

Development of a Deep-AI Learning Model to Improve Generation Z's Scientific Literacy through a Deep Learning Approach and AI Integration

Indrawati Wilujeng^{1*}, Trise Nurul Ain¹, Adhy Putri Rilianti², and Faiz Hasyim¹

¹Physics Education, STKIP Al Hikmah Surabaya, Surabaya, Indonesia

²Primary School Teacher Education, STKIP Al Hikmah Surabaya, Surabaya, Indonesia

*indrawati.physics@gmail.com

Article Info	Abstract
Article history: Received: September 22, 2025 Accepted: November 12, 2025 Published: November 13, 2025 Keywords: Artificial intelligence Deep-learning Generation Z Learning model Scientific literacy This article is licensed under a creative commons attribution-share alike 4.0 international license © 2025 Jurnal ilmiah Pendidikan Fisika	Scientific literacy is a key competency needed in the era of Smart Society 5.0. However, studies indicate that the scientific literacy of Generation Z remains low. This can be attributed to the implementation of learning models that are less relevant to the characteristics of their generation, commonly referred to as digital natives. Furthermore, an approach that can make in-depth learning meaningful yet enjoyable is also needed. One possible alternative is to develop an AI-based learning model using a deep learning approach. This study aims to develop a valid and practical Deep-AI learning model to improve the scientific literacy of Generation Z. The method used was research and development (R&D) with a model developed by Borg and Gall (limited to step seven). The model was validated by three education experts and tested on a limited sample of 25 Generation Z students. The results of the study stated that a) the Deep-AI model is valid based on an average validation score of 3.69, which is categorized as very valid, and b) the Deep-AI model is practical based on the average observation result of model implementation of 3.68, which is categorized as very good. Therefore, it can be concluded that Deep-AI is valid and practical. This model can serve as an alternative learning approach aimed at enhancing the scientific literacy skills of Generation Z students.
To cite this article: Wilujeng, I., Ain, T. N., Rilianti, A. P., & Hasyim, F. (2025). Development of a deep-ai learning model to improve generation z's scientific literacy through a deep learning approach and ai integration. <i>Jurnal Ilmiah Pendidikan Fisika</i>, 9(3), 461-471.	

INTRODUCTION

The era of Smart Society 5.0 is characterized by technological sophistication, the complexity of problems, and the need for innovation and creativity (Wilujeng et al., 2025). The strategy to face this era is through smart education (Dimitrova et al., 2024). Smart education encourages learners to form new knowledge through the mastery of technology skills in searching, analyzing, and innovating (Badshah et al., 2023; Shakhina et al., 2023; Zeeshan et al., 2022). The human's ability to understand, evaluate, and use knowledge and technology is known as scientific literacy (Fuadi et al., 2020; Li & Guo, 2021; Sjöström, 2025). According to Bybee, a person's level of science literacy is divided into four levels. They are nominal, conceptual, functional, and multidimensional (Kahar et al., 2021).

On the other hand, SDG 4, a global agenda, also emphasizes the importance of quality education. One of its targets is to ensure that every individual masters literacy and numeracy (McCullough et al., 2022). Scientific literacy is one of the skills that must be mastered by Generation Z in order to remain competitive in the era of Smart Society 5.0 (Ichsan et al., 2023; Suryanti et al., 2021; Yusmar & Fadilah, 2023). Generation Z is the generation born between 1997-2012. Especially with the presence of AI, Generation Z is

increasingly expected to be skilled in utilizing knowledge and technology ([Rajwaa & Mukti, 2025](#)). Currently, Indonesia is also preparing the vision of Golden Indonesia 2045. At that time, the productive-age workforce will be dominated by Generation Z ([Moeins et al., 2024](#)). Therefore, it is very important for them to have quality education and qualified scientific literacy. Generation Z also plays an important role in realizing the SDGs, including SDG 4 ([Sukeni et al., 2023](#)).

