness (Dimitrov & Rumrill, 2003). Pre- and post-tests for both AI and renewable energy used a scoring scheme that awarded 2 points for each correct answer and 0 points for each incorrect answer. To gauge the statistical significance of the difference between pre-test and post-test scores in both the AI and Renewable Energy training programs, a confidence interval (CI) was calculated using the Neyman (1935) and Hazra (2017) approaches. The topical sub-sessions of the training program were followed by a reflection session to review concepts and reiterate their overarching themes, with particular emphasis on the potential uses of CT, AI, and renewable energy to support the subsequent implementation of a smart rainwater harvesting system. The training concluded with the collection of participant feedback to evaluate the program and identify areas for future improvement. The overall methodological workflow of this training program is summarized in the flowchart shown in Figure 1.

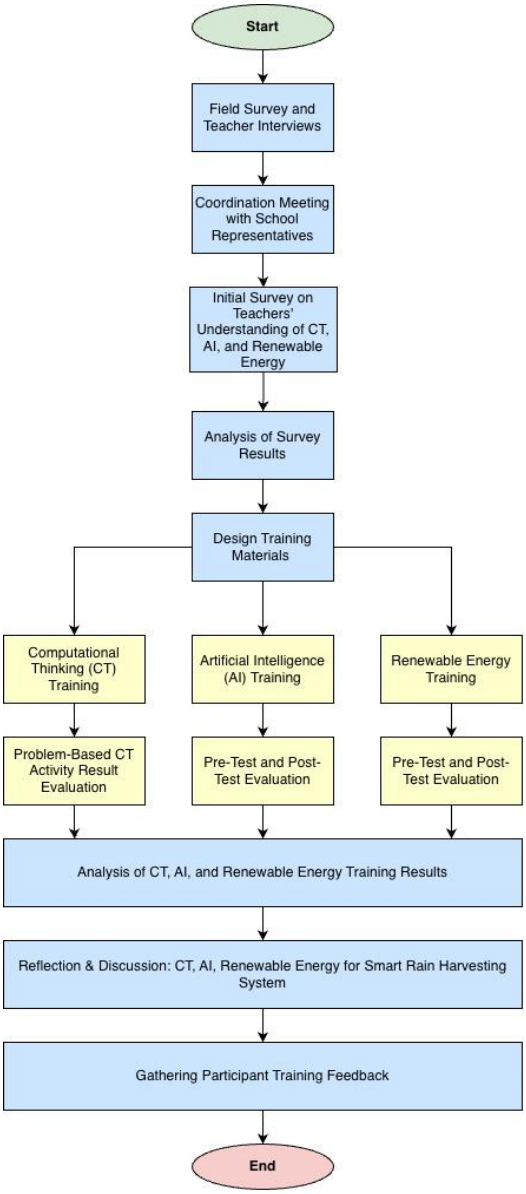

Figure 1. Methodological Workflow of the Training Program

RESULTS AND DISCUSSION

An initial assessment was conducted on January 30, 2025, to identify key issues faced by SMAN 1 Sukanagara. These interactions involved field surveys and unstructured interviews with the school's teachers and public relations staff. Based on these interviews and on-site observations, several main problems were identified, as compiled in Table 1.

Table 1. Salient problems faced at SMAN 1 Sukanagara as identified through visits and discussions

No	Description of Problem
1	Challenges in accessing clean water and developing infrastructure
2	The need to improve the understanding of technology
3	A lack of technological literacy and awareness of AI ethics within the school community

Following the field survey, the research team held further discussions with the principal and teachers of SMAN 1 Sukanagara through an online meeting on February 17, 2025. Based on this discussion, all parties agreed that technology literacy training for the teaching staff should be prioritized. This training was intended to enhance the school's teaching capabilities and to coincide with the development and installation of a solar-powered smart rainwater-harvesting system to address the clean water crisis the school was experiencing. The integration of sensors into the rainwater harvesting system through an IoT (Internet of Things) approach was proposed to aid system maintenance and provide a new on-site teaching opportunity to spark conversations and raise awareness of the issues covered in the training session.

The initial survey measuring baseline understanding of Computational Thinking (CT), Artificial Intelligence (AI), and Renewable Energy topics among the teachers of SMAN 1 Sukanagara engaged 41 teachers of Grade X and XI. The group of respondents consisted of 23 female teachers (56%) and 18 male teachers (44%) with a range of ages: 35-44 years (49%), 25-34 years (27%), 45–55 years (14%), and above 55 years (10%). Science teachers accounted for 25% of the respondents, who also included 25% social science teachers and 18.8% language teachers, with the remainder teaching in various other fields**.**

According to survey results shown in Figure 2, 70.70% of respondents reported prior familiarity with the term "Computational Thinking" (CT), while 29.30% did not. Meanwhile, 53.7% of respondents felt they did not fully understand what CT means. When asked to choose the correct definition of CT from two options, 37 of 41 respondents (90.8%) selected the correct definition, despite a majority reporting they did not fully understand the term. The survey also revealed that although only 10% of respondents had ever taught computer programming in class, 48.8% had incorporated CT elements into in-class problem-solving activities (Figure 2).

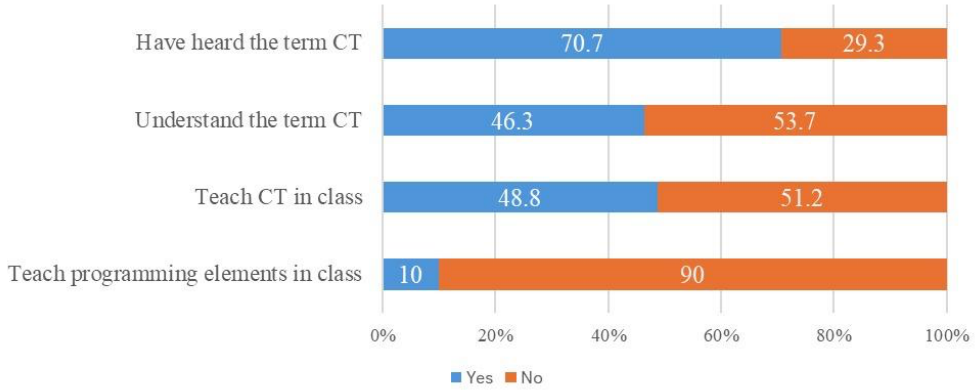

Figure 2. Initial survey results evaluating respondents' prior understanding of Computational Thinking (CT)

