

# Enhancing biology teachers' competence through AI-supported scientific argumentation learning

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## ABSTRACT

This article reports the outcome of a community service program aimed to improve the capability of biology teachers' in using artificial intelligence to support learning in building scientific argumentation. As a respond to the teachers' need, this program integrated digital technology into learning activities, promoting evidence-based reasoning for students. The activity introduced teachers to the Adaptive Interactive Study Interface for Next-Generation Learning (AISI) and train them to use it to build scientific argumentation in biology classrooms. The participants were 36 biology teachers from the local Biology Teachers' Association (MGMP Biologi) across Purwakarta Regency, West Java, Indonesia. The program was conducted through online instructional sessions, hands-on training, and guided practice. The results were evaluated using a pre-test and post-test design, supplemented by a perception questionnaire. Based on the results, teachers responded positively and were actively engaged throughout the training. AISI was perceived as easy to use, relevant to learning in biology, and effective in helping students construct, evaluate, and revise scientific arguments. The program improved teachers' pedagogical and technological capability in designing AI-supported argumentation building. These findings imply that AI-based community service programs can support teacher professional development and promote more interactive, evidence-based science learning in schools.

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## 1. INTRODUCTION

Science education requires students not solely understand scientific theories, but also to think critically, analyze evidence, and construct logical scientific arguments (National Research Council: Division of Behavioral, Social Sciences, Board on Science Education, 2012). This necessity is particularly important because students today are constantly exposed to vast amounts of information from the internet, especially through social media. Whereas the information obtained may be scientifically inaccurate or unreliable, potentially leading to misleading or incorrect understanding. Therefore, the reforming science education emphasize that students must be able to reason from evidence, evaluate comparable explanations, and justify claims using scientific principles (NGSS Lead States, 2013). In

science learning in general, including biology, these abilities are particularly important since students frequently encounter scientific issues related to health, the environment, genetics, biotechnology, and everyday life that require evidence-based reasoning rather than memorization of concepts.

Scientific argumentation is recognized as a key component of science education, enabling students to develop deep conceptual understanding, access higher-order thinking skills, and understand how scientific knowledge is constructed and justified (Driver et al., 2000; Osborne et al., 2004). However, in classroom practice, scientific argumentation remains a challenge to be implemented properly. Teachers are required to guide students not only in providing correct answers, but also in formulating claims, using relevant evidence, justifying their reasoning, and revising their arguments. Therefore, scientific argumentation should be understood not as a theoretical construct, but as a practical instructional capability that teachers need to develop.

This challenge is particularly relevant in the context of teacher professional development, where the success of argumentation-based learning depends largely on teachers' ability to translate the concept of scientific argumentation into concrete classroom strategies. Therefore, understanding the specific needs and conditions of the partner community became an important basis for designing this community service program.

The partner community in this program consisted of Biology teachers in Purwakarta Regency who were members of the local Biology Teachers' Association (MGMP Biologi). Based on the initial situation analysis, the teachers expressed strong interest in improving the quality of biology instruction and introducing more interactive, evidence-based learning activities for students. However, prior to the program, the teachers had limited experience in using Artificial Intelligence (AI)-supported tools to facilitate scientific argumentation. Biology learning activities were generally more familiar, such as concept explanations, classroom discussions, worksheets, and assessment of final answers, while structured activities that supported students in constructing claims, evaluating evidence, and improving arguments remained limited. This condition indicated a practical need for professional development that was directly relevant to classroom implementation. Moreover, the use of AI among teachers remains limited to generic purposes and has not yet been directed toward specialized AI-supported tools designed to facilitate students' scientific argumentation building.

Scientific argumentation differs from expressing opinions or providing basic explanations. In science learning, argumentation involves several components, including making claims based on data or observations, providing reasons that link data to claims, and recognizing limitations or alternative explanations (Toulmin, 2003). For teachers, this means that argumentation-based learning requires careful instructional planning, appropriate scaffolding, and continuous feedback. Without proper pedagogical support, students may offer opinions not backed with adequate evidence, while teachers struggle to assess the quality of students' reasoning. These components provide an analytical framework for examining the quality and structure of the arguments and for designing instructional scaffolds to support argumentative reasoning (McNeill & Krajcik, 2011; Simon et al., 2006).

