JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Profiling and Enhancing Scientific Literacy in Disaster Mitigation: The Effectiveness of the Discovery Learning Model for Elementary School Teacher Education Students

Anggit Grahito Wicaksono[1*], Mukhlis Mustofa[1], Daru Angga Amirrulloh[1]

[1]Elementary School Teacher Education Study Program, Universitas Slamet Riyadi, Surakarta, Indonesia.

Received: April 14, 2025
Revised: July 03, 2025
Accepted: August 25, 2025
Published: August 31, 2025

Corresponding Author:
Anggit Grahito Wicaksono
garahito@gmail.com

DOI: 10.29303/jppipa.v11i8.11064

Abstract: The critical need for effective pedagogical interventions to address Indonesia's declining scientific literacy, especially within its disaster-prone context, drives this study, which aims to investigate the effectiveness of the discovery learning model in enhancing the scientific literacy of elementary school teacher education (PGSD) students within disaster mitigation contexts. Employing a mixed-methods sequential explanatory design with 32 participants, data were collected via a pretest-posttest using a validated scientific literacy test measuring three PISA competencies and analyzed descriptively, with paired t-tests, N-gain scores, and thematic analysis. Results indicated a significant quantitative improvement ($p < 0.05$) as mean scores rose from 53.28 to 72.50 with a moderate N-gain of 0.411, while qualitative findings revealed enhanced engagement and critical thinking, albeit with persistent challenges in translating theoretical knowledge into practical application, particularly in the competencies of explaining phenomena and using evidence. It is concluded that structured discovery learning significantly enhances scientific literacy among pre-service teachers when contextualized within authentic scenarios, underscoring its essential role in teacher education for disaster-prone regions like Indonesia and recommending the incorporation of applied learning experiences to effectively bridge the theory-practice gap in science education.

Keywords: Active learning; Disaster mitigation education; Discovery learning model; Scientific literacy; Teacher education

Introduction

The 21st century has brought significant changes to the educational paradigm, emphasizing the need for students to develop skills that enable them to thrive in a rapidly evolving world. Among these skills, scientific literacy stands out as a critical competency, particularly in the context of natural disaster mitigation. Scientific literacy refers to the ability to apply scientific knowledge, formulate relevant questions, and draw evidence-based conclusions to understand the natural world and make informed decisions (Haviz et al., 2024; Schleicher, 2019; Susongko et al., 2024). In Indonesia, the importance of scientific literacy is underscored by the country's vulnerability to various natural disasters, such as earthquakes, tsunamis, and volcanic eruptions, which necessitate a population that is well-informed and capable of responding effectively to such events.

However, Indonesia's declining scientific literacy performance, as evidenced by the PISA score drop from 403 (2015) to 386 (2018) (Hartono et al., 2022; Tohir, 2019), reveals a critical gap in applying scientific knowledge to real-world contexts particularly alarming in a disaster-prone nation where scientific literacy

How to Cite:
Wicaksono, A. G., Mustofa, M., & Amirullah, D. A. (2025). Profiling and Enhancing Scientific Literacy in Disaster Mitigation: The Effectiveness of the Discovery Learning Model for Elementary School Teacher Education Students. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 362–370. https://doi.org/10.29303/jppipa.v11i8.11064

directly impacts survival capabilities. This regression underscores an urgent need for pedagogical innovations that not only address conceptual understanding but also foster applied competencies in disaster mitigation contexts. As future educators, pre-service teachers, especially those in Elementary School Teacher Education, must possess a high level of scientific literacy to effectively teach and prepare their students for the challenges of the 21st century.

The 21st century presents science educators with a dual challenge: to build conceptual scientific knowledge while also nurturing learners' capabilities to apply that knowledge to real-life, often urgent, situations (Carney, 2022). One such situation is disaster mitigation, where individuals must comprehend natural phenomena, assess risks, and make informed decisions. In disaster-prone countries such as Indonesia, these competencies become not only desirable but necessary, particularly for future educators tasked with preparing students for such realities (Asrizal et al., 2023; Desilia et al., 2023)

Scientific literacy in this context is broadly defined as the capacity to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically (Lederman et al., 2023; Lestari et al., 2020; Osborne, 2023). According to (Friedrichsen et al., 2021), integrating real-world socio-scientific issues (SSI) into science learning significantly enhances students' engagement and their ability to reason critically and ethically. Disaster mitigation offers an ideal SSI context, where content knowledge, reasoning skills, and moral decision-making converge, providing an authentic platform to foster scientific literacy among pre-service teachers (Lederman et al., 2023; Saregar et al., 2025; Zeidler & Sadler, 2023).