However, the study's results actually showed that the scientific literacy of Indonesia's Generation Z remains low. Based on the research results of [Yudha et al. \(2023\)](#), it was found that the scientific literacy skills of class XI students were in the adequate category. Based on the research result of [Saraswati et al. \(2021\)](#), the scientific literacy ability was ≤ 75 . Based on PISA data from 2018, Indonesian students' scientific literacy skills did not improve between 2000 and 2018, with the country remaining ranked 69th out of 77 countries. Meanwhile, in 2019, students' scientific literacy skills had not improved and were ranked in the bottom 9 out of 77 countries ([Lestari et al., 2024](#)). University students, as the most educated people, should have a better level of scientific literacy ([Berlian et al., 2021](#)). However, based on the research of [Nurdianti Muhajir et al. \(2021\)](#) and [Syahmani et al. \(2024\)](#), it was known that 76.9% of students' scientific literacy was actually in the lowest category, which was nominal. This is concerning, as individuals with low literacy skills are likely to encounter difficulties in processing and understanding scientific information ([Yang et al., 2024](#)).

Scientific literacy has eight indicators that have different levels of difficulty ([Rusmansyah et al., 2023](#); [Sholikah & Pertiwi, 2021](#)). The first indicator, at the lowest level, is actually the one most owned by Generation Z ([Sholahuddin et al., 2021](#)). The low level of scientific literacy among Generation Z may be due to learning models that are less relevant to their characteristics. Generation Z refers to individuals born between 1997 and 2012 ([Zis et al., 2021](#)). Since birth, they have been interacting with digital technology; thus, they are often referred to as digital natives ([Hastini et al., 2020](#)). Education has an important role in enhancing their quality in facing the Smart Society 5.0 era ([Kahar et al., 2021](#)). It is necessary to develop a new learning model in order to maximize their potential. According to [Jihannita et al. \(2024\)](#), classroom learning can improve scientific literacy. One alternative is to develop a Deep-AI learning model through a deep learning approach and the integration of artificial intelligence (AI).

The deep learning approach utilizes collaboration between students to discover and master certain materials, thereby forming new knowledge ([Akhyar, 2024](#); [Diputera et al., 2024](#); [Fitriani & Santiani, 2025](#)). This approach consists of three pillars: meaningful, mindful, and joyful learning ([Wijaya et al., 2025](#)). To facilitate Generation Z's character as digital natives, digital technology needs to be integrated into learning models. One digital technology currently developing rapidly is AI. Generation Z has grown up alongside the development of AI, making it necessary to expand students' interactions with this technology, as various future job fields will utilize AI extensively ([Sanusi et al., 2022](#)). In addition, AI can also provide meaningful learning experiences ([Chetry, 2024](#); [Turmuzi, 2025](#); [Xu, 2024](#)). Technology also plays an important role in supporting the success of the deep learning approach ([Suwandi et al., 2024](#)). Therefore, it is important to develop a Deep-AI learning model that combines the deep learning approach and AI integration to improve the scientific literacy of Generation Z. The research is also expected to contribute to the realization of SDG 4 and the ideals of Golden Indonesia 2045.

Based on the above explanation, this study aims to develop a valid and practical Deep-AI learning model to improve the scientific literacy of Generation Z. The problem-solving approach used was to develop an innovative learning model combining deep learning and AI integration, and then test its validity and practicality. The state of the art in this research

can be demonstrated through previous studies that developed innovative learning models to improve scientific literacy. Some of these include guided discovery ([Merta et al., 2020](#)), blended learning ([Lestari & Siskandar, 2020](#)), and PBL ([Aiman & Ahmad, 2020](#)). However, none of these models utilize a deep learning approach and/or integrate AI. Existing learning models are also not specifically developed for Generation Z. Therefore, there are at least two novelties in this research. They are an integration of AI into a learning model adapted to the deep learning approach and Generation Z, who are the main subjects of this study.

METHODS

The purpose of this research is to develop a Deep-AI learning model to improve the scientific literacy of Generation Z; thus, the research method used was research and development (R&D). The selected development model was the one developed by Borg and Gall ([Gustiani, 2019](#); [Borg & Gall, 1983](#)). The research flow for model development is shown in Figure 1.

