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Integrating Artificial Intelligence and Local Wisdom in Biology Learning to Develop Students' Scientific Literacy and Environmental Awareness

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Abstract

The development of Artificial Intelligence (AI) has brought fundamental changes to the world of education, including in science and biology learning. This study aims to analyze and develop the integration of Artificial Intelligence (AI) and local wisdom in biology learning to improve students' scientific literacy and environmental awareness. The study used a qualitative approach with library research methods, through the search and analysis of national and international journal articles, books, proceedings, and relevant scientific documents, especially publications from the last five years. Data were analyzed using content analysis techniques through the stages of identification, selection, classification, comparison, interpretation, and synthesis of previous research findings. The results show that the integration of AI and local wisdom has strong potential in supporting scientific literacy through the exploration of biological phenomena, information retrieval and evaluation, data analysis, verification of scientific evidence, argumentation, and problem solving. In addition, local wisdom provides ecological context and cultural values close to students' lives, while AI strengthens exploration and information processing skills, thereby encouraging concern, responsibility, and action towards the environment. In conclusion, the integration of AI and local wisdom can be a contextual, critical, ethical, and sustainability-oriented approach to biology learning by positioning AI as a facilitator of scientific thinking processes and local wisdom as a source of knowledge and ecological values.

Keywords Artificial Intelligence, Biology Learning, Local Wisdom, Environmental Awareness, Science Literacy.

INTRODUCTION

The development of Artificial Intelligence (AI) has brought fundamental changes to the world of education, including in science and biology learning. AI is no longer viewed solely as a technology for automation, but has evolved into an instrument that can support personalized learning, information retrieval and processing, feedback, teaching materials development, scientific phenomenon simulations, and the strengthening of critical thinking and problem-solving skills. In biology learning, AI holds enormous potential because its

objects of study relate to complex life phenomena, ranging from cells and genetics to biodiversity and ecosystems to environmental change. However, the use of AI in learning does not automatically result in improved learning quality. The use of AI that is solely oriented towards providing instant answers has the potential to diminish students' investigative processes, information verification, scientific argumentation, and independent thinking. A systematic review by Almasri (2024), for example, shows that AI has begun to be used in various dimensions of science learning, but its effectiveness depends heavily on how the technology is integrated into pedagogical practices. Thus, the key issue is no longer whether AI should be used in biology learning, but rather how AI is used pedagogically, critically, contextually, and meaningfully to build students' scientific literacy.

On the other hand, biology learning is characterized by its close relationship with the environment and community life. Concepts such as ecosystems, biodiversity, conservation, pollution, natural resource utilization, medicinal plants, agriculture, and the relationship between humans and nature can all be learned through the knowledge and practices of local communities. In the context of Indonesia, with its cultural and ecological diversity, local wisdom can be a learning resource that bridges scientific concepts with students' real-life experiences. Local wisdom is not merely used as a cultural illustration but can be placed as an epistemic context that allows students to identify phenomena, ask questions, gather evidence, compare traditional knowledge with scientific concepts, and then draw conclusions based on evidence. Research Sarumaha et al., (2024) shows that the promotion of local wisdom in science learning contributes to the development of scientific literacy because students can connect scientific concepts with their lives and environment. Hafizah et al., (2025) also found that the Grenden local potential-based textbook effectively improved junior high school students' scientific literacy with an N-gain of 0.58. However, this local wisdom-based approach is generally still developed through conventional teaching materials or learning models and has not been widely combined with AI capabilities that can help students explore, analyze, visualize, and verify biological phenomena more dynamically.

Theoretically, this research is built on the integration of constructivism, contextual learning, scientific literacy, environmental literacy, and human-centered AI in education. The constructivist perspective positions students as knowledge builders through experience and interaction with the environment, while contextual learning emphasizes the connection between academic material and real-world situations experienced by students. In biology learning, both perspectives can be strengthened through local wisdom because local knowledge provides a real-world context close to students' lives. Meanwhile, AI functions as cognitive and learning support that helps students develop questions, discover patterns, generate alternative explanations, conduct simulations, process data, and obtain feedback. Within this framework, AI is not positioned as a substitute for teachers or a sole source of truth, but as a learning partner that must always be criticized and verified through scientific evidence. This view aligns with the development of GenAI studies in science education, which emphasize the importance of students' ability to critically read, assess, discuss, and represent

scientific knowledge when interacting with AI. Tang et al. (2024), through a meta-synthesis of research on GenAI and literacy in science education, shows that the relationship between AI, language, science discourse, and multimodal representations opens up new opportunities for science learning, but also requires clear pedagogical design.