Despite its recognized importance, numerous studies report that Indonesian students still struggle with transferring theoretical scientific understanding to practical contexts, including disaster-related ones (Da Silva & Helnywati, 2021; Dwiningrum et al., 2021). These gaps suggest that science education must evolve from traditional content-delivery models to active, context-rich approaches. One such model is discovery learning, which emphasizes active student engagement in constructing knowledge through problem-solving, experimentation, and reflection (Chusni et al., 2022; Karan, 2023; Styers et al., 2018).

The novelty of this research lies in its specific examination of discovery learning within disaster mitigation education an understudied intersection in teacher preparation programs. While discovery learning has been explored in general science education (Diana Vivanti Sigit et al., 2024; Ozdem-Yilmaz & Bilican, 2020; Saab et al., 2005), its targeted application to develop disaster-specific scientific literacy among pre-service teachers remains virtually unexamined. This study breaks new ground by: (1) implementing a disaster-themed discovery learning model specifically designed for teacher education, (2) measuring its impact on all three PISA scientific literacy competencies (identifying issues, explaining phenomena, and using evidence) within disaster contexts, and (3) addressing Indonesia's unique vulnerability to natural disasters through pedagogical innovation.

The research importance is threefold. First, it addresses a national priority by responding to Indonesia's declining scientific literacy and high disaster vulnerability simultaneously. Second, it offers a scalable model for integrating disaster education into teacher training programs a critical need identified but insufficiently addressed in current curricula (Desilia et al., 2023). Third, it provides empirical evidence on how discovery learning specifically enhances different dimensions of scientific literacy (Berliana et al., 2023; Karabulut et al., 2025)

One of the key challenges in improving scientific literacy is the lack of effective teaching models that engage students in active learning and critical thinking. Traditional teaching methods often fail to foster the deep understanding and application of scientific concepts required for scientific literacy. In response to this, the *discovery learning* model has emerged as a promising approach. *Discovery learning* is a student-centered instructional model that encourages learners to construct their own knowledge through exploration, experimentation, and problem-solving (Bruner, 1961, 1966, 2009). This model aligns with the principles of scientific inquiry, making it particularly suitable for enhancing scientific literacy.

Discovery learning aligns well with constructivist principles and scientific inquiry, but its implementation within disaster mitigation themes in teacher education is under-explored. It holds promise for not only improving conceptual understanding but also fostering the ability to use scientific evidence in complex, uncertain situations. Recent studies suggest that discovery-based models, when combined with situational contexts and inquiry elements, can elevate scientific literacy outcomes in both school and higher education settings (Friedrichsen et al., 2021; Jufri et al., 2019; Saputra et al., 2022)

The *discovery learning* model consists of six key steps: stimulation, problem statement, data collection, data processing, verification, and generalization (Arends, 2012). These steps encourage students to engage in active learning, where they are required to observe, analyze, and draw conclusions based on evidence. By integrating these steps into the curriculum, educators can create a learning environment that promotes critical thinking and scientific reasoning. Moreover, *discovery learning* has been shown to improve

students' ability to retain and transfer knowledge, making it an effective tool for enhancing scientific literacy (Saab et al., 2005).

In the context of disaster mitigation, scientific literacy is not only about understanding scientific concepts but also about applying this knowledge to real-world situations. Disaster mitigation literacy involves the ability to identify potential risks, understand the scientific principles behind natural disasters, and take appropriate actions to reduce their impact (Sung-Chin Chung & Cherng-Jyh Yen, 2016). For pre-service teachers, developing this type of literacy is crucial, as they will be responsible for educating future generations about disaster preparedness and response. Therefore, integrating *discovery learning* into the curriculum of Elementary School Teacher Education programs can help bridge the gap between theoretical knowledge and practical application.

Several studies have demonstrated the effectiveness of *discovery learning* in improving students' scientific literacy. For example, research by Fathurrohman & Astuti (2017) found that the use of science modules based on *discovery learning* significantly enhanced students' understanding of scientific concepts. Similarly, a study by Ulfa & Oktaviana (2021) showed that *discovery learning* improved students' ability to analyze and solve scientific problems. These findings suggest that *discovery learning* can be an effective strategy for enhancing scientific literacy, particularly in the context of disaster mitigation.

Despite the potential benefits of *discovery learning*, its implementation in Elementary School Teacher Education programs remains limited. Many pre-service teachers lack the necessary skills and knowledge to effectively apply this model in their teaching practices. This highlights the need for further research and development of instructional strategies that can support the integration of *discovery learning* into teacher education programs. By doing so, educators can better prepare pre-service teachers to foster scientific literacy among their students, particularly in the context of disaster mitigation.

Previous studies have established the effectiveness of discovery learning in general science education (Choirunnisa et al., 2024; Iskandar, 2025; Ulfa & Oktaviana, 2021) and highlighted the challenges Indonesian students face in applying scientific knowledge (Da Silva & Helnywati, 2021). However, none have specifically examined how structured discovery learning develops disaster mitigation competencies among future educators. This gap is particularly significant given that pre-service teachers must not only master scientific concepts but also learn to teach them in life-saving contexts.