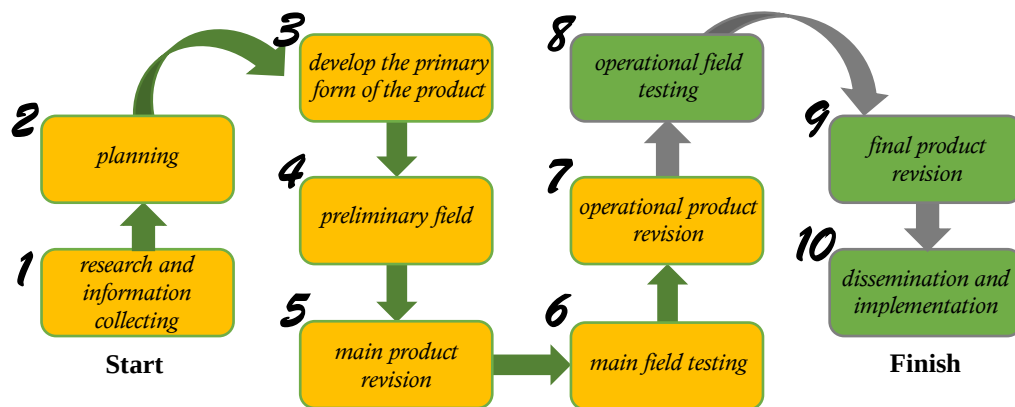


Figure 1 Research flow diagram

The research subjects involved were physics education students from Generation Z. The trial was limited to 25 students. The research subjects were selected using a purposive sampling technique based on their low scientific literacy skills. The determination of low scientific literacy skills was based on the students' scientific literacy profiles after an initial assessment.

The pre-research instruments used were lecturer interview sheets and student questionnaires. The interview sheets included several criteria, such as understanding students' scientific literacy conditions, the implementation of the deep learning approach, the integration of AI in learning, and the needs and expectations for the model to be developed. Meanwhile, the student questionnaire included the following criteria: students' learning profiles, initial scientific literacy, experience with the deep learning approach, utilization and perception of AI, as well as the needs and expectations for the model to be developed. The research instruments used were review sheets, validation sheets, and observation sheets. The review sheets and validation sheets were used to examine and validate the model books, lesson plans, teaching materials, scientific literacy skill test, and student response questionnaire. Each of them was reviewed and validated based on its content and construction aspects.

The required data includes lecturer interviews, student questionnaires, model review results, model validation results, and model implementation observation results. The

lecturer's interview and student questionnaire data constitute pre-research data used to identify the problem. The model review, model validation results, and model implementation observation results constitute the research data. Data collection techniques included interviews, questionnaires, and observations. The data analysis technique used was qualitative descriptive analysis for the interview and review results, while quantitative descriptive analysis was used for the validation, questionnaire, and observation data.

The validation sheet was used to determine the validity of the developed learning model. The validator's assessments were then tabulated and averaged. The results were then compared with the validity criteria in Table 1. A learning model is considered valid if it receives an average score from the validator of ≥ 2.75 (Ratumanan & Laurens, 2011).

Table 1 Validity criteria

Score Interval	Assessment Criteria	Information
$3.30 \leq V < 4.00$	Very Valid	Can be used without modification
$2.30 \leq V < 3.30$	Valid	Can be used with minor changes
$1.80 \leq V < 2.30$	Invalid	Can be used for multiple modifications
$1.00 \leq V < 1.80$	Completely Invalid	Cannot be used, as it requires more repair

Adapted from Hariadi et al. (2021)

The model implementation observation sheet was used to evaluate the model's practicality. Two observers conducted observations. The scores given by the observers were then averaged and compared against the practicality criteria in Table 2. A learning model is considered practical for use if it falls into the very good category.

Table 2 Criteria for evaluating the practicality of the learning model

Score Interval	Assessment Criteria
$3.30 \leq V < 4.00$	Very Good
$2.30 \leq V < 3.30$	Good
$1.80 \leq V < 2.30$	Pretty Good
$1.00 \leq V < 1.80$	Bad

Adapted from Hariadi et al., (2021)

The research procedure, according to the Borg and Gall development model, consists of 10 stages, as shown in the research flowchart (Figure 1). However, in this study, only seven steps were implemented, as testing was limited. This was conducted because the main focus of this study is on development and initial validation. Therefore, it has not yet proceeded to the stages of large-scale trials and dissemination, which require a broader implementation scale. The seven stages are explained in more detail as follows.

1st Stage: **research and information collecting**

At this stage, problem identification was carried out through two methods: reference studies and field studies. Reference studies were conducted through a review of previous research results relevant to this study. Meanwhile, field studies were conducted through interviews and questionnaires on research subjects. The output of this stage was data and information that were used as the basis for the problem statement.

2nd Stage: **planning**

At this stage, the Deep-AI learning model design was planned based on the problem base that had been obtained. The output of this stage was the Deep-AI learning model design.

