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# Improving The Digital Literacy of Science Teachers Through A STEM Approach Based on Artificial Intelligence to Realize Deep Learning

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**Abstract.** Digital literacy is one of the important competencies for science teachers as educators in learning in the 21st century. Unfortunately, not every teacher has good mastery so training is needed to improve digital literacy. The purpose of this service is to improve the digital literacy of junior high school science teachers in Semarang City through AI-based STEM learning activities in deep learning science learning. The training method uses facilitation-based action learning which begins with the presentation of material by the speaker, science learning practices by integrating STEM, AI, deep learning, questions and answers and closing. The results of the study showed that there was an increase in the digital literacy of science teachers in Semarang City after attending the training. The presentation of materials by resource persons and case study-based practical activities on science learning with an AI-assisted STEM approach and applying the principles of deep learning mindful learning, meaningful learning, and joyful learning are able to improve teachers' mastery of digital literacy. Participants also gave positive responses to the feasibility of the training materials and presentation. This means that the implementation of training to improve the digital literacy of science teachers with AI-based STEM and deep learning has been carried out very well.

**Keywords:** artificial intelligence; deep learning; digital literacy; science teacher; STEM.

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## INTRODUCTION

Education is one of the main aspects to form quality human resources and be able to keep up with the flow of life changes (Suwardi, 2021). There are various models/approaches/methods used in the implementation of education in each country. The Minister of Primary and Secondary Education of the Republic of Indonesia formalized a learning approach that will be implemented in Indonesia in the future called deep learning (Puskurjar, 2025). The deep learning approach encourages learning that helps students understand a concept deeply and applicatively, including in science learning. The deep learning approach emphasizes three main elements including mindful learning, meaningful learning, and joyful learning (Raup et al., 2022; Diputera & Zulpan, 2024). This learning is expected not only to transfer knowledge about science, but also to pay attention to the conditions or needs of students personally, be able to connect learning with real-world conditions, and be able to provide a pleasant learning experience to students. This deep learning approach can be applied by integrating technology during the learning process (Astuti et al., 2023). This makes teachers not only master the pedagogical aspects, but also need to master digital literacy to support the learning process (Hidayat, 2023).

Digital literacy relates to skills in using technology and utilizing it in solving problems, communicating, and sharing information (Sihombing et al., 2024). Mastery of teacher digital literacy can increase teacher creativity in preparing innovative learning. However, the reality in the field is that many teachers do not have adequate digital literacy skills (Lesasunanda & Malik, 2024). The results of interviews with the head of the Semarang City Science MGMP as an initial observation showed that the digital literacy skills of Semarang City Science Teachers were still low and uneven. Not all teachers are skilled in using digital media, especially AI, to be implemented in science learning, nor have teachers explicitly implemented AI-based STEM learning. This condition can be a major obstacle in the process of modernizing science learning to

prepare the golden generation in the future (Shiddiqy et al., 2023). Therefore, activities to improve digital literacy for teachers are needed. One of the efforts that can be done is by conducting AI-based STEM learning training to train teachers' digital literacy skills in science learning.

STEM is an approach that integrates 4 components in learning, namely Science, Technology, Engineering, and Mathematics (Laila et al., 2024). The STEM approach is very suitable to be applied in learning with various learning models, one of which is combining the STEM approach into case studies (Muslim et al., 2023). The integration of STEM in problem-based learning is expected to prepare students' 21st century competencies in preparation for future challenges. This shows the importance of teacher competence in implementing the STEM approach so that it has an impact on optimizing student learning outcomes. Previous research states that the implementation of STEM in science learning can train digital literacy skills (Mustofiyah et al., 2024). In addition, the use of AI in learning can also improve teacher skills in using ICT in learning (Lutfin et al., 2024). In the end, the application of the STEM approach and AI technology can improve teachers' digital literacy skills.