The current level of scientific literacy among Indonesian students further emphasizes the relevance of this program. According to the Programme for International Student Assessment (PISA) 2022, only 34% of Indonesian students reached Level 2 or higher in scientific literacy, far below the OECD average of 76% (Organisation for Economic Co-operation and Development, 2023). At this level, students are expected to recognize correct explanations for familiar scientific phenomenon and determine whether a conclusion is valid based on the data provided, both of which are essential for scientific argumentation. This condition is relevant to the partner's needs because biology teachers require practical strategies to help students practice evidence-based reasoning in regular classroom learning.

Meanwhile, the development of Indonesian students' scientific argumentation skills remains limited, partly due to science teaching practices that still tend to emphasize concept memorization while providing limited opportunities for students to construct knowledge through argumentation. This issue is also closely related to teachers' limited capabilities in facilitating argumentation-based learning. Therefore, strengthening teachers' pedagogical and technological capabilities is an important step in improving the quality of biology learning. In the partner context, the main need was not merely a theoretical understanding of scientific argumentation, but also practical training in using learning tools to support students in developing and revising arguments.

Teacher professional development is, therefore, a key factor in improving teachers' capacity to teach scientific argumentation effectively. In line with this, AI offers transformative potential to support teacher professional development in more effective and efficient ways while also provide substantive and personalized feedback and to support teachers in various aspects of teaching scientific argumentation (Celik et al., 2022). Kim et al. (2022) demonstrated that AI can provide adaptive scaffolding for scientific argumentation writing, deliver automated assessment and constructive feedback on students' arguments, and assist teachers in detecting and responding to opportunities for argumentation during classroom discussions. Nevertheless, the integration of AI into teacher professional development for scientific argumentation instruction remains relatively newly known, and many teachers still require an adequate understanding of how to use AI effectively to support the development of students' argumentative competencies.

Considering this background, this program was designed as a form of community service to introduce and explore how AI can be integrated to enhance instructional strategies for teaching scientific argumentation. The program used the Adaptive Interactive Study Interface for Next-Generation Learning (AISI), an AI-supported learning platform that guides students in organizing ideas, examining evidence, and revising scientific arguments. The selection of AISI was based on the partner's need for a practical digital tool that could be introduced through training and subsequently adapted for biology learning activities.

Based on the situation analysis, the urgency of this community service program lies in the need to support biology teachers in integrating AI meaningfully into learning, particularly to strengthen students' scientific reasoning and argumentation. Without adequate training, AI may be used only to obtain instant answers rather than to support evidence-based thinking, reflection, and discussion. Therefore, this activity emphasized practical introduction, guided use, and classroom-oriented application of AISI.

The main goal of this program is to improve biology teachers' capabilities in using AI-supported learning tools, particularly AISI, to facilitate students' scientific argumentation in biology classrooms. Specifically, the program aimed to: (1) Introduce teachers to the practical role of AI in supporting evidence-based science learning; (2) Train teachers to use AISI for scientific argumentation activities; and (3) Strengthen teachers' ability to design biology learning activities that encourage students to construct, evaluate, and revise scientific arguments. Through this program, teachers were expected to gain practical skills that could be applied in their own classrooms and contribute to more interactive, reflective, and argumentation-based biology learning.

## **2. METHODS**

To improve biology teachers' capabilities in using AI-supported learning tools, an online professional development workshop was conducted, focusing on the use of Artificial Intelligence (AI), particularly Generative Artificial Intelligence (GenAI). The introduction of AISI for science teaching were participated by senior high school and vocational high school (SMA/SMK) teachers across Purwakarta Regency, West Java, Indonesia who teach biology or related subjects. A total of 36 teachers participated

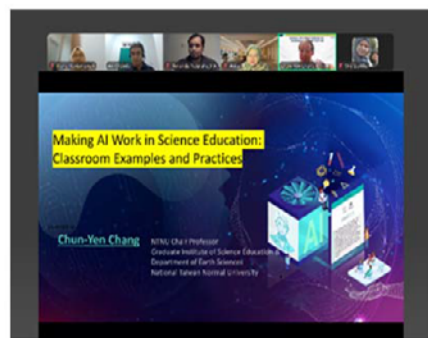
and recruited through coordination with the Science Teachers' Association (MGMP) of Purwakarta Regency. The partner in this community service program was the local MGMP, which supported participant identification, communication with teachers, and coordination of the online workshop. The community service team was responsible for preparing the training design, learning materials, technical platform, AISI demonstration, mentoring activities, and evaluation process.