3rd Stage: **develop the primary form of the product**

At this stage, the Deep-AI learning model and its components were developed. The output of this stage was referred to as draft I, which consisted of a model book, learning tools, teaching materials, scientific literacy test instruments, and student response questionnaires.

4th Stage: **preliminary field**

At this stage, construct validation was conducted on draft I. The validators involved in this stage consisted of three experts in the field of education. The output of this stage was the results of the review and validation provided by the validators.

5th Stage: **main product revision**

At this stage, the learning model was revised based on the results of the review and validation in the previous stage. The output of this stage was referred to as draft II.

6th Stage: **main field testing**

At this stage, a limited trial was conducted on draft II involving 25 students. The output of this stage was observation data from the model's implementation.

7th Stage: **operational product revision**

At this stage, revisions were made to draft II based on the results of the student questionnaire responses. The output of this stage was referred to as a valid and practical model.

RESULTS AND DISCUSSION

Learning Model Design

The developed learning model is referred to as the Deep-AI learning model. The syntax of the Deep-AI model consists of six phases, as shown in Table 3.

Table 3 Syntax of deep-AI learning model

Phase	Phase Name	Description
1	Activate	Students activate initial knowledge through prompting questions, contextual problems, or AI simulations.
2	Explore	Students are required to search, explore, and analyze information through scientific sources by utilizing AI.
3	Interpret	Students process information, create conceptual representations, and test understanding through collaborative discussions.
4	Create	Students produce science-based solutions or products by utilizing AI for design or analysis.
5	Share	Students present their works to the public, both in person and digitally.
6	Reflect	Students reflect on the learning process and results, assess strengths and weaknesses, and then develop improvement strategies.

The three pillars of the deep learning approach ([Wijaya et al., 2025](#)) are embedded within the six phases. The meaningful pillar is shown in the explore and interpret phases. The mindful pillar is demonstrated in the reflect phase, while the joyful pillar is represented in the create and share phases.

Learning Model Development

The development of its tools naturally accompanies the development of a learning model. The Deep-AI model tools consist of a model book, teaching materials, and learning materials (lesson plans, scientific literacy test instruments, and student response questionnaires). The cover of the tools is shown in Figure 2.

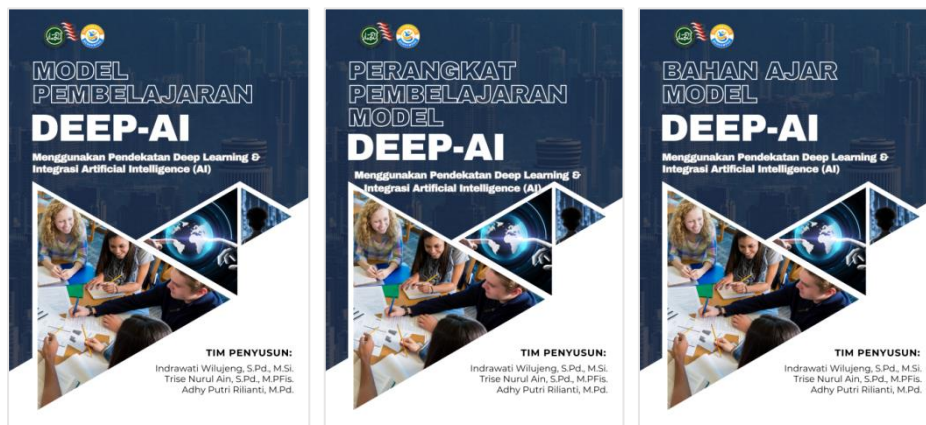


Figure 2 Deep-AI learning model toolkit

The primary differences between this developed deep-learning model and other deep-learning models lie in its significant use of AI, the targeting of Generation Z as the primary audience, and the emphasis on scientific literacy as the learning outcome.

Learning Model Validity

Three education experts validated the Deep-AI learning model. Model validation consisted of two aspects: content and construct. The content aspect included an assessment of model development needs, current knowledge, theoretical support, model planning and implementation, and the model's learning environment. The construct aspect included an assessment of the model's rationality, theoretical and empirical data support, model syntax, social system, reaction principles, support system, instructional and accompanying impacts, learning environment, and model evaluation. The validation results provided by the three validators are shown in Table 4.