Programming skills are typically taught at SMAN 1 Sukanagara within the Informatics and Information and Communication Technology (ICT) curriculum. Prior to the training, the majority of SMAN 1 Sukanagara teachers (40 of 41) already recognized the importance of CT for students in the digital era, and all respondents agreed that CT should be taught across all subjects. This highlights teachers' pre-existing awareness of the relevance of Computational Thinking in preparing students for future challenges in the digital era. However, teachers also acknowledged several obstacles in teaching CT to students (Figure 3). These findings indicate strong teacher support for integrating CT across subjects to broaden students' computational thinking abilities in various learning contexts. A lack of resources, training, and prior exposure appears to be the main factor hindering increased CT literacy at the school, rather than skepticism or insufficient buy-in among educators.

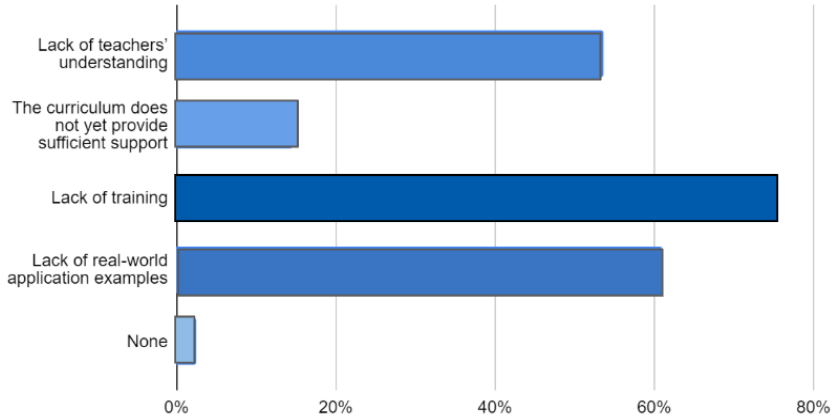

Figure 3. Main obstacles to teaching Computational Thinking (CT) in schools, as identified by respondents

Survey results confirmed that a majority of respondents (75.6%) indeed considered the lack of training to be the main challenge. Other critical challenges cited included a lack of real-world examples to help contextualize concepts (61%) and a lack of understanding among teachers (53.7%). Only a small minority of respondents mentioned other reasons. These findings underscore the importance of providing teachers with training and resources, particularly in rural areas, to strengthen CT literacy in schools. They also indicate a high level of enthusiasm among teachers to improve their CT competencies if given the opportunity, and suggest that training initiatives would be well received and potentially impactful for CT implementation in classrooms. To understand this sentiment in more detail, respondents were asked which CT topics they were most interested in learning (Figure 4). The topic "*Strategies for Teaching CT in the Classroom*" ranked highest (20.9%), while "*ICT Literacy and Ethics*" ranked lowest (12.9%).

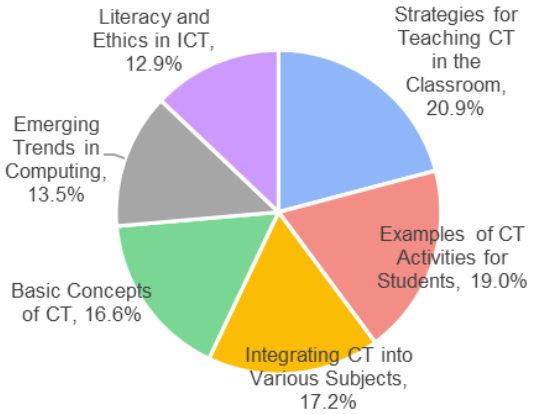

Figure 4. Computational Thinking (CT) topics preferred by respondents prior to training

The pre-workshop survey showed that 97.6% of respondents were already familiar with the term 'Artificial Intelligence' (AI). However, 71.10% had never heard of the three main AI approaches of supervised learning, unsupervised learning, and reinforcement learning (Figure 5). Although rural teachers clearly should not be expected to possess the depth of AI knowledge that would be required of AI developers, a basic understanding of these approaches is nonetheless important for teachers to grasp how AI works in general, to integrate technological literacy into learning, to understand

workforce developments in the technology sector, and to guide students to use technology responsibly and actively rather than becoming passive users.

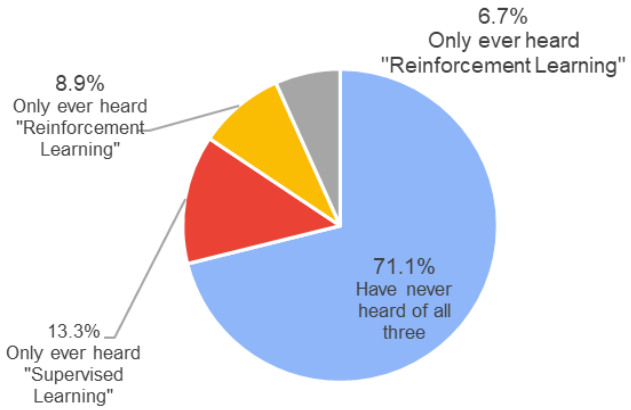

Figure 5. Respondents' familiarity with the three main AI approaches

The survey also measured how often respondents used AI-based applications (e.g., ChatGPT, Google Translate, Siri). Figure 6 indicates that among the 41 respondents, 68.3% reported using AI tools occasionally and 24.4% reported using them frequently, with the remaining participants stating that they have used AI tools only once or not at all.