Relevant research was conducted by(Sholihah & Tengah, 2024)shows that Artificial Intelligence (AI) has the potential to support learning, assessment, personalization, and various science education activities, but is still in the general context of science education and has not integrated AI with local wisdom in biology learning to develop scientific literacy as well as environmental awareness; research by Arisanti et al., (2024) shows the potential of AI in supporting literacy, scientific discourse, and multimodal representation, but has not yet linked it to local ecological knowledge, so this research offers novelty in the form of utilizing AI to explore biological phenomena that originate from local wisdom and develop the ability to understand and evaluate scientific evidence; further research by Supriadin & Pababari, (2024) shows that the integration of local Indonesian culture can support environmental awareness and the achievement of SDGs, but has not utilized AI as an instrument for exploration, analysis, and problem solving, so this study integrates local wisdom as a source of ecological context with AI as a facilitator of the scientific thinking process; research by Zalukhu, (2025) shows that the integration of local wisdom in science learning can increase the relevance and scientific literacy of students, but has not utilized AI to test, compare, and validate local knowledge with modern biological concepts, so this study offers a syntax of local wisdom AI exploration scientific verification environmental problem solving–reflection; research Adenia & Setiyawan, (2025) proves that Grenden local wisdom-based textbooks are effective in increasing scientific literacy with an N-gain of 0.58, but the use of local wisdom is still dominant in the form of teaching materials and has not provided space for AI, data, simulations, or adaptive feedback, so this study develops the concept of an AI-supported local wisdom learning ecosystem that combines AI, local knowledge, biological investigations, environmental data, and problem solving;

Thus, the main research gap of this study lies in the suboptimal integration between AI and local wisdom in a single biology learning design that simultaneously targets scientific literacy and environmental awareness, while the novelty of this research lies in the development of a learning approach that positions AI as a facilitator of scientific exploration, analysis, and verification, local wisdom as a source of ecological context and values, biology learning as a space for integration, scientific literacy as a scientific competency, and environmental awareness as an orientation of attitudes and actions, so that students are not only able to utilize AI technology critically, but also able to connect scientific knowledge with local wisdom to understand and solve environmental problems contextually and sustainably.

Based on the problems and research gaps, this study aims to analyze and develop a biology learning design that integrates AI and local wisdom through exploration activities of biological phenomena, identification of local environmental problems, information search and processing, data analysis, verification of information generated by AI with scientific sources

and local knowledge, and the preparation of evidence-based arguments, so as to improve students' scientific literacy skills in explaining phenomena scientifically, evaluating information, using evidence, and making decisions based on scientific reasoning and analyzing the effectiveness of the integration of AI and local wisdom in developing students' environmental awareness through an understanding of local wisdom values, concern for biodiversity and ecosystems, the ability to identify and analyze environmental problems in the surrounding area, and the ability to formulate alternative solutions oriented towards environmental conservation and sustainability. Thus, this study is expected to produce a biology learning approach that not only utilizes AI as a learning technology, but also integrates it with local knowledge and values so that students are able to use technology critically and responsibly, understand biological concepts based on scientific evidence, and have concern and commitment to protecting the surrounding environment.

METHODS

This study uses a qualitative approach with a library research method to analyze in-depth the integration of Artificial Intelligence (AI) and local wisdom in biology learning and its potential in developing students' scientific literacy and environmental awareness. Research data are sourced from national and international journal articles, books, proceedings, and relevant educational policy documents published primarily in the last five years. Data collection was conducted through a literature search in scientific databases. The obtained literature was selected based on relevance, source credibility, year of publication, and suitability to the research focus. Then, it was analyzed using content analysis through the stages of identification, classification, comparison, interpretation, and synthesis of previous research findings. The analysis is directed at identifying the forms of AI utilization in biology learning, the role of local wisdom as a learning context, its contribution to scientific literacy and environmental awareness, and unanswered research gaps. The results of the synthesis are then used to formulate a conceptual framework for the integration of AI and local wisdom that is contextual, critical, and ethical, and oriented towards developing students' scientific literacy and environmental awareness.