Based on this background, training and mentoring on AI-based STEM learning to train the digital literacy skills of junior high school science teachers in Semarang City is important, especially to realize deep learning in accordance with the current education curriculum in Indonesia. Through this activity, it is expected that teachers' digital literacy skills will increase and can apply them to relevant science learning to increase the knowledge and applicative skills needed in the present. The purpose of this training activity is to organize training and mentoring learning activities with AI-based STEM design for science teachers through MGMP activities with a facilitation-based action learning model. The specific objective is to improve the digital literacy of science teachers through AI-based STEM learning activities in science learning based on Deep Learning.

## METHODS

Training and mentoring activities were carried out at SMP Negeri 36 Semarang. The method of solving partner problems, by organizing programmed training. The design of the solution method refers to the model developed by Rusilowati & Cahyono (2012), namely facilitation-based action learning. Facilitation-based action learning activities are divided into three stages; preparation, implementation and evaluation. Activities are carried out with the participation of partners, and are carried out in participatory collaboration between the implementing team and partners, both at the preparation, implementation and evaluation stages.

### Preparation Phase

Preparatory activities are carried out through several stages starting with the coordination of the community service lecturer team with the management of MGMP IPA SMP Semarang City, sending invitation letters to partner teachers by the chairman of MGMP IPA SMP Semarang City as well as partner members, preparing a schedule for the implementation of mentoring, carried out together with partners; 4) compiling AI-based STEM training materials on science learning in the Semarang City junior high school science teacher group, determining material topics on AI-based STEM-based science learning to be offered to partner teachers, and preparing case study materials and STEM projects for training and mentoring activities with partners.

### Implementation Stage

The implementation of the service consists of several activities including 1) training in the application of AI-based STEM learning on acid and base materials. Activities are carried out with the active participation of participants (partners) in the form of questions and answers and discussions; 2) assistance in the application of AI-based STEM learning in acid and base science materials to partners; 3) assistance in the implementation of AI-based STEM learning processes in science materials to conduct case studies, design projects and present the results of AI-based STEM projects in science learning for junior high school science teacher groups in Semarang City. During the activity, the lecturer team together with student facilitators provided intensive assistance to each partner group of science teachers in Semarang City. This made the implementation of the activity run smoothly without obstacles or lagging behind the participants. At the end of the activity, documentation was made in the form of making an implementation video.

**Evaluation Stage**

The evaluation stage of the implementation of community service activities is carried out with pretest and posttest questionnaires. Before the implementation of the training, all participants were given pretest questions to measure initial digital literacy. Furthermore, at the end of the implementation, all participants were given posttest questions to measure digital literacy after training. At the end of the training, participants were also given an activity evaluation questionnaire using a Likert scale. This evaluation questionnaire aims to determine the level of success of the training activities that have been carried out. The results of the questionnaire response were analyzed using the formula: The improvement of digital literacy and the response of Semarang City science teachers to the service was measured by quantitative statistical calculations.

## RESULTS AND DISCUSSION

The service team consisting of lecturers and students of the Science Education Study Program, Semarang State University conducted training using STEM-based AI to improve the digital literacy of science teachers in Semarang City. This activity was held on Tuesday, May 22, 2025 at SMP Negeri 36 Semarang. Before the training activities were held, the service team made preparations for 2 months with MGMP IPA Koa Semarang partners including coordinating the implementation schedule, preparing training materials, and other preparations needed at the beginning to the end of the activity. Furthermore, training activities were carried out with the attendance of 38 junior high school science teachers in Semarang City.

The implementation of the service activities began with a pretest in the form of a questionnaire to measure the initial digital literacy competencies of science teachers in Semarang City. The activity continued with the delivery of material for three sessions by competent speakers from lecturers of the UNNES Science Education Study Program. The material presented sequentially starting from the first session related to digital literacy, utilization of AI in learning, and STEM-based science learning and Deep Learning. The material was delivered using power point media. To strengthen the improvement of digital literacy of science teachers, in the second material the speaker conducted a simulation with the participants to provide direct experience. The whole material presented is interrelated to provide in-depth and broad knowledge to Semarang City Science teachers about digital literacy with AI-STEM-based science learning according to the current educational approach, namely Deep Learning.