The program was implemented in three main stages: preparation, implementation, and finalization. The preparation stage aimed to ensure administrative, academic, and technical readiness prior to the workshop. Activities at this stage included obtaining formal permission to conduct the community service program through the Science Education Study Program, Faculty of Mathematics and Sciences Education, Universitas Pendidikan Indonesia; assigning roles and responsibilities among the organizing team and coordinating with the international partner, National Taiwan Normal University, particularly regarding learning materials and invited speakers; and distributing formal invitation letters to teachers through the MGMP IPA of Purwakarta Regency.

**Table 1.** Implementation of community service activities

Activities	Time
<b>Day 1: Introduction and Theoretical Foundation:</b> - Scientific Argumentation: Benefits, Challenges, and Approaches - Adaptive Interactive Study Interface (AISI) for Science Classroom	Wednesday, Oct 27 <sup>th</sup> , 2025
<b>Day 2: Developing Students' Scientific Argumentation Skills via AISI-</b> supported Lesson Planning, Pedagogical Design, and Evaluation	Wednesday, Oct 29 <sup>th</sup> , 2025

The program's implementation consisted of two online sessions, as shown in Table 1. The implementation stage was organized as a series of workshop activities, including presentations, demonstrations, guided practice, discussions, and participant reflection. The emphasis was placed on how teachers could use AISI in practical contexts of biology learning rather than merely understanding AI and scientific argumentation theoretically. The first workshop session was held on October 27, 2025. This session introduced the importance of scientific argumentation in science education, the role of AI as a learning support tool, and the basic features of AISI. Participants were introduced to the AISI website, available at <https://aisi.tw/tutorial/index.html>. The facilitators demonstrated how AISI could help students organize ideas, examine evidence, and revise scientific arguments. Participants were also invited to discuss possible biology topics that could be connected to scientific argumentation activities. The online implementation of this introductory workshop session is shown in Figure 1.

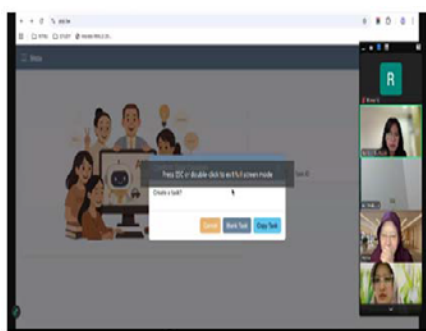


**Figure 1.** Introduction to AI and scientific argumentation in science education during the first online workshop session

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The second workshop session was held on October 29, 2025, and focused on developing AISI-based instructional modules and providing formative feedback. This session was more practical and participatory, as teachers were guided to explore the AISI platform and design learning activities adaptable to their classroom contexts. The session included guided practice on using the AISI platform, discussion of technical and pedagogical issues, and development of draft AISI-based instructional lesson plans. Several participants then presented their draft AISI-based instructional lesson plans, after which the facilitators provided feedback. The feedback focused on the suitability of the learning topic, the clarity of student activities, the integration of scientific argumentation, and the feasibility of using AISI in biology classrooms. Participants were instructed to revise their lesson plans based on the feedback received and to submit the revised versions after the workshop. The practical use of the AISI platform during the second session is shown in Figure 2.



**Figure 2.** Practical demonstration and guided use of the AISI platform during the second workshop session.

The finalization stage aimed to facilitate reflection, evaluation, and documentation of the program outcomes. Activities at this stage included group discussions with participants about the training materials, their learning experiences during the workshop, and the potential implementation of AI and AISI in classroom practice. They also included collecting post-workshop data on teachers' perceptions of AI and their views on AISI through a final questionnaire or brief interviews. A formal report on the community engagement program for the AISI workshop on classroom learning was also prepared to meet academic and administrative accountability requirements.