Table 4 Deep-AI learning model validation results

Aspect	Validator Score			Average	Criteria
	Expert 1	Expert 2	Expert 3		
Content	3.67	3.72	3.62	3.67	Very Valid
Construct	3.71	3.70	3.72	3.71	Very Valid
Average	3.69	3.71	3.67	3.69	Very Valid

The average content and construct validation score for the Deep-AI learning model was 3.69 (Very Valid). Based on these results, it can be stated that the developed learning model is valid and can be used for further testing. While valid, the validation score is not perfect. Several suggestions are still needed, including the addition of several key references, limitations on the use of AI in the model, and further elaboration on several sections.

Model Practicality

The practicality of a model can be determined by how well it is implemented in the classroom. A model implementation observation sheet was used to determine the practicality of the developed model. The assessment aspects observed were the phases of the Deep-AI model, including activate, explore, interpret, create, share, and reflect. All phases are complete in two meetings. Table 5 shows the results of observations conducted by two observers during the implementation of the Deep-AI model.

Table 5 Results of learning observations using the Deep-AI model

No.	Model Deep-AI Phase	Observer Score		Average	Category
		Observer 1	Observer 2		
1.	Activate	3.45	3.55	3.50	Very Good
2.	Explore	3.72	3.67	3.70	Very Good
3.	Interpret	3.67	3.80	3.74	Very Good
4.	Create	3.88	3.70	3.79	Very Good
5.	Share	3.68	3.78	3.73	Very Good
6.	Reflect	3.57	3.65	3.61	Very Good
Average		3.67	3.69	3.68	Very Good

Based on Table 5 above, the average observation result for all phases obtained by both observers was 3.68, categorized as very good. This indicates that the lecturer successfully implemented the learning in accordance with the learning tools that had been prepared and aligned with the phases of the Deep-AI model. Therefore, the Deep-AI model is practical. The highest practicality score was found in the "create" phase. This indicates that in this phase, Generation Z's learning experiences can be effectively facilitated, as stated by [Chetry \(2024\)](#) and [Xu \(2024\)](#), who noted that the use of AI provides meaningful learning experiences.

CONCLUSION

The developed Deep-AI learning model has met the valid and practical criteria. The Deep-AI model is declared valid based on the average model validity of 3.69, categorized as very valid. The Deep-AI model is declared practical based on the average observation of the model's implementation in learning, which is 3.68, categorized as very good. This model can be used as an alternative learning model to improve the scientific literacy skills of Generation Z. The limitation of this study is that it has not yet depicted the effectiveness of the implementation of the Deep-AI model in increasing the scientific literacy of Generation Z. Therefore, the recommendation for further research is to examine the effectiveness.

CONFLICTS OF INTEREST

There is no conflict of interest in this research and its publications.

AUTHOR CONTRIBUTIONS STATEMENT

Organize all the work, IW; Compilation of Model Tools, TNA; Validation Implementation, ADP.; and Publication, FH.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for funding this research through the Regular Fundamental Research scheme under the Directorate of Research, Technology, and Community Service (DRTPM) with SP DIPA-139.04.1.693320/2025 (Revision 4, April 30, 2025).

REFERENCES

- Aiman, U., & Ahmad, R. (2020). Model pembelajaran berbasis masalah (pbl) terhadap literasi sains siswa kelas v sekolah dasar. *Jurnal Pendidikan Dasar Flobamorata*, 1(1), 1–5. <https://doi.org/10.51494/jpdf.v1i1.195>
- Akhyar, D. Al. (2024). Membentuk karakter peserta didik dengan pendekatan deep learning. *GHIROH, Jurnal Ilmiah Pendidikan Agama Islam*, 3(2), 173–179.
- Badshah, A., Ghani, A., Daud, A., Jalal, A., Bilal, M., & Crowcroft, J. (2023). Towards