RESULTS AND DISCUSSION

Results

Integrating Artificial Intelligence and Local Wisdom in Biology Learning to Develop Scientific Literacy

The analysis of various literature shows that the integration of Artificial Intelligence (AI) and local wisdom has strong potential to strengthen biology learning oriented towards developing students' scientific literacy. AI can be utilized as a supporting technology in various learning activities, such as searching and processing information, formulating questions, exploring biological phenomena, simulations, visualizing abstract concepts, analyzing data, providing feedback, and developing alternative problem-solving strategies.

Meanwhile, local wisdom provides a real-world context close to students' lives, such as environmental conservation practices, the use of local plants, natural resource management, traditional agriculture, plant-based medicine, and community practices in maintaining ecosystem balance. The synthesis results show that when AI and local wisdom are combined, biology learning is no longer solely oriented towards mastering concepts, but provides opportunities for students to connect biological concepts with phenomena they encounter in everyday life. This integration also allows students to utilize technology productively without losing the social and cultural context as an important part of the learning process.

The study also shows that local wisdom can serve as a starting point for problem-based learning and scientific inquiry. Local phenomena known through community experience can be transformed into scientific questions, which are then studied using biological concepts and AI assistance. For example, community practices in protecting water sources, managing agricultural land, preserving certain plants, or maintaining biodiversity can be used as context for studying ecosystems, interactions between living things, conservation, pollution, and environmental sustainability. In this process, AI can help students find additional information, compare various sources, identify possible cause-and-effect relationships, and develop alternative explanations. However, the synthesis of results emphasizes that information generated by AI must be verified using textbooks, scientific articles, observations, and credible sources of knowledge. Thus, students not only become users of AI but also become critical users of technology and able to assess the validity of information based on scientific evidence.

The integration of AI and local wisdom further demonstrates its strong relevance to scientific literacy indicators. Scientific literacy is not only related to the ability to memorize concepts, but also includes the ability to explain phenomena scientifically, design or understand scientific investigations, interpret data and evidence, evaluate information, and use scientific knowledge in decision-making. In this context, the use of AI can help students obtain diverse information and representations about a phenomenon, while local wisdom provides authentic problems that must be explained using scientific concepts. Students can be guided to compare traditional knowledge with modern biological knowledge, identify similarities and differences, evaluate evidence, and determine whether a local practice has a scientific basis or requires further explanation. This process has the potential to develop critical thinking skills because students do not passively receive information but rather engage in interpretation, verification, argumentation, and evidence-based decision-making.

The study's findings indicate that the effectiveness of AI integration in learning depends heavily on the pedagogical design used. AI does not automatically improve scientific literacy if it is only used to provide answers or complete student assignments. Conversely, AI becomes more meaningful when positioned as a learning support that encourages students to ask questions, explore alternative answers, test information, analyze data, and reflect. In local wisdom-based biology learning, AI can be used at every stage of inquiry, from identifying local problems and searching for information, formulating questions, analyzing phenomena, interpreting data, and developing solutions. This pattern results in learning that combines

students' local experiences with digital technology capabilities and scientific processes. Thus, the integration of AI and local wisdom can create a more contextual learning experience while encouraging students to use scientific skills to understand the biological phenomena around them.

The synthesis also demonstrates that this integration plays a crucial role in developing contextual and transformative scientific literacy. Local knowledge, previously understood as community traditions, can be re-examined through a biological perspective, enabling students to understand the ecological, biological, or conservation rationales behind these practices. Conversely, biological concepts learned in class become more meaningful when applied to explain phenomena that actually occur in the students' environment. AI plays a role in expanding access to information and enabling students to explore more flexibly, while local wisdom keeps the learning process rooted in real-life contexts. These results suggest that integrating the two can be an alternative approach to addressing biology learning that is overly oriented toward memorizing concepts and lacking authentic investigative experiences for students.