Data were collected using multiple techniques, including a pre-workshop questionnaire to identify teachers' initial perceptions of GenAI in teaching and learning, specifically teachers' GenAI epistemic beliefs and self-regulation (Sui & Chang, 2025). A post-workshop questionnaire to examine changes in teachers' perceptions of AI, gather feedback on AISI, and document the activities in the form of Zoom recordings, attendance lists, and screenshots. Quantitative data from the questionnaires were analyzed using descriptive statistics to examine trends in teachers' perceptions before and after the workshop. Qualitative data from open-ended responses and group discussions were analyzed thematically to identify key perspectives, expectations, and challenges related to the implementation of AI and AISI in science classrooms.

### 3. RESULTS AND DISCUSSION

#### Teachers' Understanding of AI-Supported Scientific Argumentation

The results of this community service program indicates that the AISI workshop contributed to improving teachers' practical understanding of how AI can support scientific argumentation in biology

and science learning. Teachers' perceptions of GenAI were examined through pre- and post-workshop questionnaires. Overall, almost all aspects showed improvement from pre-test to post-test, confirmed by statistical analysis. Particularly, the results can be interpreted as indicating notable changes in how teachers evaluated information sources and in their confidence in using information obtained from AI. Teachers became more critical of AI-generated information and increasingly recognized that AI responses are not always correct. This suggests that the workshop helped teachers understand that AI should be used carefully and critically in science learning. Rather than treating AI as a source of final answers, teachers began to view AI as a learning support tool that can help students organize ideas, compare information, and develop evidence-based explanations.

Prior to the workshop, many teachers were familiar with AI in general, but they had limited experience using it specifically to support scientific argumentation. After the workshop, teachers demonstrated better understanding of how AISI can be used to guide students in constructing claims, using evidence, articulating reasoning, and revising arguments. This improvement represents one of the program's main outcomes because the activity was designed not only to introduce a digital platform but also to strengthen teachers' pedagogical capabilities in using AI-supported learning tools.

**Table 2.** Descriptive overview of teachers' understanding before and after the workshop

<b>Aspects</b>	<b>Conditions Before the Workshop</b>	<b>Conditions After the Workshop</b>
Understanding of AI in learning	Teachers generally understood AI as a digital tool for obtaining information.	Teachers understood AI as a learning support tool that can assist reasoning, feedback, and argument development.
Awareness of AI limitations	Teachers had limited awareness of the need to verify AI-generated responses.	Teachers became more aware that AI responses may be inaccurate, biased, or incomplete, and that they should be checked critically.
Understanding of scientific argumentation	Teachers recognized the importance of critical thinking but had limited experience in structuring argumentation activities.	Teachers understood that scientific argumentation involves claims, evidence, reasoning, evaluation, and revision.
Use of AISI in Biology/ science learning	Teachers had not yet used AISI in classroom learning.	Teachers were able to identify how AISI could support students' argumentation in biology and science topics.
Readiness for classroom application	Teachers had limited examples of AI-supported learning in argumentation.	Teachers began designing and discussing AISI-based instructional activities.

Table 2 shows the practical changes that occurred after the workshop. The improvement was reflected in teachers' increased awareness of responsible AI use, their ability to identify the pedagogical functions of AISI, and their readiness to explore AISI for classroom learning. Therefore, the program produced a concrete improvement in teachers' initial capability in using AI-supported tools for scientific argumentation.

### **The Effectiveness of AISI in Supporting Scientific Argumentation**

The effectiveness of the AISI in supporting scientific argumentation, as perceived by teachers, was examined using a questionnaire comprising 17 statements, using 5-points Likert scale ranging from Strongly Disagree to Strongly Agree. The items were grouped into four categories: perceptions of the AISI workshop, perceived ease of use of AISI, perceived effectiveness of AISI in enhancing students'

scientific argumentation, and attitudes toward and intentions to use AISI. The detailed distribution of responses for each category is shown as 100% stacked bar charts in Figures 3-6.