(a)

(b)

(c)

**Figure 1.** Presentation Session by the Service Team: (a) Digital literacy, (b) Utilization of AI in learning, (c) STEM-based science learning and Deep Learning

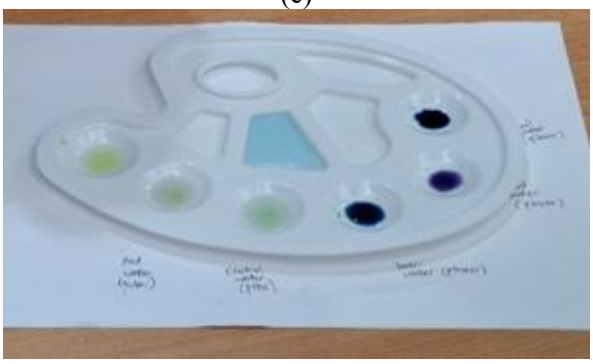
After the presentation of the material by the resource person, the training activities continued with the practice of STEM-based science learning by utilizing AI and the Deep Learning approach. The practical activities carried out are related to the concept of acids and bases, one of the science materials at the junior high school level. In its implementation, teachers as participants were divided into 9 groups consisting of 4-5 people. Each group is given a worksheet that presents a case study on the use of synthetic dyes that result in environmental pollution. All groups were asked to apply the science concepts of acids and bases integrated with the STEM approach to create innovative solutions. In the problem solving process, participants were focused on using digital AI technology.

Practical activities are carried out to solve the problem of using synthetic dyes by producing natural dye products that are more environmentally friendly. The practice applies the STEM approach, 1) the science aspect applied is related to the concept of acid-base and the use of natural indicator materials such as bay flowers, turmeric, bougenville flowers, and dragon fruit; 2) the technology aspect is related to the use of digital color detector applications, google lens to produce dyes from natural materials; 3) the engineering aspect is related to the work steps or how to make natural dyes by participants; 4) the mathematic aspect is in the form of mathematical calculations made when making color pigments. Each group mixed natural indicator materials with acid and base solutions to get 5 different color tones. The results of the experiment were then analyzed using the color detector application to find out the name label of the color obtained. In addition to doing the practice, each group filled in the worksheet according to the results of the practice carried out. Furthermore, group representatives presented the results of the practice of making dyes from natural materials and giving responses by other groups.

(a)

(b)

(c)



(d)

**Figure 2.** Deep Learning AI-STEM Science Learning Practice Activity: (a) The practice of making natural colors with acid-base principles, (b) Completing worksheets, (c) Presentation of experimental results, (d) The results of the practice of making natural colors

During the training activities, all participants were enthusiastic. The interactive delivery of the material by the resource person made the participants listen well. Not only that, practical activities were facilitated so that no participants were left behind and mistakes occurred. The training activity was closed with a question and answer session. After the practical activities, an evaluation was carried out in the form of a posttest questionnaire to measure the effect of training activities on the digital literacy of science teachers in Semarang City. There are six digital literacy indicators used, namely device and software operations, information and data literacy,

**Table 1.** Science Teacher Digital Literacy Analysis Results

| Digital Literacy Indicators | Average Score (%) | | N-Gain | N-Gain Criteria |
|---|---|---|---|---|
| | Pretest | Posttest | | |
| Device and Software Operations | 63 | 95 | 0.86 | High |
| Information and Data Literacy | 57 | 96 | 0.90 | High |
| Communication and Collaboration | 55 | 95 | 0.88 | High |
| Digital Content Creation | 40 | 98 | 0.96 | High |
| Security | 65 | 93 | 0.80 | High |
| Problem Solving | 48 | 98 | 0.96 | High |

communication and collaboration, digital content creation, security, and problem solving. The results of the digital literacy analysis of science teachers can be seen in Table 1.