Therefore, this study investigates the effectiveness of a tailored discovery learning model in enhancing three dimensions of scientific literacy within disaster mitigation contexts among elementary teacher education students. It addresses two critical gaps: (1) the lack of disaster-themed pedagogical models in teacher education, and (2) the need for nuanced understanding of how discovery learning specifically develops different scientific literacy competencies in high-risk environmental contexts.

The findings will contribute to both theoretical understanding of discovery learning in specialized contexts and practical applications for teacher education in disaster-prone regions, ultimately supporting the development of scientifically literate educators who can foster resilience in future generations.

Method

This study employed a mixed-methods research design with an explanatory sequential approach (Creswell, 2021). This design was chosen to allow for a thorough exploration of the research problem, as it enables the collection of both numerical data and in-depth insights. The quantitative phase, utilizing a pre-experimental design with a one-group pretest-posttest approach (Fraenkel et al., 2012), was conducted first to measure the intervention's effectiveness. This was followed by a qualitative phase to provide a deeper understanding and elaboration of the quantitative findings through thematic analysis of interview responses.

Time and Place of Research

The research was conducted during the 2024/2025 academic year at the Elementary School Teacher Education Program (PGSD) of Universitas Slamet Riyadi (UNISRI) in Surakarta, Indonesia. The study was integrated into the Basic Natural Sciences course, providing an authentic context for the intervention. The participants were 32 first-semester students enrolled in the aforementioned course. Participants were selected using purposive sampling (Sugiyono, 2013), as they were deemed suitable for the study due to their enrollment in a course that aligns directly with the research objectives and their scheduled exposure to foundational disaster mitigation topics within the curriculum.

Tools and Materials

The primary instrument for quantitative data collection was a scientific literacy test adapted from the Minimum Competency Assessment (AKM) for high school students (Direktorat Jenderal Pendidikan Tinggi, 2020), which has been validated and deemed reliable for

measuring scientific literacy. The test consisted of five two-tier multiple-choice questions designed to measure three core competencies based on the PISA framework: (1) identifying scientific questions or issues, (2) explaining scientific phenomena, and (3) using scientific evidence (Roberts & Bybee, 2014; Schleicher, 2019; Thomson et al., 2013). For qualitative data, a semi-structured interview guide was used to gather in-depth insights into students' experiences and perceptions of the discovery learning model. The learning materials included lesson plans, disaster mitigation case studies, data sets for analysis, and simulation scenarios tailored to the discovery learning stages.

Research Stages

The implementation of the research followed a structured sequence: (1) pretest: administered to measure students' baseline scientific literacy before the intervention; (2) intervention (implementation of discovery learning model): the treatment was carried out over several sessions using the six steps of the discovery learning model (Arends, 2012): stimulation (presenting disaster scenarios), problem statement (identifying key questions), data collection (gathering information from provided materials), data processing (analyzing and interpreting data), verification (comparing findings with scientific concepts), and generalization (formulating conclusions and applying knowledge to new mitigation contexts); (3) posttest: administered after the intervention to assess the impact on students' scientific literacy scores; and (4) interviews: Conducted following the quantitative analysis with a subset of participants to elaborate on the statistical findings and explore their learning experiences in depth.

Data Analysis

Quantitative data from the pretest and posttest were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics, specifically a paired sample t-test to determine the significance of the difference between scores. The effectiveness of the intervention was further measured by calculating the normalized gain (N-gain) score using Formula 1:

$$N - gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score} \quad (1)$$

The N-gain score was categorized as high (≥0.7), medium (0.3–0.7), or low (<0.3) based on established criteria (Hake, 2002). Qualitative data from transcripts were analyzed using thematic analysis (Braun & Clarke, 2006) to identify, analyze, and report recurring themes and patterns related to the students' experiences. The validity of the scientific literacy test was ensured through expert validation, where the instrument was reviewed by experts in science education and disaster mitigation. The reliability of the test was assessed using Cronbach's alpha, which yielded a value of 0,85, indicating high internal consistency (Field, 2024). The credibility of the qualitative data was ensured through triangulation, where findings from interviews were cross-checked with observational notes and test results to ensure consistency and trustworthiness (Creswell, 2021).

Result and Discussion

Profile of Students' Scientific Literacy in Disaster Mitigation Context

The pretest results revealed that the average scientific literacy score of Elementary School Teacher Education students in the context of disaster mitigation was 53,28, indicating a low level of scientific literacy. The scores for the three indicators of scientific literacy were as follows (see Table 1).