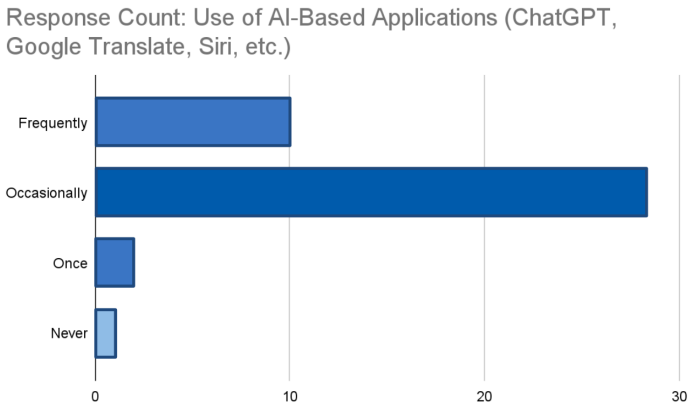

Figure 6. Respondents' use of AI-based applications

The survey also found that 78% (32 out of 41) of respondents reported that AI or digital technology topics were mentioned during the teaching of other general subjects in class. This is consistent with Firdaus et al. (2025), who indicated that AI technologies, such as Generative AI (GenAI), were already prevalent in many Indonesian classrooms. To ensure these technologies are implemented effectively to support student learning, teachers need at least a basic understanding of how AI and GenAI work. Based on the survey, 58.50% (24 out of 41) of respondents stated that they understood how AI works and how it is used, and acknowledged the importance of GenAI in supporting classroom learning. Various GenAI technologies, such as Gemini, DALL-E, and ChatGPT, are now widely available. Survey results show that 80.5% of respondents were familiar with the term GenAI. Additionally, 70.7% (29 out of 41) of respondents reported having already used GenAI tools themselves to generate text, images, or other content (Figure 7).

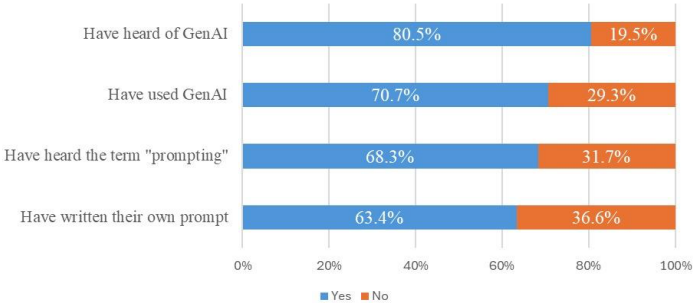

Figure 7. Respondents' familiarity with Generative Artificial Intelligence (GenAI)

In a GenAI context, *prompting* refers to the provision of instructions by a user so that an AI system produces a desired output. Effective prompting is necessary to obtain optimal output from GenAI. Among the respondents, 68.3% had heard the term "prompting" in the context of GenAI. Furthermore, 63.4% already had experience formulating their own prompts to generate the content they wanted, although only 60.9% believed they had used effective prompting when using Gen AI. The majority of respondents (68.3%) expressed a strong interest in learning effective prompting techniques, indicating a relatively high level of enthusiasm for the subject.

On the other hand, the availability of GenAI also raises teachers' concerns about its potential misuse by students, especially in schools. A total of 53.7% of respondents indicated the risk of student misuse as a major concern. Other challenges reported include limited teacher understanding, lack of formal training, and limited access to technology (Figure 8).

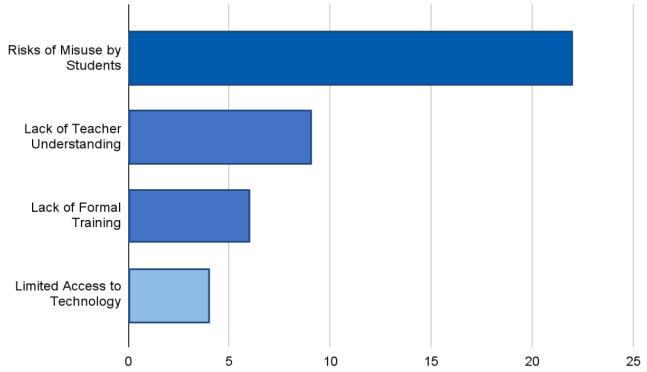

Figure 8. Main obstacles in using Generative AI in schools, as reported by respondents

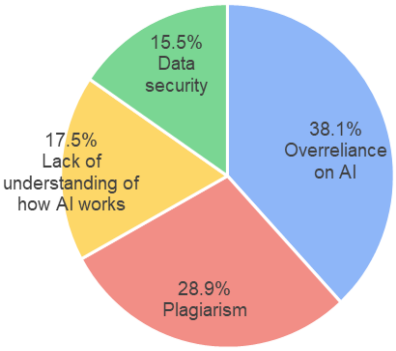

Figure 9. Respondents' primary concerns regarding student use of AI

As Figure 9 indicates, teachers' greatest concern regarding students' AI use is over-dependence on the technology, followed by plagiarism (unethical use of AI), a lack of understanding of how AI works, and data security issues. The teachers' awareness of the need for AI training, especially regarding students' lack of understanding of AI ethics, aligns with earlier studies by Fatimah et al. (2025) and Putri et al. (2025). Respondents expressed the need for guidelines or policies regulating AI use in schools if ethical issues related to AI are to be widely appreciated. The majority of respondents (73.2%) stated that such guidelines are highly necessary. Additionally, in-depth training focused on topics such as AI fundamentals, a GenAI introduction, AI ethics, and school AI policies is needed. Most respondents (85.4%) expressed interest in workshop topics related to AI implementation in learning (Figure 10).

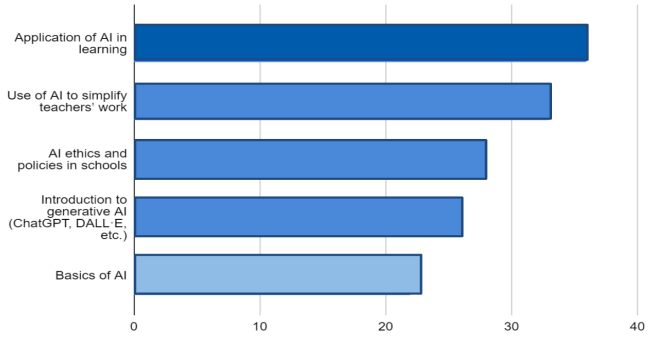

Figure 10. Respondents' preferred AI workshop topics

The survey also investigated respondents' interest in learning how AI can be used to address pressing environmental issues, such as the limited access to clean water and energy experienced by many schools. Most respondents (92.6%) reported an interest in learning more about how AI could address these problems. Additionally, 78.04% agreed that the use of AI technologies, such as sensors and Internet of Things (IoT) connectivity, was important to support the rainwater harvesting system being developed to address the school's clean water shortage.