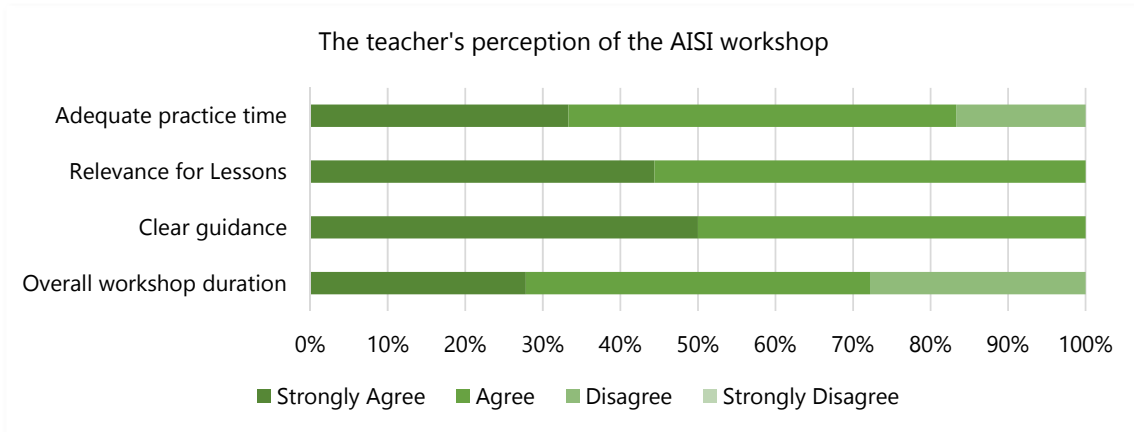


Figure 3. The teacher's perception of the AISI workshop

On average, participants strongly agreed or agreed that the workshop was relevant to their classroom learning needs and that the facilitators' guidance was clear and easy to understand. These findings indicate that the training design and facilitation were perceived as appropriate and supportive for teachers' professional learning. This positive response suggests that the workshop addressed the partner's needs, particularly the need for practical training on AI-supported learning that could be connected to biology and science classroom activities.

However, some participants reported that the training duration and the time allocated for hands-on practice were insufficient and should be increased in future implementations. This feedback is important because it shows that teachers need more time to explore AISI, develop learning activities, and practice applying the platform to their own teaching topics. Therefore, one practical result of the program was the identification of future support needs, especially longer training duration, more guided practice, and follow-up mentoring.

During the workshop, teachers were actively involved in asking questions, observing demonstrations, exploring the AISI platform, discussing possible classroom uses, and developing initial instructional ideas. This active engagement shows that the program was not limited to one-way information delivery but functioned as a participatory professional development activity for the partner community.

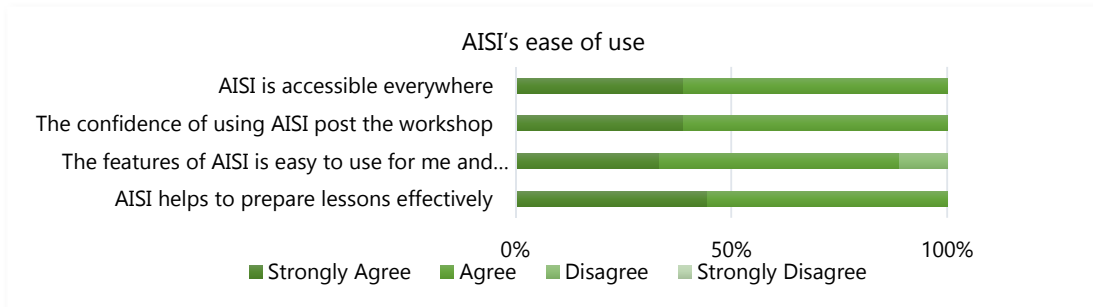
### Teachers' Perceptions of the Ease of Using AISI

Regarding the ease of use of AISI, participants' responses were dominated by Agree and Strongly Agree across statements, indicating that AISI helped them prepare learning activities more effectively, increased their confidence in using the platform, and was easily accessible both inside and outside the classroom. These results suggest that teachers generally perceived AISI as user-friendly and practically feasible for classroom integration.