- smart education through internet of things: A survey. *ACM Computing Surveys*, 56(2), 1–33.
- Berlian, M., Muhtahid, I. M., Vebrianto, R., & Thahir, M. (2021). Profil literasi sains dalam pembelajaran ipa di era covid-19: Studi kasus di universitas terbuka. *Journal of Natural Science and Integration*, 4(1), 77–84. <https://doi.org/10.24014/jnsi.v4i1.11662>
- Borg, W. R. & Gall, M. D. (1983). *Educational research: An introduction*, 4th edition. Longman Inc.
- Chetry, D. K. K. (2024). Transforming education: How AI is revolutionizing the learning experience. *International Journal of Research Publication and Reviews*, 5(5), 6352–6356. <https://doi.org/10.55248/gengpi.5.0524.1277>
- Dimitrova, V., Nikolov, N., & Gospodinov, T. (2024). Education in the era of smart cities: Transformation and opportunities. *Environment. Technology. Resources. Rezekne, Latvia Proceedings of the 15th International Scientific and Practical Conference*, 2, 352–357. <https://doi.org/10.17770/etr2024vol2.8084>
- Diputera, A. M., Zulpan, & Eza, G. N. (2024). Memahami konsep pendekatan deep learning dalam pembelajaran anak usia dini yang meaningful, mindful, dan joyful: kajian melalui filsafat pendidikan. *Jurnal Bunga Rampai Usia Emas*, 10(2), 108–120. <https://doi.org/10.24114/jbrue.v10i2.65978>
- Fitriani, A., & Santiani, S. (2025). Analisis literatur: Pembelajaran deep learning dalam pendidikan. *Jurnal Ilmiah Nusantara (JINU)*, 2(3), 50–57. <https://doi.org/10.61722/jinu.v2i3.4357>
- Fuadi, H., Robbia, A. Z., Jamaluddin, J., & Jufri, A. W. (2020). Analisis faktor penyebab rendahnya kemampuan literasi sains peserta didik. *Jurnal Ilmiah Profesi Pendidikan*, 5(2), 108–116. <https://doi.org/10.29303/jipp.v5i2.122>
- Gustiani, S. (2019). Research and development (R&D) method as a model design in educational research and its alternatives. *Holistics Journal*, 11(2), 12–22.
- Hariadi, B., Sunarto, M. J. D., Sagirani, T., Amelia, T., & Lemantara, J. (2021). Higher order thinking skills for improved learning outcomes among indonesian students : A blended web mobile learning (BWML) model. *International Journal of Interactive Mobile Technologies*, 15(7), 4–16.
- Hastini, L. Y., Fahmi, R., & Lukito, H. (2020). Apakah pembelajaran menggunakan teknologi dapat meningkatkan literasi manusia pada generasi z di indonesia? *Jurnal Manajemen Informatika (JAMIKA)*, 10(1), 12–28. <https://doi.org/10.34010/jamika.v10i1>
- Ichsan, I., Suharyat, Y., Santosa, T. A., & Satria, E. (2023). Effectiveness of STEM-Based learning in teaching 21 st century skills in generation z student in science learning: A meta-analysis. *Jurnal Penelitian Pendidikan IPA*, 9(1), 150–166. <https://doi.org/10.29303/jppipa.v9i1.2517>
- Jihannita, J., Fadly, W., Ekapti, R. F., Luthfiana, D., & Widowati, A. (2024). The Development of science module integrated with ethnoscience of singo barong mask to improve scientific literacy and cultural preservation attitudes. *Journal of Innovation in Educational and Cultural Research*, 5(2), 356–363. <https://doi.org/10.46843/jiecr.v5i2.790>
- Kahar, M. I., Cika, H., Nur Afni, & Nur Eka Wahyuningsih. (2021). Pendidikan era revolusi industri 4.0 menuju era society 5.0 di masa pandemi covid 19. *Moderasi: Jurnal Studi Ilmu Pengetahuan Sosial*, 2(1), 58–78. <https://doi.org/10.24239/moderasi.vol2.iss1.40>
- Lestari, D. P., Paidi, P., & Suwarjo, S. (2024). Effect of the inquiry-based nature of science argumentation instructional model in scientific literacy skills. *Journal of Education and Learning*, 18(3), 734–744. <https://doi.org/10.11591/edulearn.v18i3.21024>