Almost all respondents (95.1%) indicated familiarity with the term 'Renewable Energy'. Despite this, around 17.1% of respondents admitted they were unable to distinguish between renewable and non-renewable energy sources. Approximately 71% of respondents stated they had tried or seen renewable energy technologies firsthand, while 29% had not yet tried them. Most respondents (70.73%) understood that renewable energy sources are accessible across all parts of Indonesia, but 29.26% believed their availability is still limited or unreliable in certain regions. Some respondents had not yet understood that renewable energy sources, such as solar and water, can be found everywhere, including across all regions of Indonesia.

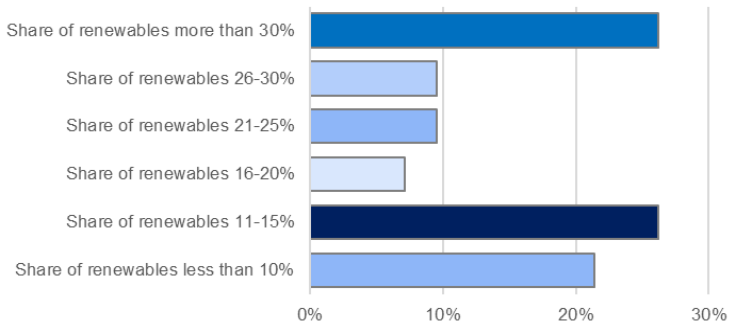

Figure 11. Respondents' estimates of the percentage of Indonesia's national energy supply represented by renewable energy in 2024

Figure 11 illustrates respondents' perceptions of the relative prevalence of renewable energy in Indonesia's national energy supply in 2024. Responses ranged widely, with the largest fraction (26.8%) believing that renewable energy accounts for 11-15% of the national supply. Another 26.8% of respondents estimated that more than 30% of national energy already comes from renewable sources. About a quarter of all respondents thus had a fairly accurate perception of the actual situation, in which renewable energy represented 11-15% of the national energy supply in 2024.

This optimistic view is consistent with the survey results, which show that the majority of respondents (73.2%) consider renewable energy vital for environmental sustainability. This indicates a high level of awareness of the strategic role of renewable energy. Support for renewable energy is also consistent with respondents' other statements; the majority (80.48%) agreed that renewable energy should be prioritized over fossil fuels, indicating a shift in public preference towards more environmentally friendly energy sources.

On the other hand, respondents also believed that there are significant obstacles to the development of renewable energy in Indonesia. According to respondents, the biggest obstacles are a lack of public awareness, high investment costs, and limited available technology. One effort to increase public awareness, especially among students and teachers, is to include renewable energy materials in the senior high school curriculum. However, based on the survey results, only 51.2% of respondents were aware that renewable energy issues had already been included in the national curriculum for senior high school. This indicates a persistent lack of awareness about integrating renewable energy into formal education. Teachers' reported interest in learning about renewable energy was very high, with around 97.6% of respondents indicating interest in learning more. The most popular renewable energy topic among respondents (Figure 12) was *household/small-scale utilization* (87.8%). In addition, topics such as *teaching renewable energy through creative media, such as renewable energy kits, and an introduction to renewable energy types* also attracted considerable interest.

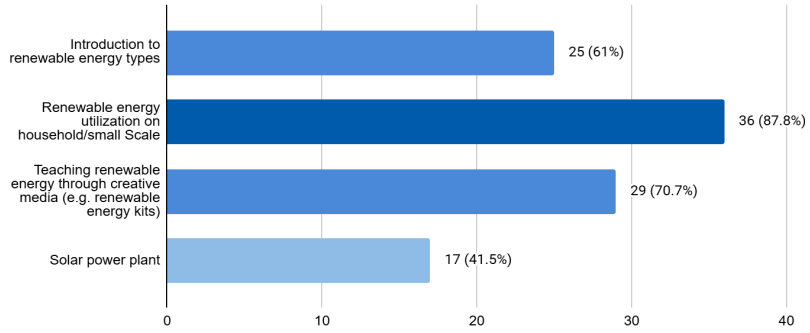

Figure 12. Popular Renewable Energy topics identified by respondents

The CT, AI, and Renewable Energy training event was held on July 7 2025 at SMAN 1 Sukanagara, with 60 teachers participating. To evaluate participants' understanding, practice questions were given during the CT session, and pre-tests and post-tests were given during the AI and Renewable Energy sessions. A complete list of pre-test and post-test questions is included in the Appendix. To measure comprehension of the CT material covered, participants were given the challenge of completing a task in a game scenario contextualized with references to elements of West Javanese cultural traditions. Presented with a series of cartoon faces drawn in the style of characters from Sundanese *wayang golek* theater, participants were prompted to the devise a system of 'encoding' and 'decoding' faces using a string of four alphanumeric characters that, if sent via text message, would allow a receiver to reproduce the face in adequate detail such that it could be correctly distinguished from other faces in a line-up.

Teachers were given a practice prompt to assess their understanding of the four basic concepts of CT, namely *decomposition*, *pattern recognition*, *abstraction*, and *algorithms*. Results indicated that, following training, the majority of the cohort was able to identify the most relevant aspects of the problem space at hand—and discard the others—through a process of *abstraction*, and to perform *decomposition* by breaking down problems into simpler parts (e.g., distinguishing between hat elements, hair shapes, face shapes, and colors of the images of characters presented). When the activity concluded, two groups had successfully compiled a series of algorithmic instructions that mostly accomplished the assigned task. However, the sequences of instructions they submitted were not yet fully structured in a way that would allow them to be used directly by an unfamiliar user to produce consistent results.