Based on the overall results of the study, it can be concluded that the integration of AI and local wisdom has the potential to form a biology learning model that develops scientific literacy through the relationship between local phenomena, AI technology, the investigative process, scientific evidence, and decision-making. This model positions students as active subjects who identify problems, explore local knowledge, use AI to expand information, verify information, analyze evidence, develop arguments, and generate solutions based on biological concepts. Thus, the results of the study support the first objective that the integration of AI and local wisdom can be a relevant learning approach to develop students' abilities to explain biological phenomena scientifically, evaluate information, use evidence, and make decisions based on scientific reasoning. This finding also shows that the success of integration is not determined by technological sophistication alone, but by the ability of teachers to design learning activities that direct AI to strengthen scientific thinking processes and local wisdom to provide an authentic life context.

Integration of Artificial Intelligence and Local Wisdom in Developing Students' Environmental Awareness

The results of the literature analysis indicate that local wisdom plays a significant role in building environmental awareness because it encompasses values, norms, knowledge, and community practices related to the relationship between humans and nature. Various forms of local wisdom, such as prohibitions on excessive extraction of natural resources, conservation practices, water management, forest protection, sustainable plant use, and traditional land management, reflect the existence of ecological knowledge that develops based on community experience. When these values are integrated into biology learning, students have the opportunity to understand the environment not only as an object of scientific study, but as part of their social and cultural lives. The results of the synthesis indicate that this approach can strengthen students' emotional connection to the environment because the

problems studied originate from a close and real environment. Learning becomes more meaningful because students not only understand the concepts of pollution, conservation, ecosystems, and biodiversity, but also understand the real consequences of environmental damage on people's lives.

The integration of AI then provides a new dimension in developing environmental awareness. AI can help students explore information about environmental conditions, identify factors causing ecosystem damage, compare various alternative solutions, visualize environmental changes, and analyze the relationship between human activities and ecosystem conditions. In local wisdom-based learning, students can begin activities by identifying community practices related to the environment, then use AI to gain a scientific perspective on those practices. For example, students can analyze local water management practices using the concept of the water cycle, examine the use of local plants based on biodiversity principles, or analyze traditional conservation practices using concepts of ecology and sustainability. With this approach, AI serves to broaden students' understanding, while local wisdom provides a foundation of values and context that makes environmental learning more relevant to their lives.

The study's findings suggest that environmental awareness can develop when students not only acquire knowledge about the environment but also engage in the process of identifying problems and formulating actions. The integration of AI and local wisdom allows learning to be directed at authentic environmental issues such as water pollution, waste management, reduced biodiversity, habitat destruction, overuse of natural resources, and changes in local ecosystem conditions. Students can use AI to explore the causes and impacts of problems, then use local knowledge to understand how communities have responded to these issues. Furthermore, students can evaluate the effectiveness of local practices based on scientific principles and design alternative solutions that are appropriate to environmental conditions. This process can foster awareness that environmental sustainability is not solely the responsibility of the government or certain institutions, but also the responsibility of individuals and communities.

Research findings also indicate that the integration of AI and local wisdom has the potential to build environmental awareness through a combination of cognitive, affective, and behavioral aspects. In the cognitive aspect, students gain knowledge about the concepts of ecology, biodiversity, pollution, conservation, and sustainability. In the affective aspect, engagement with local wisdom can foster a sense of ownership, concern, appreciation for the environment, and respect for community practices that support sustainability. In the behavioral aspect, students are guided to design and implement concrete actions such as waste management, biodiversity conservation, water conservation, wise resource utilization, or environmental campaigns. AI can support this process by providing information, developing activity plans, analyzing data, and evaluating alternative solutions. However, final decisions must still be based on scientific considerations, local conditions, social values, and environmental needs.

The literature synthesis further indicates that the use of AI in environmental education needs to be placed within an ethical and critical framework. The ease of accessing information through AI can be both an opportunity and a challenge, as students may potentially receive inaccurate or inappropriate information for local conditions. Therefore, the integration of AI with local wisdom must be guided by a process of verification and reflection. Students need to compare information obtained from AI with scientific sources, environmental observations, community experiences, and empirical data. This process not only improves the quality of learning but also develops students' ability to understand that technology does not always produce accurate information. Thus, the environmental awareness developed is not merely emotional concern, but one supported by scientific knowledge, cultural values, critical thinking skills, and a readiness to take concrete action.