Table 1. The scores for indicators of scientific literacy

Indicators of scientific literacy	Average Score	Category
Identifying scientific questions or issues	52.50	Low
Explaining scientific phenomena	54.29	Low
Using scientific evidence	48.28	Low

Based on Table 1, it can be illustrated in Figure 1 as follows:

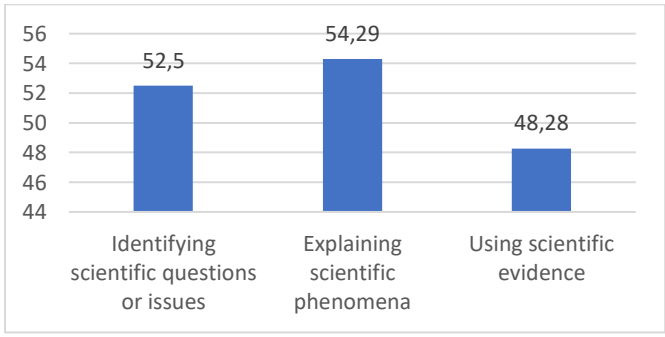

Figure 1. Graph of Students' Average Scientific Literacy Ability Scores

These results suggest that students found using scientific evidence the most challenging to support their conclusions, which aligns with previous findings that students often lack the ability to analyze and interpret data effectively (Erduran et al., 2004; Hadiprayitno et al., 2021).

The low pretest scores reflect the challenges faced by Indonesian students in developing scientific literacy, as evidenced by the declining PISA scores in recent years

(Hadiprayitno et al., 2022; Tohir, 2019). The students' difficulties in using scientific evidence suggests a gap in their ability to analyze and interpret data, which is a critical component of scientific literacy (Parmin & Khusniati, 2021; Rozi et al., 2025; Schleicher, 2019). This finding underscores the need for educational interventions that focus on enhancing students' ability to engage with scientific evidence and apply it to authentic contexts.

Effectiveness of the Discovery Learning Model

The posttest results showed a significant improvement in students' scientific literacy, with the average score increasing to 72,50. The paired sample t-test revealed a significant difference between the pretest and posttest scores ($t = -28,62$, $p < 0,05$), indicating that the discovery learning model positively impacted on students' scientific literacy. The N-gain score of 0,411 further confirmed that the intervention was moderately effective in enhancing students' scientific literacy (Hake, 2002).

The significant improvement in posttest scores demonstrates the effectiveness of the *discovery learning* model in enhancing students' scientific literacy. The model's emphasis on active learning, exploration, and problem-solving aligns with the principles of scientific inquiry, making it particularly suitable for fostering scientific literacy (Mashudi et al., 2024; Rosnidar et al., 2021). The moderate N-gain score (0,411) suggests that while the model was effective, there is still room for improvement, particularly in helping students master complex scientific concepts and apply them to disaster mitigation scenarios.

The six steps of the *discovery learning* model—stimulation, problem statement, data collection, data processing, verification, and generalization played a crucial role in improving students' scientific literacy. For example, during the data collection and processing stages, students were able to develop analytical skills by gathering and interpreting data related to disaster mitigation (Basyah et al., 2023; Gunada et al., 2020). Similarly, the verification and generalization stages helped students validate their findings and apply their knowledge to new situations, which are essential components of scientific literacy (Arends, 2012; Widiartini et al., 2025)

Qualitative Findings from Interviews

The qualitative data from interviews provided deeper insights into students' experiences with the discovery learning model. Students reported that the model helped them engage more actively in the learning process and develop critical thinking skills. However, some students expressed difficulties in connecting theoretical knowledge to real-world applications, particularly in understanding complex scientific concepts related to disaster mitigation. These findings are consistent with previous studies that highlight the challenges students face in applying scientific knowledge to practical situations (Vosniadou, 2019).

The qualitative findings highlight the challenges students face in connecting theoretical knowledge to practical applications. This is particularly evident in their difficulty understanding complex scientific concepts, such as the mechanisms of early warning systems for floods or the factors contributing to landslides. These challenges are consistent with previous research, which suggests that students often struggle with transferring knowledge from one context to another (Vosniadou, 2019). To address this, future implementations of the *discovery learning* model could incorporate more experiential learning activities and real-world case studies to facilitate students' transition from theory to practice.

The quantitative analysis showed facilitate students' transition from theory to practice a moderate yet statistically significant improvement in students' scientific literacy, aligning with global trends in active learning-based instruction. Similar studies by Sam (2024) dan Kotsis (2024) report that discovery-based and inquiry-based learning approaches increase students' conceptual clarity and evidence-based reasoning in science education, especially when paired with contextual themes like environmental hazards. In our study, the largest gains were observed in the domains of explaining scientific phenomena and using scientific evidence, suggesting that the iterative learning cycles within discovery learning foster deeper cognitive engagement.