Based on the results of group discussions and brief presentations made when groups were prompted to explain their 'algorithms' to other groups, one common point of confusion was identified: some participants tended to direct a great deal of attention to the task of choosing symbols or 'codes' that were considered somehow aesthetically satisfying or appropriate—for example, the choice of the letter 'M' to encode a character's red (*merah*) skin tone or 'K' for yellow (*kuning*) skin—rather than focusing on issues more relevant to the task at hand, such as determining which image elements were most necessary to encode in order to reproduce the target image, or drafting a set of clear instructions so that the encoding and decoding processes would reproduce the target image if implemented by an unfamiliar user. It is unclear whether this occurred due to a fundamental misunderstanding of CT concepts or simply because selecting aesthetic codes was more enjoyable or comfortable for those participants. If the activity were to be repeated, it seems that instructors should emphasize that participants' work would be evaluated solely on how faithfully the decoded image reproduces the original target image, rather than on the internal details of the algorithm. Even so, an excessively prescriptive approach is not recommended, as participants clearly enjoyed the opportunity to exercise some playful aesthetic creativity. Also, variations among the algorithms produced by the different groups, whether they represent substantial differences in functionality or mere surface aesthetics, provide a further opportunity for participants to reflect on the concept of *abstraction*: Which kinds of differences between algorithms actually affect how the algorithms work, and which can be changed without altering the algorithm's functionality?

Overall, the results demonstrated that participants understood and applied the core concepts of Computational Thinking, but further exposure and guidance would be required to strengthen their skills in systematically developing algorithms. Pre- and post-test results for the AI topical session are compared in Table 2. A total of six questions were asked (Appendix Table 2). Of all participants, 37 completed pre- and post-tests. The average pre-test score was 7.57 ± 0.85 (63.08%) out of a maximum possible score of 12. This increased to 9.62 ± 0.64 (80.16%) at the post-test stage, indicating a 17.08% increase.

Table 2. Comparison of pre-test and post-test results for the Artificial Intelligence (AI) training session

	Pre-test*	**Post-test***
Number of Questions	6	6
Average Score	7.57 ± 0.85	9.62 ± 0.64
Total Respondent	37	37

*) Maximum score for *Artificial Intelligence* (AI) pre-test and post-test is 12

Table 3 compares AI pre-test and post-test results based on question categories. Several question categories, for example, the Reinforcement Learning implementation category, saw

significant increases. During the pre-test, 40.54% of respondents answered questions related to Reinforcement Learning correctly; after the post-test, this increased significantly to 86.49%. Similar increases were observed across several other topics (Table 3), indicating that the learning intervention positively impacted participants' comprehension of AI topics.

Table 3. Pre- and Post-test scores and score improvements by question category

Categories of Question	Percentage of Correct Answers		Percentage of Increase (%)
	Pre-Test (%)	Post-Test (%)	
AI Definition	59.46	89.19	29.73
Unsupervised Learning	78.38	83.78	5.40
Supervised Learning	72.97	91.89	18.92
Reinforcement Learning Implementation	40.54	86.49	45.95
Generative AI Definition	83.78	89.19	5.41
Prompt Example	40.54	40.54	0.00
Average	62.61 ± 15.13	80.18 ± 15.69	17.56 ± 14.13

Identical sets of nine questions were used both for the pre-test and post-test on renewable energy. The test was divided into three sections: two questions on the definition of renewable energy and the concept of energy transition, five questions on types of renewable energy and the concept of clean energy, and two questions on solar PV integration and rainwater harvesting. Our analysis compares the 35 complete pre-/post-test pairs received.

The maximum score that participants could achieve was 18 points. The average pre-test score obtained was 13.20 ± 0.91 (73.33%) within a 95% confidence interval, out of a maximum possible 18 points (Table 4). This standard deviation indicates relatively wide disparities in prior understanding among respondents, even though they already possessed some basic knowledge of renewable energy. In the post-test stage, the average score increased to 15.77 ± 0.76 (87.61%) within a 95% confidence interval from the previous score. This signifies a 14.28% increase in understanding after training, indicating that the training session succeeded in strengthening participants' comprehension of renewable energy and its potential applications in schools.

Table 4. Result of Renewable Energy Pre-Test and Post-Test

	Pre-test*	Post-test*
Number of Questions	9	9
Average Score	13.20 ± 0.91	15.77 ± 0.76
Total Respondent	35	35

*) Maximum score for Renewable Energy pre-test and post-test is 18

A comparison of responses for each category of question (Table 5) shows variations among the three categories (renewable energy definitions and energy transition concepts, types of renewable energy and clean energy concepts, and solar PV integration and rainwater harvesting). The data indicate a significant increase in participants' knowledge of solar PV integration and rainwater harvesting. The questions in this section were specifically designed to ensure that teachers understood the technology's installation process. This also trained teachers to maintain and cultivate their knowledge of PV integration and rainwater harvesting technology.

Table 5. Comparison of Renewable Energy Pre-Test and Post-Test Results Based on Question Category

Question	Percentage of Correct Answer Pre-Test (%)	Percentage of Correct Answer Post-Test (%)	Percentage of Increase (%)
Definition of Renewable Energy and the Concept of Energy Transition			
Question 1	97.14	97.14	0.00
Question 2	91.43	91.43	0.00
Types of Renewable Energy Sources and the Concept of Clean Energy			
Question 1	71.43	91.43	20.00
Question 2	94.29	94.29	0.00
Question 3	68.57	80.00	11.43
Question 4	74.29	82.86	8.57
Question 5	77.14	82.86	5.71
Integration of Solar PV and Rainwater Harvesting			
Question 1	17.14	80.00	62.86
Question 2	68.57	88.57	20.00
Average	73.33 ± 15.59	87.62 ± 4.17	14.29 ± 12.97

Overall, these results show that the renewable energy training had a positive impact on participants' understanding. While some questions did not show improvement in the post-test, in those cases, more than 90% of participants had already answered correctly during the pre-test. For example, for the second question in the 'Definition of Renewable Energy and the Concept of Energy Transition' category, the score was 91.43% on both pre- and post-test. The training material, which emphasized the concept of energy transition, types of renewable energy sources, and the application of the Smart Solar Panel Rainwater Harvesting system in schools, helped participants better understand opportunities for sustainable energy in the school environment.