- Lestari, H., & Siskandar, R. (2020). Literasi sains siswa melalui penerapan model pembelajaran blended learning dengan blog. *Naturalistic : Jurnal Kajian Penelitian Pendidikan Dan Pembelajaran*, 4(2b), 597–604. <https://doi.org/10.35568/naturalistic.v4i2b.769>
- Li, Y., & Guo, M. (2021). Scientific literacy in communicating science and socio-scientific issues: prospects and challenges. *Frontiers in Psychology*, 12(November), 1–15. <https://doi.org/10.3389/fpsyg.2021.758000>
- McCullough, B. P., Kellison, T., & Melton, E. N. (2022). The routledge handbook of sport and sustainable development. In *Routledge Taylor and Francis Group*. <https://doi.org/10.4324/9781003023968>
- Merta, I. W., Artayasa, I. P., Kusmiyati, Lestari, N., & Setiadi, D. (2020). Profil literasi sains dan model pembelajaran dapat meningkatkan kemampuan literasi sains. *Jurnal Pijar Mipa*, 15(3), 223–228. <https://doi.org/10.29303/jpm.v15i3.1889>
- Moeins, A., Alhemp, R., Goenawan, D., & Lukas, A. (2024). *Strategi penguatan kinerja generasi z dalam menghadapi indonesia emas 2045*. Takaza Innovatix Labs.
- Nurdianti Muhajir, S., Rahmalia Lestari, P., & Sri Rahayu, N. (2021). tingkatan literasi sains mahasiswa calon guru fisika. *Jurnal Pendidikan Universitas Garut*, 15(1), 378–384.
- Rajwaa, D. N. E., & Mukti, W. A. H. (2025). Inovasi pembelajaran ipa berbasis kecerdasan buatan: meningkatkan literasi sains di sekolah. *Jurnal Studi Ilmiah*, 1(1), 1–6.
- Ratumanan, G. T., & Laurens. (2011). *Evaluasi hasil belajar tingkat satuan pendidikan*. Unesa University Press.
- Rusmansyah, R., Leny, L., & Sofia, H. N. (2023). Improving students' scientific literacy and cognitive learning outcomes through ethnoscience-based pjbl model. *Journal of Innovation in Educational and Cultural Research*, 4(1), 1–9. <https://doi.org/10.46843/jiecr.v4i1.382>
- Sanusi, I. T., Olaleye, S. A., Agbo, F. J., & Chiu, T. K. F. (2022). The role of learners' competencies in artificial intelligence education. *Computers and Education : Artificial Intelligence*, 3(100098), 1–10.
- Saraswati, Y., Sifak Indana, & Elok Sudibyo. (2021). Science literacy profile of junior high school students based on knowledge, competence, cognitive, and context aspects. *IJORER : International Journal of Recent Educational Research*, 2(3), 329–341. <https://doi.org/10.46245/ijorer.v2i3.118>
- Shakhina, I., Podzygun, O., Petrova, A., & Gordiichuk, G. (2023). Smart education in the transformation digital society. *Modern Information Technologies and Innovation Methodologies of Education in Professional Training Methodology Theory Experience Problems*, 67(1), 51–64. <https://doi.org/10.31652/2412-1142-2023-67-51-64>
- Sholahuddin, A., Hayati, N., Rilia Iriani, Saadi, P., & Susilowati, E. (2021). Project-based learning on ethnoscience setting to improve students' scientific literacy. *The 4th International Conference on Mathematics and Science Education (ICoMSE) 2020*, 1–8.
- Sholikah, L., & Novika, P. F. (2021). Analysis of science literacy ability of junior high school students based on programme for international student assesment (PISA). *INSECTA Integrative Science Education and Teaching Activity Journal*, 2(1), 95–104.
- Sjöström, J. (2025). Vision iii of scientific literacy and science education: An alternative vision for science education emphasising the ethico-socio-political and relational-existential. *Studies in Science Education*, 61(2), 239–274. <https://doi.org/10.1080/03057267.2024.2405229>
- Sukeni, K., Anynussyawiby, & Anggul, G. (2023). Peran generasi z dalam mendukung sustainable development goals melalui pengembangan ekonom hijau menuju indonesia