However, the qualitative data indicate that the translation of theory into practice remains a significant challenge. Students often reported difficulty applying their understanding of disaster mechanisms such as tectonic shifts or flood dynamics to decision-making scenarios like risk mapping or community preparedness planning. This finding resonates with the observations of van Merriënboer (2023), who assert that conceptual understanding must be supported by cognitive scaffolds and real-world simulations for effective knowledge transfer to occur.

Emerging pedagogical frameworks propose the integration of discovery learning with digital simulations or experiential community projects to close the theory-practice divide. For instance, studies by Wiese et al. (2021) dan Khanal et al. (2022) demonstrate that the use of virtual disaster labs and role-play activities in teacher education significantly enhance pre-service teachers' disaster response skills and their ability to evaluate scientific information critically. These approaches encourage the application of knowledge in

uncertain, complex environments one of the core aims of scientific literacy.

Moreover, it is essential to recognize the role of metacognition in facilitating meaningful discovery learning. Students who actively plan, monitor, and evaluate their own learning are better equipped to adapt scientific reasoning in unfamiliar contexts (Nusantari et al., 2021). Integrating metacognitive prompts into each phase of discovery learning may further enhance students' scientific reasoning and resilience, particularly in relation to disaster readiness.

In summary, while the discovery learning model demonstrated positive outcomes in improving scientific literacy among pre-service teachers, its effectiveness could be significantly amplified by integrating simulation technologies, metacognitive supports, and authentic case studies. Future studies should explore longitudinal impacts and scalability in diverse settings. Furthermore, curriculum developers should consider embedding these innovations within national teacher training frameworks to cultivate scientifically literate educators capable of addressing Indonesia's unique disaster education needs.

Conclusion

This study conclusively demonstrates that the discovery learning model is an effective pedagogical strategy for enhancing the scientific literacy of elementary school teacher education students, particularly within the context of disaster mitigation. The quantitative findings revealed a moderate yet significant improvement in overall scientific literacy, with the normalized gain (N-gain) score of 0,411. Notably, the most substantial gains were observed in the competencies of *explaining scientific phenomena* and *using scientific evidence*, underscoring the model's strength in fostering deeper cognitive engagement and evidence-based reasoning. However, the study also identified persistent challenges, particularly in students' ability to translate theoretical knowledge into practical applications, such as designing disaster mitigation plans or interpreting early warning systems. This indicates a need for more scaffolded, experiential learning components within the discovery learning framework. Generalization of these findings suggests that the discovery learning model is a adaptable and effective approach for improving scientific literacy in teacher education programs, especially in disaster-prone regions like Indonesia. Its structured, inquiry-based phases—stimulation, data processing, verification, and generalization—provide a replicable framework that can be contextualized to various socio-scientific themes. Practical implications of this research include 1) the integration of simulation-based learning or virtual disaster scenarios to bridge the theory-practice gap; 2) the need for metacognitive strategies and real-world case studies to support knowledge transfer; and 3) the adoption of discovery learning in national teacher training curricula to build a generation of educators capable of fostering disaster-resilient communities. For future research, it is recommended to explore the longitudinal effects of this model, its scalability across different educational levels and regions, and its integration with digital tools for more immersive learning experiences. By addressing these areas, educator preparation programs can more effectively cultivate scientifically literate teachers who are equipped to navigate and teach about complex, real-world challenges.

Acknowledgments

We extend our sincere gratitude to all individuals and institutions who contributed to the successful completion of this research. First, we acknowledge the financial support provided by Universitas Slamet Riyadi Surakarta through the 2024 University Research Grant, which enabled the implementation of this study. This research would not have been possible without the institutional support of Universitas Slamet Riyadi's Research and Community Service Institute (LPPM), which provided the necessary infrastructure and administrative assistance.

Author Contributions

Conceptualization, A.G.W. and M.M.; methodology, A.G.W. and D.A.A.; validation, A.G.W., M.M., and D.A.A.; formal analysis, A.G.W.; investigation, A.G.W. and M.M.; resources, A.G.W.; data curation, A.G.W. and D.A.A.; writing—original draft preparation, A.G.W.; writing—review and editing, M.M. and D.A.A.; visualization, A.G.W.; supervision, M.M.; project administration, A.G.W.; funding acquisition, A.G.W. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by Universitas Slamet Riyadi Surakarta through the 2024 University Research Grant. The Article Processing Charge (APC) was covered by the Universitas Slamet Riyadi's Research and Community Service Institute (LPPM), as part of its institutional support for high-quality publications.

Conflicts of Interest

The author's interest in publishing this article is for the purpose of research output in the form of publication in a scientific journal as evidence of required performance. There is no conflict of interest.

References

Arends, R. (2012). *Learning to Teach*. McGraw-Hil.