The positive response to AISI's ease of use is an important outcome of the program because teachers are more likely to adopt a learning tool when they perceive it as accessible, understandable, and relevant to their classroom needs. Through the workshop, teachers gained initial experience in operating AISI and identifying how its features could support students' scientific argumentation. This

reflects an improvement in teachers' technological capability, particularly in relation to AI-supported science learning.

Moreover, as shown in Figure 4, a small proportion of participants indicated that certain features of AISI were still difficult to understand, suggesting the need for additional technical guidance or clearer interface design. This result indicates that although AISI was generally perceived as easy to use, whereas teachers demonstrated varying levels of confidence in using the platform independently. Therefore, technical assistance, tutorial videos, written guides, and repeated practice are needed to support sustained classroom implementation.

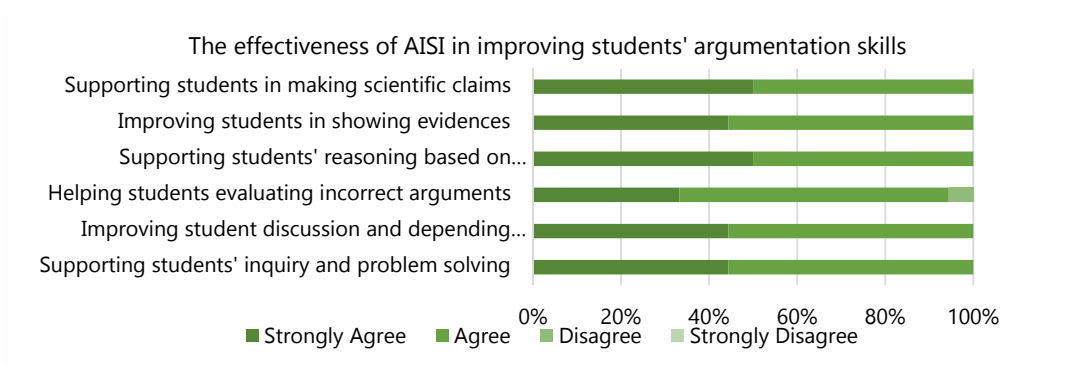


**Figure 4.** AISI's ease of use

From the perspective of community service, the workshop enabled teachers to move from viewing AI as a general technology to trying an AI-supported platform for instructional purposes. This change is crucial since proper technology integration requires teachers to understand not only how a tool works, but also how supportive it is towards learning objectives, student activities, and classroom assessment.

### Perceived Usefulness of AISI for Students' Scientific Argumentation

Responses regarding the perceived effectiveness of AISI in improving students' scientific argumentation were also predominantly positive, as shown in Figure 5, with more than 50% of participants selecting Agree for each statement. These results indicate that teachers believed AISI could support inquiry-based learning and problem solving, improve students' ability to discuss and defend arguments, help students evaluate weak or incorrect arguments, encourage data- or evidence-based reasoning, and assist students in constructing claims grounded in scientific concepts.



**Figure 5.** The effectiveness of AISI in improving students' argumentation skills

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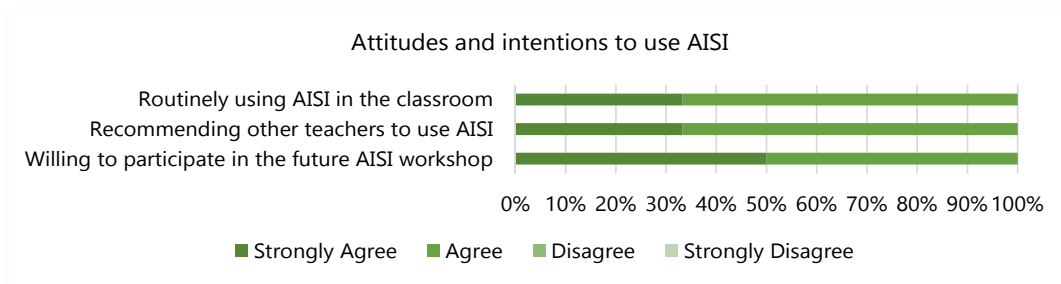
This finding represents one of the program's main impacts. After participating in the workshop, teachers recognized the potential of AISI in supporting students' scientific argumentation. Teachers perceived that AISI could help students formulate claims, provide evidence, evaluate the strength of arguments, and revise explanations. This is directly related to the program objective of strengthening teachers' capability in using AI-supported tools to facilitate scientific argumentation.