Based on the results of the analysis in Table 5, questions from the 'Definition of Renewable Energy and Energy Transition Concepts' category had the highest percentage of correct answers. This indicates that the training participants had a correct understanding of the definition of renewable energy and energy transition. The category' Integration of Solar PV and Rainwater Harvesting' showed the highest average increase, indicating increased knowledge about integrated solar PV and rainwater harvesting technology.

Finally, a reflection session was held to broaden participants' perspectives on the implementation of CT, AI, and Renewable Energy to support the further implementation of a smart rainwater harvesting system in the school. Participant feedback showed that 35.48% of teachers were 'satisfied' and 64.51% were 'very satisfied' with the training. Participants shared that the training experience had motivated them to more actively encourage students to save energy, use appropriate technologies more responsibly, and create simple innovations that apply renewable energy. Teachers' reflections also indicated that after the training, they felt motivated to practice Computational Thinking concepts when solving problems, to use AI wisely, safely, and responsibly, and to support the wider application of green technology.

Overall, the results of this study indicate that training approaches integrating Computational Thinking, Artificial Intelligence, and Renewable Energy as interrelated components of a unified framework can strengthen teachers' readiness to implement emerging technologies in rural and disaster-prone areas. This integrated approach represents a novel contribution, particularly in the Indonesian context, where access to technology, especially in rural and disaster-prone areas, remains

limited. Furthermore, the proposed framework offers a scalable model that may be adapted and applied in other regions facing similar social, environmental, and technological constraints.

CONCLUSION

Survey results indicate that the primary obstacle to integrating computational thinking (CT) concepts into rural schools' lesson plans is a lack of relevant technology training. Teachers expressed a strong interest in learning about applications of AI in learning, even as concerns about students' potential over-dependence on technology remain. Regarding renewable energy, the most prevalent theme identified was the implementation of small-scale renewable energy. Based on evaluations made using a problem-based approach and comparisons of pre-test and post-test scores, the CT, AI, and Renewable Energy training positively impacted participants' comprehension of the material presented. The CT training helped teachers practice more structured approaches to problem-solving. Comparisons of pre- and post-tests indicated that the training program significantly enhanced teachers' comprehension, with increases of 17.08% and 14.28% in their correct responses to questions about AI and renewable energy material, respectively. These improvements demonstrate the potential of intensive training programs, such as those undertaken in the present study, to enhance participants' understanding of technology, particularly in rural schools where relevant resources are typically limited, and to provide crucial support for broader efforts to implement smart and renewable technologies in schools.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTING INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

FUNDING INFORMATION STATEMENT

We would like to express our gratitude to the Directorate of Agromaritime Community Development (DPMA), Bogor Agricultural University, for supporting the Dosen Pulang Kampung (Lecturers Return to Their Hometowns) program, with contract number 15990/IT3.L1/PM.01.01/P/2025. In addition, the authors would like to thank SMAN 1 Sukanagara and the communities in Sukamekar and Sukanagara villages for their support and participation in implementing this program. Our gratitude also extends to the student team of the *Dosen Pulang Kampung* program, who assisted us throughout the grant activities: Jesika Oktaviani, Salsabila Azzahra, Viby Ladyscha Yalasena Winarno, Zara Zannetta, and Dicky Anugrah.

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Jurnal Pemberdayaan Masyarakat
Volume x Nomor x Tahun 20xx | Hal. xxx – xxx
ykgm.org
DOI: 10.46843/jmp.v1i1.xxx

APPENDIX

Table 1. List of Pre-Workshop Survey Questions at SMAN 1 Sukanagara

Pre-Workshop Survey at SMAN 1 Sukanagara	
Respondent Demographics	
No	**Question**
1	Name (Optional)
2	Gender o Male o Female
3	Age in 2025 o < 25 years o 45-55 years o 25-34 years o >55 years o 35-44 years
4	Role at School o Student o Education Staff o Teacher o Other
5	(For Teachers) Subjects you teach (You may list more than one):
6	(For Students) Your current grade: o Grade X o Grade XII o Grade XI
7	Major (for students and teachers). If "Other", please specify. o Science (IPA) o Language o Social Sciences (IPS)
Survey on Computational Thinking	
A. Prior Knowledge	
No	**Question**
1	Have you ever heard the term "Computational Thinking"? o Yes o No
2	Do you understand what Computational Thinking means? o Yes o No
3	Which of the following statements do you think is the most accurate? o Computational Thinking mainly focuses on programming (coding)

o Computational Thinking mainly focuses on developing ways of thinking that enable systematic problem-solving

4 Have you ever taught materials or activities involving Computational Thinking in class?
o Yes o No

5 Have you ever taught materials or activities involving programming (coding) in class?
o Yes o No

B. Attitudes and Perceptions Toward Computational Thinking

No	Question
1	How important do you think Computational Thinking skills are for students in the digital era? 1 2 3 4 Not Important o o o o Very Important
2	What do you think is the main challenge in teaching Computational Thinking at school? o Lack of teacher understanding o The curriculum does not provide adequate support o Lack of training o Lack of real-world application o Other
3	How strongly do you agree that Computational Thinking can be taught across all subjects, not just Informatics/ICT? 1 2 3 4 Strongly Disagree o o o o Strongly Agree

C. Interest and Readiness to Join the Training

1 Are you interested in participating in training on Computational Thinking (CT) and its application in teaching?
o Yes o No

2 Which topics are you most interested in learning? (You may choose more than one)
 Basic concepts of Computational Thinking
 Latest trends in computing
 ICT Literacy and Ethics (Information and Communication Technology)
 Strategies for teaching CT in the classroom
 Integrating CT into various subjects
 Examples of CT activities for students
 Other

3 What type of training do you prefer?
 Hands-on workshop
 Discussions and case studies

- Expert/guest speaker sessions
- Self-paced learning modules
- Other

Pre-Workshop Survey: Artificial Intelligence (AI), Generative AI, and AI Ethics

A. Understanding of AI, Generative AI, and AI Ethics

1 Have you heard the term "Artificial Intelligence(AI)" before?
o Yes o No

2 In your opinion, what is AI?

3 Have you ever used AI-based applications (e.g., ChatGPT, Google Translate, Siri, etc.)?
o Yes, frequently
o Yes, occasionally
o Yes, once
o Never