Asrizal, A., Hikmah, N., Febriya, D., & Mawaddah, F. (2023). Impact of Science Learning Materials

Integrating Natural Disasters and Disaster Mitigation on Students' Learning Outcomes: A Meta Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 586–595. https://doi.org/10.29303/jppipa.v9i9.2680

Basyah, N. A., Syukri, M., Fahmi, I., Ali, I., Rusli, Z., & Putri, E. S. (2023). Disaster Prevention and Management: A Critical Review of The Literature. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1045–1051. https://doi.org/10.29303/jppipa.v9i11.4486

Berliana, G. Y., Sugiyanto, S., & Fardhani, I. (2023). Student's Learning Outcomes and Scientific Literacy Improvement Through the Implementation of Reading to Learn and Discovery Learning Models. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2563–2572. https://doi.org/10.29303/jppipa.v9i5.2573

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bruner, J. S. (1961). The Act of Discovery. *Harvard Educational Review, 31*, 21–32.

Bruner, J. S. (1966). *Toward a Theory of Instruction*. The President and Fellows of Harvard College.

Bruner, J. S. (2009). *The Process of Education*. Harvard University Press.

Carney, S. (2022). Reimagining our futures together: a new social contract for education. *Comparative Education*, *58*(4), 568–569. https://doi.org/10.1080/03050068.2022.2102326

Choirunnisa, S. A., Suad, S., & Sumaji, S. (2024). The Difference and Effectiveness of the Discovery Learning and Direct Learning Model on the Science Learning Outcomes. *ASEANA: Science and Education Journal*, *4*, 16–20. https://doi.org/10.53797/aseana.v4i1.3.2024

Chusni, M. M., Saputro, S., & Rahardjo, S. B. (2022). Enhancing critical thinking skills of junior high school students through discovery-based multiple representations learning model. *International Journal of Instruction*, *15*(1), 927–945.

Creswell, J. W. (2021). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research, eBook, global edition*. Pearson Education, Limited.

Da Silva, A. M., & Helnywati, H. (2021). A Cross-Disciplinary Project-Based Learning to Raise Indonesian Students' Awareness of Natural Disasters. *International Journal of Education*, *14*(1), 1–10. https://doi.org/10.17509/ije.v14i1.25102

Desilia, N. R., Lassa, J., & Oktari, R. S. (2023). Integrating Disaster Education into School Curriculum in Indonesia: A Scoping Review. *International Journal of Disaster Management*, *6*(2), 263–274. https://doi.org/10.24815/ijdm.v6i2.34867

Diana Vivanti Sigit, Tsania Arrumaisha, & Rizhal Hendi Ristanto. (2024). Enhancing Critical Thinking: Integrating Guided Discovery Learning and Concept Mapping (GDL-CM) in Climate Change Concept. *Jurnal Pendidikan IPA Indonesia*, *13*(4). https://doi.org/10.15294/f3t8yf33

Direktorat Jenderal Pendidikan Tinggi. (2020). *Buku Panduan Merdeka Belajar-Kampus Merdeka*. Direktorat Jenderal Pendidikan Tinggi Kemdikbud RI.

Dwiningrum, S. I. A., Sumunar, D. R. S., Haryanto, Sitompul, N., Setyawan, S. L. H. P., Sholekhah, E., Aswasulasikin, & Nahdi, K. (2021). Student Knowledge about Disaster in Vocational School and High School: Case study in Lombok, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *630*(1), 012020. https://doi.org/10.1088/1755-1315/630/1/012020

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education*, *88*(6), 915–933. https://doi.org/10.1002/sce.20012

Fathurrohman, M. A., & Astuti, R. K. (2017). Pengembangan modul fisika dasar I berbasis literasi sains. *PSEJ (Pancasakti Science Education Journal)*, *2*(2), 163–171.

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage publications limited.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education*.

Friedrichsen, P. J., Ke, L., Sadler, T. D., & Zangori, L. (2021). Enacting Co-Designed Socio-Scientific Issues-Based Curriculum Units: A Case of Secondary Science Teacher Learning. *Journal of Science Teacher Education*, *32*(1), 85–106. https://doi.org/10.1080/1046560X.2020.1795576

Gunada, I. W., Ayub, S., Doyan, A., Taufik, M., & Kosim, K. (2020). Development of Disaster Mitigation Learning Structures. *Jurnal Penelitian Pendidikan IPA*, *6*(1), 69–74. https://doi.org/10.29303/jppipa.v6i1.324

Hadiprayitno, G., Kusmiyati, K., Lestari, A., Lukitasari, M., & Sukri, A. (2021). Blended Learning Station-Rotation Model: Does it Impact on Preservice Teachers' Scientific Literacy? *Jurnal Penelitian Pendidikan IPA*, *7*(3), 317–324. https://doi.org/10.29303/jppipa.v7i3.676