Another important output of the training was the development of initial AISI-based instructional activities. During the second workshop session, participants were guided to design learning activities that integrated biology or science content with scientific argumentation and the use of AISI. Several teachers presented their instructional modules in the form of draft and received feedback from the facilitators. The feedback focused on the relevance of the topic, the clarity of student activities, the integration of argumentation components, and the feasibility of using AISI in classroom practice.

These instructional modules drafting activities are important outputs of the community service program. As they demonstrate that participants not only received information, but also began applying the workshop materials to their own teaching activities. Although the draft activities still require further refinement and proven classroom implementation, these serve as concrete evidence that the program supported teachers in designing more interactive and argumentation-oriented learning activities.

### Teachers' Intention to Apply AISI and Follow-Up Needs

Taken together, all participants agreed to use AISI in their classrooms, participate in follow-up training activities, and recommend AISI to other teachers, as shown in Figure 6. At the end of the questionnaire, participants were also invited to suggest ways to improve the training. Most respondents requested future AISI training to be conducted over a longer period. Other suggestions included organizing face-to-face training sessions to improve focus and engagement, and providing more tutorial videos to support independent learning and ongoing use of the AISI platform.



**Figure 6.** Attitudes and intentions to use AISI

Teachers' willingness to use AISI, participate in follow-up training, and recommend the platform to other teachers indicates that the program positively impacted their readiness to integrate AI-supported tools into classroom learning. This implicates an important outcome coming from the partner because the success of this community service program is reflected not only in the completion of the activity but also in participants' constant use of the knowledge and skills obtained.

Simultaneously, participants' suggestions indicate that the program needs to be continued and enhanced. For example, teachers require more time for hands-on practice, more opportunities to design and revise lesson plans, and more support materials to guide independent use of AISI. Therefore, follow-up activities should focus on practical mentoring, peer sharing through MGMP, and assistance with classroom implementation.

For conclusion, the results show that the community service program produced several practical outcomes. First, teachers' understanding of AI-supported scientific argumentation improved after the workshop. Second, teachers responded positively to the training's relevance, clarity, and usefulness. Third, teachers perceived AISI as relatively easy to use and useful for supporting students' scientific argumentation. Fourth, participants produced initial AISI-based instructional activities as concrete outputs of training. Fifth, teachers expressed willingness to apply AISI in their classrooms and participate in follow-up activities. These results indicate that the program strengthened teachers' pedagogical and technological capability and provided a foundation for more interactive, evidence-based learning in biology and science.

The results of this community service program show that AISI-based training provided practical improvements for biology and science teachers in Purwakarta Regency. The program responded to the partner's need for professional development that was directly related to classroom practice, particularly in integrating AI-supported learning tools to facilitate building scientific argumentation. The positive responses from participants indicate that the workshop design was relevant to teachers' needs because it combined explanation, demonstration, guided practice, discussion, and reflection. This practical format is consistent with the view that to become effective, teacher professional development should be applicable to classroom realities, involve active learning, and support the application of new knowledge into daily teaching practice (Desimone & Garet, 2015; Tondeur et al., 2018).

The improvement in teachers' understanding of AI use has important implications for the partner. Before the workshop, AI was generally understood as a digital tool for obtaining information. After the workshop, teachers developed a clearer understanding that AI should function as a learning support tool for reasoning, feedback, and scientific explanation, rather than as a replacement for teachers or a source of instant answers. This aligns with studies emphasizing that AI in education should support learning processes and teacher decision-making while maintaining teachers' pedagogical role (Celik et al., 2022; Kim et al., 2022; Wang et al., 2024). Consequently, teachers became more aware that AI-generated outputs may contain inaccuracies or bias and, therefore, need to be evaluated critically (Bender et al., 2021; Huang et al., 2025).