4 Have you heard the following terms? (You may choose more than one)
- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning
- Have not heard any of the three

5 Have you heard the term "Generative AI" (such as ChatGPT, DALL·E, or similar tools)?
o Yes o No

6 Have you ever used Generative AI tools to create text, images, or other content?
o Yes o No

7 Do you know what "prompting" means (giving instructions to AI so it produces content as desired)?
o Yes o No

8 Have you ever tried creating your own prompts? (e.g., "Summarize this article," "Write a poem about teachers")
o Yes o No

9 How confident are you in creating effective prompts when using Generative AI tools such as ChatGPT?

	1	2	3	4	
Very Unconfident	o	o	o	o	Very Confident

10 Have the general subjects in your class ever touched on topics related to AI or intelligent digital technologies?
o Yes o No

B. Attitudes and Views toward AI, Generative AI, Prompting, and AI Ethics

1 How important do you think it is for teachers to understand how AI and Generative AI work, as well as how to use them properly?

	1	2	3	4	
Not Important	o	o	o	o	Very Important

2 How interested are you in learning effective prompting techniques?

	1	2	3	4	
Not Interested	o	o	o	o	Very Interestes

3 What do you think is the biggest challenge in using Generative AI in the school environment?
- o Lack of teacher understanding
- o Limited access to technology
- o Risk of misuse by students
- o Lack of formal training
- o Other

4 What are your concerns regarding students' use of AI? (You may choose more than one)
- □ Plagiarism
- □ Dependency
- □ Data security
- □ Lack of understanding
- □ Other

C. Interest and Readiness to Participate in Training

1 In your opinion, how necessary is it for schools to develop guidelines or policies for the use of AI?

	1	2	3	4	
Not Necessary	o	o	o	o	Very Necessary

2 How interested are you in participating in training on AI, including the use of Generative AI and its ethical considerations?

	1	2	3	4	
Not Interested	o	o	o	o	Very Interested

3 Which topic are you most interested in having included in this workshop?
- □ AI Fundamentals
- □ Introduction to Generative AI (Chatgpt, DALL·E, etc.)
- □ AI Applications in teaching and learning
- □ AI ethics and school policies
- □ Other

4 How much knowledge or exposure do you have regarding the concept of the Internet of Things (IoT)?
- o Have never heard of it
- o Have ever heard of it, but do not understand
- o Have a basic understanding of concept

o Understand it fairly well

Additional Section: AI and IoT for Rain Harvesting Systems

1 How important do you think the use of technologies such as sensors or the Internet of Things (IoT) is in supporting a rain harvesting system?

	1	2	3	4	
Not Important	o	o	o	o	Very Important

2 If a rainwater collection system at school were equipped with AI and automatic sensors, what benefits do you think students or the school could gain?

3 How interested are you in learning about the application of AI and IoT for environmental issues such as water, energy, or school agriculture?

o Very interested

o Interested

o Neutral

o Not Interested

High School Student Survey on Renewable Energy – SMAN 1 Sukanagara

A. Understanding of Renewable Energy

1 Have you ever heard of "Renewable Energy"?

o Yes o No

2 Can you differentiate between "Renewable Energy" and "Non-Renewable Energy"?

o Yes o No

3 Describe Renewable Energy in 2-3 words

4 In your opinion, are renewable energy sources available in Indonesia?

o Yes, available across all regions of Indonesia

o Only in certain regions of Indonesia

o Not available at all

o Not sure

5 In your opinion, what percentage of renewable energy was used in Indonesia's national energy supply in 2024?

o Less than 10%

o 11-15%

o 16-20%

o 21-25%

o 26-30%

o More than 30%

B. Attitudes and Views Toward Renewable Energy

1 How important do you think it is to use renewable energy for the environment?

	1	2	3	4	
Very Unimportant	o	o	o	o	Very Important

2 Do you agree that Indonesia should prioritize the use of renewable energy over fossil fuels?

	1	2	3	4	
Strongly Disagree	o	o	o	o	Strongly Agree

3 In your opinion, what are the challenges in using renewable energy in Indonesia?
- High investment costs
- Limited technological advancement
- Low public awareness
- Other

4 Do you think renewable energy topics are already included in the national curriculum for the senior high school level?
- o Yes, already included
- o Not sure
- o Not included

C. Interest in Renewable Energy

1 Have you ever tried or seen the use of renewable energy?
o Yes o No

2 Are you willing to learn more about renewable energy?
o Yes o No

3 Which renewable energy topics are you interested in exploring?
- Introductio to types of renewable energy
- Small-scale/home applications of renewable energy
- Teaching renewable energy through creative media (e.g., renewable energy kits)
- Solar Power Plants (PLTS)
- Other

Table 2. List of Pre-test and Post-test Questions for Artificial Intelligence Session

***Pre-test* of Artificial Intelligence**	
No	**Questions**
1	Choose the most appropriate definition for *Artificial Intelligence* (AI) a. As a way for AI to provide answers that are more proper and relevant to the user's needs b. Allows AI to learn more c. The implementation of well-defined prompts will make AI work faster d. So that users are not required to re-read the results from AI

2 Unsupervised Learning is used in the following circumstances:
   a. Dataset has been clearly labeled or answered
   b. AI learns from sample questions and answer keys
   c. Dataset does not include predefined labels or categories
   d. AI is rewarded or punished for every action it took

3 Supervised Learning means:
   a. Computer learns without any data
   b. Computers were given input data and output labels to learn
   c. Computers are left to learn independently without any assistance
   d. Computer only received data

4 The Reinforcement Learning method is most suitable for:
   a. Games and robotics
   b. Typing fast
   c. Manual drawing
   d. Create multiple-choice questions

5 What is Generative AI?
   a. Messaging apps
   b. Search engine similar to Google
   c. Text-based AI tools to assist in communication and writing
   d. Graphic design program