Hadiprayitno, G., Lestari, N., Kusmiyati, K., Sukri, A., & Irawan, J. (2022). Analysis on Students Problem-Solving Skill and Scientific Literacy Based on Higher Order Thinking Skills (HOTS) Viewed from Gender. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2508–2512. https://doi.org/10.29303/jppipa.v8i5.2287

Hake, R. R. (2002). Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on Mathematics and Spatial Visualization. *Physics Education Research Conference*, *8*(August 2002), 1–14. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=10EI2q8AAAAJ&citation_for_view=10EI2q8AAAAJ:IjCSPb-OGe4C

Hartono, H., Indra Putri, R. I., Inderawati, R., & Ariska, M. (2022). The strategy of Science Learning in Curriculum 2013 to Increase the Value of Science's Program for International Student Assessment (PISA). *Jurnal Penelitian Pendidikan IPA*, *8*(1), 79–85. https://doi.org/10.29303/jppipa.v8i1.1185

Haviz, M., Nasrul, E., Azis, D., Maris, I. M., & Wahyudi, F. (2024). The Use of Socio-Scientific Issues to Promote Prospective Biology Teachers' Scientific Literacy and Research Skill Development. *Jurnal Pendidikan IPA Indonesia*, *13*(2). https://doi.org/10.15294/v7kbh850

Iskandar, S. (2025). Analysis of Effectiveness of Discovery Learning Model in Science Learning Activities for Basic Students. *Jurnal Pijar Mipa*, *20*(2), 246–250. https://doi.org/10.29303/jpm.v20i2.8548

Jufri, A. W., Ramdani, A., Jamaluddin, J., & Azizah, A. (2019). Development of Scientific Literacy and Pedagogical Content Knowledge (PCK) of Prospective Science Teachers through Lesson Study-Based Courses. *Jurnal Penelitian Pendidikan IPA*, *5*(2), 179–184. https://doi.org/10.29303/jppipa.v5i2.235

Karabulut, H., Gökçe, H., & Kariper, İ. A. (2025). Implementation of discovery learning-based STEM education with hands-on activities in distance education. *Innovations in Education and Teaching International*, *62*(2), 594–611. https://doi.org/10.1080/14703297.2024.2327833

Karan, E. (2023). Discovery-Based Approach Combined with Active Learning to Improve Student Learning Experiences for STEM Students. *Journal of Education and Training Studies*, *11*(4), 16. https://doi.org/10.11114/jets.v11i4.6205

Khanal, S., Medasetti, U. S., Mashal, M., Savage, B., & Khadka, R. (2022). Virtual and Augmented Reality in the Disaster Management Technology: A Literature Review of the Past 11 years. *Frontiers in Virtual Reality*, *3*, 843195. https://doi.org/10.3389/frvir.2022.843195

Kotsis, K. T. (2024). Significance of Experiments in Inquiry-based Science Teaching. *European Journal of Education and Pedagogy*, *5*(2), 86–92. https://doi.org/10.24018/ejedu.2024.5.2.815

Lederman, N. G., Zeidler, D. L., & Lederman, J. S. (2023). *Handbook of Research on Science Education*. Routledge. https://doi.org/10.4324/9780367855758

Lestari, H., Setiawan, W., & Siskandar, R. (2020). Science Literacy Ability of Elementary Students Through Nature of Science-based Learning with the Utilization of the Ministry of Education and Culture's "Learning House." *Jurnal Penelitian Pendidikan IPA*, *6*(2), 215–220. https://doi.org/10.29303/jppipa.v6i2.410

Mashudi, M., Raharjo, T. J., & Kusmawan, U. (2024). Development of a Science Learning Module using the Guided Discovery Method to Increase Learning Independence and Scientific Literacy Ability. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 982–987. https://doi.org/10.29303/jppipa.v10i2.6244

Nusantari, E., Abdul, A., Damopolii, I., Alghafri, A. S. R., & Bakkar, B. S. (2021). Combination of Discovery Learning and Metacognitive Knowledge Strategy to Enhance Students' Critical Thinking Skills. *European Journal of Educational Research*, *volume-10-*(volume-10-issue-4-october-2021), 1781–1791. https://doi.org/10.12973/eu-jer.10.4.1781

Osborne, J. (2023). Science, scientific literacy, and science education. In *Handbook of research on science education* (pp. 785–816). Routledge.

Ozdem-Yilmaz, Y., & Bilican, K. (2020). *Discovery Learning – Jerome Bruner* (pp. 177–190). https://doi.org/10.1007/978-3-030-43620-9_13

Parmin, P., & Khusniati, M. (2021). The readiness of pre-service integrated science teachers toward the next generation science standards. *Jurnal Cakrawala Pendidikan*, *40*(3), 713–724. https://doi.org/10.21831/cp.v40i3.37001

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In *Handbook of research on science education, Volume II* (pp. 559–572). Routledge.

