



Integration of Deep Learning Approach and EMKONTAN Model to Improve Environmental Literacy, Creativity, and Collaboration of Students

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Abstract

This study aimed to conduct a need analysis for integrating the Deep Learning approach (meaningful–mindful–joyful) into the Ecomapping and Sustainable Conservation (EMKONTAN) learning model (DL-EMKONTAN) in an Environmental Science course. Using a qualitative descriptive design, data were collected from 10 lecturers and 230 students through questionnaires, observations, document review, and semi-structured interviews. Descriptive statistics and Miles–Huberman analysis were applied. The result indicated that students' competencies remain at a moderate level. Creative thinking skills were mostly at beginner levels; collaboration was moderate for productivity, respect, and compromise but weaker for responsibility; and environmental literacy was “enough” for ecological knowledge, sensitivity, and issue research yet lower for issuing analysis and pro-environmental behavior. Lecturers reported learning is still dominated by lectures and paper-based tasks, with limited assessment of creativity, collaboration, and environmental literacy. The proposed DL-EMKONTAN learning syntax consists of observing problems, analyzing, planning, implementing, monitoring/evaluating, and follow-up planning.

Keywords: Collaboration skills; deep learning; EMKONTAN; environmental literacy; needs analysis

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INTRODUCTION

Environmental problems are becoming increasingly complex, widespread, and difficult to resolve (Nguyen et al., 2023; Young & Stokke, 2020). These problems include of pollution, deforestation, global warming, and climate change. Higher education institutions play a strategic role in addressing these issues (Abina et al., 2023). However, learning at higher education institutions remain less than optimal in instilling environmental literacy in students (Kurniawan et al., 2024). Research shows that students' environmental literacy levels, including environmental competence, knowledge, attitudes, environmental behavior and responsibility, are in the moderate-to-good category (Irawati et al., 2024; Nasution, 2021). This situation calls for innovative learning efforts.

Several studies have shown that resolving environmental problems requires strong environmental literacy (Putri et al., 2023). Environmental literacy, defined as an individual's ability to understand, interpret, and act, is a crucial factor in ensuring environmental balance (Kaya & Elster, 2019). This environmental literacy encompasses not only environmental knowledge but also skills in analyzing environmental problems, as

well as responsible attitudes and behaviors (Afifah et al., 2024). However, experts also believe that literacy cannot be optimal without the support of critical thinking and collaboration skills (Husamah et al., 2025). This is because environmental problems are complex and cannot be solved solely from a single field of study or perspective.

Both of these supporting factors for environmental literacy are still at a level that requires improvement. For example, regarding critical thinking skills, researchers found that nearly all indicators, from interpreting to explaining data, were at a medium level (Magaji, 2021). This situation affects students' ability to understand problems, develop ideas, and formulate appropriate solutions (Cheng, 2019). Such skills involve imagination, innovation, and the ability to identify new relationships among existing elements (Bentz & O'Brien, 2019; Meitayani et al., 2022).

On the other hand, students' collaboration skills have developed significantly over the past 10 years (Arwidiyarti et al., 2022; Barnett & Francis, 2023). Several studies have shown that students' collaborative skills are considered good to excellent on a class basis (Alfaeni et al., 2022; Fitriana, 2023). However, collaboration, which involves sharpening ideas through discussion (Palmgren-Neuvonen et al., 2021), sharing resources (Davidsen et al., 2020; Tiantong & Teemuangsai, 2013), and other structured efforts, contributes to problem-solving (Graesser et al., 2019). This indicates that collaboration needs to be facilitated through learning designs that encourage active interaction, collective reflection, and joint problem-solving, especially in the context of environmental issues (Eskiyurt & Özkan, 2024).

Efforts to improve environmental literacy among students in Indonesia have been linked to improvements in the quality of learning (Hudha et al., 2021). An analysis of environmental science course syllabic shows that almost all stills predominantly use conventional methods, a combination of lectures, discussions, and assignments. As a result, students feel bored and lack the challenge of learning to solve environmental problems (Ørngreen et al., 2021). To strengthen the role of higher education in solving environmental problems, more challenging and stimulating learning approaches and models are needed. One promising approach is Deep Learning (DL), which emphasizes meaningful understanding, mindful engagement, and joyful learning. In environmental learning, DL has the potential to improve environmental literacy because it encourages students to understand concepts more deeply, relate them to real environmental conditions, reflect critically on environmental issues, and develop responsible decisions and actions (Safira & Astuti, 2025).

However, DL mainly serves as a pedagogical orientation. Therefore, DL needs to be integrated with a more contextual and applicable learning model. In this study, EMKONTAN was chosen because it provides a structured framework that engages students with real environmental problems, facilitates investigation and discussion, promotes collaborative solution-building, and helps transform abstract environmental concepts into meaningful learning experiences (Nurwidodo et al., 2023, 2021; Nurwidodo & Hindun, 2024). In other words, DL provides the learning orientation, while EMKONTAN functions as the practical strategy to actualize that orientation in environmental science learning.

Previous studies have generally discussed collaboration skills, environmental literacy, and innovative learning approaches separately. However, limited studies have specifically examined the integration of DL and EMKONTAN to improve students' environmental literacy and collaboration skills in environmental science courses. This gap forms the basis for the present study.