6 A prompt such as “Create an 11th-grade mathematics lesson plan for the even semester using a project-based approach” is:
   a. I don’t know
   b. Effective due to the comprehensive information provided
   c. Not effective
   d. Fairly effective

Post-test of Artificial Intelligence	
No	**Questions**
1	AI is a system that is capable of: a. Automatically sends message b. Imitate human ways of thinking in order to complete tasks c. Print financial report d. Assist human work
2	AI that learns by grouping unlabeled data is called: a. Reinforced Learning b. Unsupervised Learning c. Supervised Learning d. Self Learning
3	What does *Supervised Learning* mean in the context of Artificial Intelligence? a. AI learning methods without involving the use of data b. AI learns from data without the knowledge of the final outcome c. AI learning methods using labled data (both input and output are known) d. AI learning by directly imitating human movements.
4	Examples of Reinforcement Learning: a. AI learning from rewards while playing games b. AI typing fast

c. AI reading poetry
d. AI making school logo

5 What does *Generative AI* mean in the context of Artificial Intelligence?
a. AI that can only receive and evaluate data without processing it
b. AI that is capable of generating or creating new contents such as text, images, or voice based on the data it has learned
c. AI that is used specifically to store files and documents
d. AI that is designed to analyze data and provide summaries only

6 The prompt: "Please make multiple choice questions for 11th grade Biology about the respiratory system, complete with answer keys." is:
a. Bad prompt
b. Effective prompt
c. Too long
d. Fairly effective

Table 3. List of Pre-test and Post-test Questions for Renewable Energy Session

I.	**Definition of Renewable Energy and the Concept of Energy Transition**
No	**Questions**
1	What is the meaning of "renewable energy"? a. Non-sustainable energy b. Energy derived from exhaustible sources c. Energy derived from renewable and sustainable sources d. Non-renewable but sustainable energy
2	Which of the following is a greenhouse gas (GHG) emission? a. CO2 c. O2 b. He d. H2
II.	**Types of Renewable Energy and the Concept of Clean Energy**
1	Which of the following is not a renewable energy source? a. Wind c. Geothermal b. Petroleum d. Water
2	What is the disadvantage of solar power plants? (They do not produce electricity at night) a. The power generated depends on local wind speeds b. They do not require batteries or energy storage c. Exploration and drilling are required before installation d. The electricity generated is highly dependent on the time of day and the weather
3	The following are examples of fossil fuel use, except: a. Electricity sourced from steam-fired power plants b. Cooking using LPG c. Using direct heat for drying food d. Electricity sourced from steam generated by burning coal
4	Besides using renewable energy, one effort that helps reduce greenhouse gas emissions is? a. Refusing reforestation of deforested forests b. Using air purifiers at home c. Turning off lights when not in use d. Actively campaigning to extend the life of coal-fired power plants

5 Which of the following is a government effort to promote the use of renewable energy?
   a. Accelerating the energy transition by issuing a renewable energy law
   b. Allowing land clearing for oil palm plantations
   c. Extending the lifespan of coal-fired power plants
   d. Reducing the blending percentage of biodiesel and biodiesel fuel

III. Integration of Solar PV and Rainwater Harvesting

1 What is the capacity of the solar panels (Solar PV) used for the rainwater harvesting system at SMA 1 Sukanagara?
   a. 15 Wp c. 20 Wp
   b. 100 Wp d. 50 Wp

2 What steps should be taken to maintain the operation of the solar panels? (e.g., ensuring the panel surface is clean, ensuring cables are not loose or broken)
   a. Unplug the battery cables at night
   b. Regularly clean dust from the solar panels
   c. Shade the solar panels under a roof
   d. Move the battery box off the roof



Figure 1. Computational Thinking (CT) training instructional session



Figure 2. Artificial Intelligence (AI) training instructional session

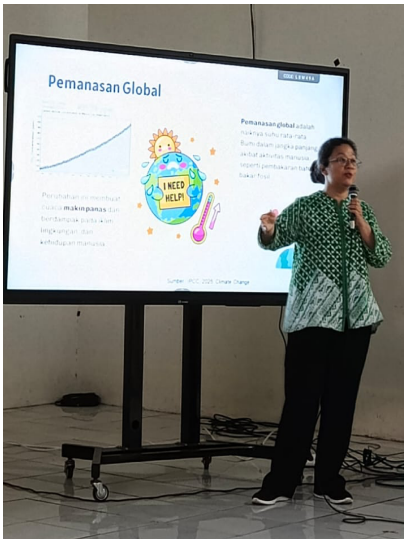

Figure 3. Renewable Energy training instructional session



Figure 4. Hands-on demonstration of a working solar panel



Figure 5. Reflection & discussion on CT, AI, Renewable Energy, and the Smart Rain Harvesting System

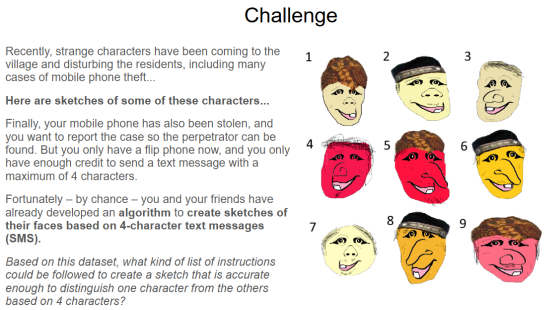

Figure 6. Interactive challenge prompt presented during the Computational Thinking (CT) training

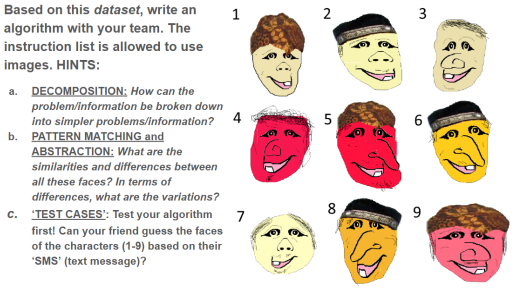

Figure 7. Practice prompts presented during the CT training to assess participants' working knowledge of core concepts: *Decomposition*, *Pattern Recognition*, *Abstraction*, and *Algorithms*