Rosnidar, R., Yusrizal, Y., Mustafa, M., & Susanna, S. (2021). Application of Discovery Learning Model in Increasing Student Interest and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 542–548. https://doi.org/10.29303/jppipa.v7i4.745

Rozi, F., Yusnadi, Suyanti, R. D., & Ansya, Y. A. (2025). Culturally Responsive Teaching as a Strategy to Improve Students' Science Literacy in Higher Education. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 58–67. https://doi.org/10.29303/jppipa.v11i6.11268

Saab, N., Van Joolingen, W. R., & Van Hout-Wolters, B. H. a. M. (2005). Communication in collaborative discovery learning. *British Journal of Educational Psychology*, *75*(4), 603–621. https://doi.org/10.1348/000709905X42905

Sam, R. (2024). Systematic review of inquiry-based learning: assessing impact and best practices in education. *F1000Research*, *13*, 1045.

https://doi.org/10.12688/f1000research.155367.1

Saputra, I. G. P. E., Sukariasih, L., Nursalam, L. O., & Desa, S. S. (2022). The Effect of Scientific Literacy Approach with Discovery Learning Model toward Physics Concepts Understanding. *Jurnal Pendidikan Fisika*, *10*(2), 144–153. https://doi.org/10.26618/jpf.v10i2.7769

Saregar, A., Putra, F. G., Diani, R., Anugrah, A., Misbah, M., & Umam, R. (2025). Innovative Integrated Disaster Education in Physics Learning: An Effort to Enhance Students' Disaster Literacy Skills. *Jurnal Pendidikan IPA Indonesia*, *14*(2). https://doi.org/10.15294/jpii.v14i2.23959

Schleicher, A. (2019). PISA 2018: Insights and Interpretations. *OECD Publishing*.

Styers, M. L., Van Zandt, P. A., & Hayden, K. L. (2018). Active Learning in Flipped Life Science Courses Promotes Development of Critical Thinking Skills. *CBE—Life Sciences Education*, *17*(3), ar39. https://doi.org/10.1187/cbe.16-11-0332

Sugiyono. (2013). *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D*. Alfabeta.

Sung-Chin Chung, & Cherng-Jyh Yen. (2016). Disaster Prevention Literacy among School Administrators and Teachers: A Study on the Plan for Disaster Prevention and Campus Network Deployment and Experiment in Taiwan. *Journal of Life Sciences*, *10*(4). https://doi.org/10.17265/1934-7391/2016.04.006

Susongko, P., Abdul Wahab, N. B., Arfiani, Y., & Kusuma, M. (2024). Validation and Implementation of 3-Dimensional Scientific Literacy Test (Lisa3D Test): Measuring Scientific Literacy for Senior High School Students based on Scientific Reasoning, Scientific Inquiry, and Nature of Science. *Jurnal Pendidikan IPA Indonesia*, *13*(3). https://doi.org/10.15294/591rx526

Thomson, S., De Bortoli, L., & Buckley, S. (2013). *PISA 2012: How Australia measures up: The PISA 2012 assessment of students' mathematical, scientific and reading literacy*. Australian Council for Educational Research (ACER).

Tohir, M. (2019). *Hasil PISA Indonesia Tahun 2018 Turun Dibanding Tahun 2015*. OSF Preprints. https://doi.org/10.31219/osf.io/pcjvx

Ulfa, M., & Oktaviana, E. (2021). Peningkatan Kemampuan Berliterasi melalui Model Discovery Learning Berbantuan Media Pohon Literasi. *Jurnal Basicedu*, *5*(6), 5204–5212. https://doi.org/10.31004/basicedu.v5i6.1549

van Merriënboer, J. (2023). *Learning in Simulated and Real Environments*. Maastricht University. https://doi.org/10.26481/spe.20230330jm

Vosniadou, S. (2019). The Development of Students' Understanding of Science. *Frontiers in Education*, *4*. https://doi.org/10.3389/feduc.2019.00032

Widiartini, K. L., Artawan, P., & Tika, I. N. (2025). Pengaruh Model Pembelajaran Discovery Learning Berbasis Tri Kaya Parisudha Terhadap Literasi Sains dan Hasil Belajar IPA Pada Siswa SMP. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 198–205. https://doi.org/10.29303/jppipa.v11i7.11517

Wiese, L. K., Love, T., & Goodman, R. (2021). Responding to a simulated disaster in the virtual or live classroom: Is there a difference in BSN student learning? *Nurse Education in Practice*, *55*, 103170. https://doi.org/10.1016/j.nepr.2021.103170

Zeidler, D. L., & Sadler, T. D. (2023). Exploring and expanding the frontiers of socioscientific issues. In *Handbook of research on science education* (pp. 899–929). Routledge.