Based on the overall analysis results, it can be concluded that the integration of AI and local wisdom has strategic potential to develop students' environmental awareness through biology learning that connects scientific knowledge, local experiences, digital technology, ecological values, and concrete actions. Local wisdom provides a foundation for environmental values and identity, while AI expands students' abilities to obtain, analyze, and evaluate information and design alternative solutions. The integration of the two enables students to understand environmental issues more comprehensively while simultaneously fostering environmental awareness and responsibility. Thus, the research results support the second objective that AI-based biology learning with local wisdom not only has the potential to increase environmental knowledge but also encourages the formation of caring attitudes, responsibility, and a tendency to take environmental conservation actions in a contextual and sustainable manner. These findings strengthen the research's position that integrating modern technology with local knowledge can be an important strategy in developing a generation capable of critically utilizing AI while possessing a strong ecological awareness.

Discussion

The integration of Artificial Intelligence (AI) and local wisdom in biology learning has strong potential in developing students' scientific literacy and environmental awareness. This finding aligns with constructivism theory, which views knowledge as actively constructed through experience, interaction with the environment, and the process of connecting new knowledge to prior experiences. In the context of this research, local wisdom serves as a source of authentic experience and context, while AI functions as a supporting technology that helps students explore, process, and develop information. This finding aligns with studies(Soegiarto et al., 2023)which shows that AI has great potential in science learning through personalization, information exploration, assessment, and support for learning activities. However, the results of this study expand on these findings because AI is not positioned as a stand-alone technology, but rather integrated with local knowledge and practices in biology learning. Thus, the integration of AI–local wisdom results in a more contextual approach because students not only interact with digital technology but also connect scientific

knowledge with biological and environmental phenomena found around them. This position also aligns with the contextual learning perspective, which emphasizes the importance of linking learning materials to students' real lives to make the knowledge gained more meaningful.

The findings regarding the increased potential for scientific literacy through the integration of AI and local wisdom can also be explained through the concept of scientific literacy, which places the ability to explain phenomena scientifically, evaluate information, use evidence, and make decisions as essential components of student competency. In this study, AI provides students with opportunities to gain diverse information and perspectives on biological phenomena, while local wisdom provides authentic problems that must be examined using scientific concepts and evidence. This pattern aligns with studies(Ummi et al., 2026)which positions GenAI as a technology that can support literacy, scientific discourse, and knowledge representation in science education. However, this research provides an extension because the use of AI is directed at inquiry and verification processes, not simply generating information or answers. Students are guided to compare AI information with scientific sources, observations, and community knowledge to form an evidence-based evaluation and argumentation process. These findings also strengthen research(Ramadani, 2025)which demonstrates that integrating local wisdom can enhance the relevance of science learning and help students understand concepts within their own lives. The difference is that this study adds AI as a supporting tool to expand the exploration and analysis process, so that scientific literacy is built not only through local context but also through critical skills in using digital technology.

Research findings on the role of local wisdom in developing environmental awareness reinforce the view that environmental education is more effective when learning is linked to the values, experiences, and practices of local communities. The perspectives of place-based education and environmental education emphasize that students' attachment to places and their surroundings can foster ecological understanding and a sense of environmental responsibility. These research findings align with(Firdaus, 2024)which demonstrates the importance of integrating local culture in building students' environmental awareness and supporting the achievement of sustainable development goals. In this study, local wisdom serves as both a source of knowledge and a source of values that teach a harmonious relationship between humans and nature. This also supports the research.(Irawan et al., 2025)This study integrates the local wisdom of Ngaha Aina Ngoho into learning to increase environmental awareness in high school students. However, this study expands on this approach by incorporating AI as a means of exploring and analyzing environmental issues. This means that students not only understand the environmental values inherent in community traditions but can also examine them based on biological concepts and scientific information obtained through digital technology.

Research findings regarding the use of local wisdom as a learning context also strengthen the results. Gudesma, (2024) which shows that Grenden's local wisdom-based

teaching materials can improve students' scientific literacy with an N-gain of 0.58. These results indicate that local context can be an effective means of bridging scientific concepts with students' experiences. This study shares similarities in placing local wisdom as a learning resource, but provides further development through AI integration, so that local wisdom is not only present in the form of teaching materials, but becomes the basis for investigative and problem-solving activities. This finding is also relevant to research (Putra & Wahyuni, 2025) which shows that local wisdom-based science learning tools can increase student engagement and understanding. The difference is that this study positions AI as a strategic component in the inquiry process, specifically to help students search for information, analyze data, compare perspectives, and formulate solutions. Thus, the research results point to the concept of an AI-supported local wisdom learning ecosystem, a learning environment that combines local knowledge, AI technology, scientific activities, and environmental issues as a unified learning environment.