Teachers' positive perceptions of AISI's ease of use and usefulness suggest that the platform has potential for classroom adoption. According to the Technology Acceptance Model, perceived ease of use and perceived usefulness influence users' willingness to adopt technology (Venkatesh & Davis, 2000). In this program, teachers viewed AISI as easily accessible, supportive for lesson preparation, and useful for helping students construct claims, use evidence, justify reasoning, and revise scientific explanations. These functions are consistent with argumentation-based science learning, which emphasizes scaffolding students' reasoning through structured activities and teacher guidance (Driver et al., 2000; Kim et al., 2022; McNeill & Knight, 2013; Osborne et al., 2004).

A key output of the program was the development of draft AISI-based instructional activities. This output demonstrates that participants were not only introduced to the platform, but also began applying it to biology and science learning contexts. The draft modules reflected teachers' initial efforts to integrate content, scientific argumentation, and AI-supported learning. For the partner, the benefits of the program include increased awareness of using AI responsibly, improved understanding of scientific argumentation, initial skill in using AISI, and the production of practical instructional products. These outcomes suggest a possible shift from content-centered teaching toward more interactive, evidence-based learning that gives students opportunities to explain, defend, and revise their ideas.

The results also indicate the need for sustainable support. Participants requested longer training duration, more hands-on practice, face-to-face activities, and additional tutorial videos. Therefore,

the sustainability of the program should be supported through follow-up mentoring, classroom implementation assistance, peer-sharing forums through MGMP, and the development of simple guides or exemplar AISI-based lesson plans. Overall, the program improved teachers' initial pedagogical and technological capability and provided a practical foundation for integrating AI-supported scientific argumentation into biology and science classrooms.

#### **4. CONCLUSION AND RECOMMENDATIONS**

The community service program was successfully implemented through two online training sessions conducted via Zoom. The program introduced science teachers to the pedagogical use of artificial intelligence, particularly the AISI, to support scientific argumentation in classroom learning. In line with its objective, this program aimed to strengthen teachers' capability in using AI-supported learning tools to facilitate students' scientific argumentation. Participants responded positively to the workshop, indicating that the training was relevant to their professional needs and aligned with current demands for integrating digital technologies into science education. The participating teachers perceived AISI as easy to use and pedagogically effective in fostering students' abilities to construct scientific claims, use evidence, and articulate reasoning. The findings further indicate that teachers demonstrated readiness and willingness to adopt AISI in their instructional practices, suggesting the practical feasibility of integrating AI-based tools into everyday science teaching. Furthermore, the pre-test and post-test results related to GenAI literacy suggest that the program contributed not only to improving teachers' technological understanding but also to promoting an epistemic transformation in their beliefs about knowledge construction, learning processes, and the role of AI in mediating scientific reasoning. This highlights the potential of AI-oriented professional development to influence both pedagogical practice and underlying epistemological orientations.

Despite these positive outcomes, several limitations were identified, particularly associated with the online delivery method. These included limited opportunities for hands-on practice, peer interaction, and immediate technical support, as well as differences in participants' levels of digital readiness, including internet access. To address these challenges, future programs should provide longer-duration follow-up training and, if possible, adopt mixed or full implementation with offline methods to strengthen experiential learning, mentoring, and collaborative lesson design. The development of comprehensive supporting resources, such as structured training modules, user guides, video tutorials, and exemplar lesson plans aligned with scientific discourses and the national curriculum, is also strongly recommended to facilitate sustained classroom implementation. For program sustainability, follow-up activities should be organized in collaboration with the partner through the MGMP, such as mentoring clinics, peer-sharing forums, classroom implementation assistance, and collaborative revision of AISI-based lesson plans. These activities are important to ensure that teachers can continue using AISI after the workshop and adapt it to their own biology or science teaching contexts. Future community service activities should therefore prioritize continuity of support, practical classroom application, and the development of a shared collection of AISI-supported learning resources for teachers.

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### Declaration of generative AI and AI-assisted technologies in the writing process.

During the preparation of this manuscript, the authors utilized Grammarly Premium to support grammar and language editing. All suggestions generated by the tool were carefully reviewed and revised by the authors, who take full responsibility for the final content of the article.

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### Enhancing biology teachers' competence through AI-supported scientific argumentation learning

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