Based on Table 1. the overall digital literacy skills of science teachers in Semarang City obtained an N-Gain score of 0.89 with high criteria. The training activities improved digital literacy skills on the device and software operation indicators significantly with high criteria. The device and software operation indicator measures teachers' ability to effectively use, manage, and solve basic problems related to hardware and software supporting learning (Son & Ha., 2025; Ng et al., 2022). The training implementation was able to improve the ability to identify and use software tools and technologies to obtain data, information, and digital content for science, including AI. In the second session related to the utilization of AI in learning, participants gained knowledge of various kinds of AI and how it works so that it can be utilized in lesson planning, science learning process, making AI-assisted learning media, and learning evaluation. The use of color detector software in practical activities also supports the improvement of teachers' understanding of application features and their usefulness. This is in line with Mubarok et al. (2024) that the ability to understand and use hardware and software includes the ability to understand and use hardware and software and digital operating systems, namely the ability of individuals to know the functions of features on digital devices and applications and use them.

The indicator of information and data literacy of science teachers in Semarang City experienced a significant increase with a high category. This indicator measures the ability of science teachers to search, retrieve, store, manage, organize data, information, digital content, and AI for science learning. During the practical activities, participants utilized AI Google Lens connected to Google search sources to identify the name of characteristics, and the principle of color change in the materials used. Through searches on AI-based devices, participants obtain information and data that are relevant to learning (Munsarif et al., 2025). Direct experience using AI-based digital technology can improve mastery of the second indicator of digital literacy, namely information and data literacy (Romlah et al., 2025). The results of this study are supported by Wang & Yuan (2023) that the information and data literacy indicators on teachers' digital literacy competencies measure teachers' ability to access, evaluate, manage, and use information and data critically and ethically to support the learning process.

Teachers' mastery of digital literacy also determines their ability to communicate and collaborate with teams or groups with digital technology (Warsiyah et al., 2022). Good communication and collaboration skills enable teachers to share data, information and digital content with teams through digital technology suitable for science learning. In the classroom learning process, the ability of this digital literacy indicator can encourage teachers to realize active communication and collaboration of students in learning. Communication and collaboration indicators in teachers' digital literacy competencies measure teachers' ability to utilize digital technology to communicate, share information, and collaborate effectively with students, peers, and other education stakeholders (Son & Ha., 2025; Ng et al., 2022).

Another digital literacy indicator measured in the training is digital content creation. This indicator measures teachers' ability to design, create, and modify digital content that is relevant, creative, and supports learning objectives (Carolus et al., 2023). During the training, the presenters displayed various types of AI that can be used to create learning media, ranging from using AI to brainstorm content or science learning media as needed, making AI-based power points, making

AI-based learning videos, making AI-based illustrations, and utilizing AI in using digital simulations. This makes teachers have a better level of understanding and are able to practice it in science learning. The delivery of material related to the use of AI also improves the teacher's ability to maintain security in the use and problem solving techniques. Security indicators in teachers' digital literacy competencies measure teachers' ability to protect personal data, maintain digital security, and apply ethics and responsibility in the use of information technology (Natamulia & Karlimah, 2023). The problem-solving indicator relates to the teacher's ability to identify, analyze, and solve problems related to digital technology to support learning effectiveness (Avinç & Doğan, 2024).

**Table 2.** Participants' Responses to the Implementation of the Training

| Aspects | % | Criteria |
|---|---|---|
| **Aspects of the suitability of training materials** | | |
| The training materials are suitable for the needs of teachers in the 21st century learning era and the industrial revolution 4.0 | 97.1 | Very good |
| The training materials are according to the needs of students in the 21st century learning era and the industrial revolution 4.0 | 98.0 | Very good |
| The training materials are able to improve teachers' understanding of digital literacy, STEM approaches and Artificial Intelligence in Deep Learning-based science learning | 98.0 | Very good |
| The complete coverage of training materials is useful in providing teacher instructions for implementing STEM and Artificial Intelligence in Deep Learning-based science learning | 97.5 | Very good |
| Training materials are according to the professional demands of 21st century teachers and the industrial revolution 4.0 | 94.0 | Very good |
| **Aspects of Training Presentation** | | |
| The objectives to be achieved in the training are clearly communicated to participants | 96.0 | Very good |
| Accuracy of the sequence of training presentation according to the agreed schedule | 95.7 | Very good |
| The training materials were presented interestingly by the speakers | 96.2 | Very good |
| The presentation of the material makes it easy for teachers to implement STEM and Artificial Intelligence in Deep Learning-based science learning | 98.5 | Very good |
| Presentation of training materials encourages teachers to actively look for sources and materials to implement STEM and Artificial Intelligence in Deep Learning-based science learning | 97.7 | Very good |