This study extends these findings by integrating AI as a tool for analysis and decision-making. While e-modules provide a structured source of information, AI provides a more flexible exploration space, allowing students to develop questions and explore various possible solutions. However, the use of AI still needs to be controlled through digital literacy and ethical principles, as the information generated by AI is not always accurate. Therefore, the research findings support a critical AI literacy approach, namely the ability to use AI while understanding its limitations, potential biases, and the need to verify information. This integration is crucial so that students are not passive users of AI but are able to utilize technology critically to solve biological and environmental problems.

Overall, the discussion shows that the research results have continuity and provide development to various previous studies. This study demonstrates the importance of local wisdom in science learning, scientific literacy, and environmental awareness. This study brings together these two groups of studies within an integrative framework, namely AI as a facilitator of exploration, analysis, and verification of information; local wisdom as a context, source of knowledge, and ecological value; biology learning as a space for integration; scientific literacy as scientific competence; and environmental awareness as an orientation for attitudes and actions. Conceptually, these findings indicate that modern technology and local knowledge do not have to be positioned as two things that are in conflict, but can complement each other in building biology learning that is relevant to the needs of the 21st century. The main novelty of this research lies in the synthesis of both through the process of identifying local phenomena.→AI-assisted exploration→scientific verification→evidence analysis→argumentation→environmental problem solving→reflection and action, so that learning not only produces students who are able to understand biological concepts and use technology, but also students who are critical of digital information, value local knowledge, and have concern and responsibility for environmental sustainability.

The novelty of this research lies in the development of an integrative framework of Artificial Intelligence (AI) and local wisdom in biology learning, which is simultaneously

aimed at developing students' scientific literacy and environmental awareness. Unlike previous research, which generally examined AI in science learning in general or local wisdom to improve scientific literacy and environmental awareness separately, this research combines both in a systematic learning process. AI is not positioned merely as a medium for obtaining information or generating answers, but as a facilitator of exploration, analysis, data interpretation, information verification, and solution development. While local wisdom is positioned as a source of context, ecological knowledge, cultural values, and students' real-life experiences. This integration is realized through a learning flow that identifies local biological phenomena.→exploration of local wisdom→utilization of AI→verify information with scientific sources→evidence analysis→scientific argumentation→environmental problem solving→reflection and action. Another novelty is the emphasis on the critical and responsible use of AI, so that students not only have scientific literacy and environmental awareness, but also are able to evaluate the accuracy, relevance, and limitations of AI-generated information. Thus, this research produces a new perspective that AI as technological intelligence and local wisdom as ecological-cultural intelligence can be integrated to form biology learning that is contextual, critical, ethical, and oriented towards environmental sustainability.

CONCLUSION

The results of the literature study indicate that the integration of Artificial Intelligence (AI) and local wisdom in biology learning has strong potential to develop students' scientific literacy and environmental awareness, because AI can function as a facilitator in information exploration, data analysis, phenomenon visualization, information evaluation, and solution formulation, while local wisdom becomes a source of context, ecological knowledge, cultural values, and real experiences that are close to students' lives. The integration of both through the stages of identifying local biological phenomena, exploring local wisdom, utilizing AI, verifying information with scientific sources, analyzing evidence, developing arguments, solving environmental problems, and reflecting can help students understand biological concepts more contextually while developing the ability to explain phenomena scientifically, evaluate information, use evidence, and build concern and responsibility for the environment. Based on these results, it can be concluded that the integration of AI and local wisdom is a relevant approach to building contextual, critical, ethical, and sustainability-oriented biology learning, with AI as a supporter of the scientific thinking process and local wisdom as an ecological and cultural foundation. Therefore, teachers and schools are recommended to develop AI-based learning–local wisdom while still emphasizing information verification, critical and responsible use of AI, and utilization of local environmental potential as a learning resource, while further research is recommended to empirically test the effectiveness of the model through experimental research or research and development on scientific literacy, environmental awareness, critical thinking, and students' problem-solving abilities.

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