- emas 2045. *Prosiding Pekan Ilmiah Pelajar (PIJAR)*, 156–163.
- Suryanti, S., Widodo, W., & Yermiandhoko, Y. (2021). Gadget-based interactive multimedia on socio-scientific issues to improve elementary students' scientific literacy. *International Journal of Interactive Mobile Technologies*, 15(1), 56–69. <https://doi.org/10.3991/IJIM.V15I01.13675>
- Suwandi, S., Putri, R., & Sulastri, S. (2024). Inovasi pendidikan dengan menggunakan model deep learning di indonesia. *Jurnal Pendidikan Kewarganegaraan Dan Politik (JPKP)*, 2(2), 69–77.
- Syahmani, S., Iriani, R., Kusasi, M., Prasetyo, Y. D., Norhasanah, H., & Rahman, F. A. (2024). Culturally wetland responsive teaching to improve science literacy and wasaka character. *Journal of Innovation in Educational and Cultural Research*, 5(2), 196–206. <https://doi.org/10.46843/jiecr.v5i2.1075>
- Turmuzi, A. (2025). Pendekatan deep learning untuk menciptakan pengalaman belajar yang bermakna. *Journal Scientific of Mandalika*, 6(7), 1711–1719.
- Wijaya, A. A., Haryati, T., & Wuryandini, E. (2025). Implementasi pendekatan deep learning dalam peningkatan kualitas pembelajaran di sdn 1 wulung, randublatung, blora. *Indonesian Research Journal on Education*, 5(1), 451–457.
- Wilujeng, I., Ain, T. N., Rilianti, A. P., Hasyim, F., & Fiqiyah, M. (2025). The effectiveness of h5p-assisted differentiated-independent learning model to increase low-ability students' scientific literacy. *Jurnal Pendidikan IPA Indonesia*, 14(1), 32–41.
- Xu, Z. (2024). AI in education: Enhancing learning experiences and student outcomes. *Applied and Computational Engineering*, 51(1), 104–111. <https://doi.org/10.54254/2755-2721/51/20241187>
- Yang, S., Brossard, D., Li, N., & Barolo, L. (2024). Bridging gaps in covid-19 vaccine knowledge : Effects of multimodal narratives on message elaboration and recall across science literacy levels. *Clinical Epidemiology and Global Health*, 28(101681), 1–7. <https://doi.org/10.1016/j.cegh.2024.101681>
- Yudha, S., Simorangkir, M., & Nurfajriani, N. (2023). Analysis of science literacy of xi class students in buffer solution materials. *Journal of Learning Improvement and Lesson Study*, 3(2), 1–6. <https://doi.org/10.24036/jlils.v3i2.46>
- Yusmar, F., & Fadilah, R. E. (2023). Analisis rendahnya literasi sains peserta didik indonesia: Hasil pisa dan faktor penyebab. *LENZA (Lentera Sains): Jurnal Pendidikan IPA*, 13(1), 11–19. <https://doi.org/10.24929/lenza.v13i1.283>
- Zeeshan, K., Hämmäläinen, T., & Neittaanmäki, P. (2022). Internet of things for sustainable smart education: An overview. *Sustainability (Switzerland)*, 14(7), 1–15. <https://doi.org/10.3390/su14074293>
- Zis, S. F., Effendi, N., & Roem, E. R. (2021). Perubahan perilaku komunikasi generasi milenial dan generasi z di era digital. *Satwika : Kajian Ilmu Budaya Dan Perubahan Sosial*, 5(1), 69–87. <https://doi.org/10.22219/satwika.v5i1.15550>

AUTHOR PROFILES



Indrawati Wilujeng   received M.Si. degree in physics from Institut Teknologi Sepuluh Nopember. She is a lecturer in Physics Education Study Program in STKIP Al Hikmah Surabaya since 2015 up to now. She is teaching and doing research in physics education. Her current research interests include teacher education and digital learning media. She can be contacted at: indrawati.physics@hikmahuniversity.ac.id



Trise Nurul Ain   received M.P.Fis degree in physics teaching master from Institut Teknologi Bandung. She teaches college students from 2015 up to now. Her current research is focused on physics learning media. Her publication topics are about physics learning, physics learning media, and teacher competences. She can be contacted at: risenurulain@hikmahuniversity.ac.id



Adhy Putri Rilianti  received M. Pd. degree in primary education from the State University of Yogyakarta. She was an elementary teacher for about six years. Then, she teaches college students from 2018 up to now. Her current research interests include science learning and student development. Her publication topics are about science learning in elementary school, teacher competences, and student development. She can be contacted at: adhyputrir@hikmahuniversity.ac.id.



Faiz Hasyim   received Dr. degree in science education from Universitas Negeri Surabaya. He is a lecturer in the Physics Education Study Program in STKIP Al Hikmah Surabaya since 2015 up to now. His current research interests are physics education and high order thinking skills. His research topics are critical thinking skills, innovation in education and bibliometric. He can be contacted at: faiz@hikmahuniversity.ac.id.