Table 2 shows that the average percentage of participants' responses to the service was 96.9% with details of the response to the material feasibility aspect of 96.9% and the presentation of training of 96.8%. These results indicate that the training has been presented very well. The description of the feasibility aspects of the training material can be described as follows. In the aspect of training materials according to the needs of teachers in the 21st century learning era and industrial revolution 4.0, the average percentage obtained is 97.1%. Training materials according to the needs of students in the 21st century learning era and industrial revolution 4.0 amounted to 98%. The training materials are able to increase teachers' understanding of digital literacy, STEM approaches and Artificial Intelligence in Deep Learning-based science learning by 98%. The completeness of the coverage of training materials is useful in providing teacher instructions for implementing STEM and Artificial Intelligence in Deep Learning-based science learning by 97.5%. The training material is in accordance with the professional demands of 21st century teachers and the industrial revolution 4.0 by 94%.

Another aspect is the presentation of the training. The description of the presentation aspect of the training includes, in the aspect of the objectives to be achieved by the training delivered

clearly to the learners obtained a score of 96%. The accuracy of the order of the training presentation according to the agreed schedule was 95.7%. The training material was presented interestingly by the resource person by 96.2%. The presentation of the material makes it easy for teachers to implement STEM and Artificial Intelligence in Deep Learning-based science learning by 98.5%. The presentation of training materials encourages teachers to actively seek sources and materials to implement STEM and Artificial Intelligence in Deep Learning-based science learning by 97.7%.

Digital literacy is a competency that needs to be mastered by science educators in the 21st century education era (Zuhri et al., 2024). Teacher digital literacy is also one of the main elements that determine the success of deep learning education (Jayatri et al., 2025). Through STEM-based science learning training that utilizes artificial intelligence (AI) and applies a deep learning approach that focuses on mindful learning, meaningful learning, and joyful learning can improve the digital literacy of science teachers as a whole. In this training, teachers are not only introduced to the integration of science, technology, engineering, and mathematics (STEM) concepts in an applicable manner, but are also invited to explore various AI technologies relevant to science learning, such as the use of google lens applications, the use of AI-based chatbots for scientific discussions, and experimental data analysis using intelligent digital tools. The training process is designed based on mindful learning, which emphasizes teachers' awareness of the scientific thinking process and the use of technology in supporting learning. With a meaningful learning approach, teachers are given real challenges in the form of case studies of STEM-based contextual science learning that integrates AI, so that they build a deep and relevant understanding of materials, technology, and pedagogy. Meanwhile, joyful learning is applied through fun collaborative, explorative and creative activities based on AI, which builds teachers' confidence and enthusiasm in using digital technology. All these experiences directly improve the digital literacy of science teachers, not only in the technical aspects of using digital devices and applications, but also in the aspects of critical thinking about digital information, collaboration, and innovation in adaptive and transformative learning designs in the digital era (Atmojo & Wardana, 2025).

## CONCLUSION

Community service in the form of AI-assisted STEM-oriented learning training by integrating deep learning was successful and could improve the digital literacy of junior high school science teachers in Semarang City. This is evidenced by the N-Gain score in each digital literacy indicator in the high category and the positive response of participants to the implementation of the training. The presentation of materials by resource persons and case study-based practical activities on science learning with AI-assisted STEM approach and applying the principles of deep learning mindfull learning, meaningfull learning, and joyfull learning are able to improve the mastery of digital literacy of teachers. Participants considered the training presented to be very interesting, innovative, and added knowledge and real experience to be applied in science learning. The results of this research are expected to contribute to increasing the capacity and competence of science teachers needed as educators in the 21st century learning era. The limitation of this research is the scope of participants so that in future research the service team can conduct training for science teachers on a wider scale.

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