As an approach, deep learning contains components of meaningful, mindful, and joyful learning (Sliwka et al., 2024). This approach emphasizes in-depth conceptual

understanding and mastery of competencies, rather than simply memorizing material (Maas et al., 2018). The government, through recent policies, has encouraged the strengthening of deep learning as a foundation for designing and improving the quality of learning that emphasizes not only concepts but also sustainable applications (Kemendikdasmen, 2025; KemenPan-RB, 2025). This approach encourages students to actively engage in the learning process, think critically, and connect concepts to everyday life. As an approach, deep learning offers the potential to be integrated into any learning model, including EMKONTAN.

On the other hand, the EMKONTAN learning model is an innovative learning model that emphasizes learning with environmental issues (Nurwidodo et al., 2021; Nurwidodo & Hindun, 2024). This model integrates six steps of scientific thinking, starting from environmental observation, problem identification and analysis, preparation of action plans, monitoring, evaluation, and follow-up. The EMKONTAN model is dedicated to improving environmental literacy, critical thinking skills, and collaboration skills. However, although environmental-based learning models have been widely recognized as important for promoting active and contextual learning, studies that specifically integrates the deep learning approach with such models in higher education remain limited. Existing studies have more often examined innovative learning models or deep learning principles separately, rather than exploring how both can be systematically combined in environmental science learning to address complex sustainability-related problems. As a result, there is still a lack of empirical and conceptual understanding of how the deep learning approach can strengthen the implementation of environmental-based learning models at the university level.

Therefore, this study aims to integrate the deep learning approach with EMKONTAN as a way to improve environmental literacy, critical thinking skills, and collaboration skills in students.

METHODS

This study employed descriptive mixed-methods design, with qualitative data as the primary source and quantitative descriptive data as supporting evidence. Data collection instruments included questionnaires, observations, document analysis, and interviews. The data sources were ten lecturers teaching environmental science as a profession and 230 students from private universities in Malang-East Java. Questionnaires were administered to the lecturers to identify their needs for developing the DL-EMKONTAN Integrated learning model. Furthermore, students were also given questionnaires to obtain data on their needs for the same learning model.

A purposive sampling technique was used to select participants for this study. This method was chosen because it allowed for the selection of individuals who met specific criteria related to the objectives of the research. Specifically, the participants included lecturers who taught environmental science courses and students who had engaged in environmental science learning. The lecturer sample met the following criteria: (1) actively teaching environmental science-related courses, and (2) having experience in planning or implementing environmental learning. The student sample met the criteria of: (1) being enrolled in environmental science learning, and (2) having prior experience participating in classroom learning activities relevant to environmental issues. This technique was considered appropriate because not all lecturers and students had direct experience relevant to the development needs of the DL-EMKONTAN integrated learning model.

Data were collected through a survey using a questionnaire. The questionnaire was used to gather lecturers' and students' perceptions regarding the need for the developed learning model. The questionnaire indicators covered several aspects, including: (1) the need for a more meaningful and engaging environmental science learning process; (2) the need for a learning model that supports environmental literacy; (3) the need for a learning model that facilitates collaboration skills; (4) the relevance of integrating Deep Learning principles into environmental science learning; and (5) the need for a contextual and problem-solving-oriented learning model such as EMKONTAN. The data obtained from the questionnaire were analyzed and then summarized in tabular form.

Before being administered, the questionnaire was reviewed by experts to ensure content validity in terms of relevance, clarity, and suitability with the research objectives. In addition, the internal consistency of the questionnaire was examined to ensure the reliability of the instrument. Furthermore, semi-structured interviews were used to obtain and strengthen information about the learning model students needed. Interviews were used to uncover issues more openly by soliciting respondents' opinions and ideas (Owusu et al., 2023). Observations and document analysis were also used to complement the questionnaire and interview data, particularly to identify the existing characteristics of environmental science learning and the need for integrating DL and EMKONTAN in classroom practice.

The quantitative data obtained from the questionnaires were analyzed using descriptive statistics, such as percentages and frequencies, to describe respondents' needs and perceptions toward the DL-EMKONTAN integrated learning model. Meanwhile, the qualitative data obtained from interviews, observations, and document analysis were analyzed using Miles and Huberman's interactive model, which consists of data collection, data reduction, data display, and conclusion drawing (Miles et al., 2014). In the data reduction stage, the researchers selected, coded, and categorized relevant information related to the need for the DL-EMKONTAN integrated learning model. In the data display stage, the reduced qualitative data were organized narratives and in table form to facilitate interpretation. Finally, conclusions were drawn by identifying recurring patterns, relationships, and major themes across the questionnaire, interview, observation, and document data.

RESULTS & DISCUSSION

Results

The needs analysis stage was conducted to validate gaps, namely identifying students' creative thinking skills, collaboration skills, and environmental literacy in environmental science lectures, identifying learning model needs, confirming target, identifying current lecture implementation, and developing product development plans. The results of the identification of students' creative thinking skills, collaborative skills and environmental literacy are presented in Table 1.

Table 1 shows that students' creative thinking, collaboration skills, and environmental literacy were generally in the moderate category, with percentage scores ranging from 51.43% to 55.97%. These findings indicate that students have not yet reached a high level of competency in the measured aspects, particularly in responsibility and environmental behavior, which obtained the lowest percentages. Therefore, these skills still need to be improved in environmental science lectures. In addition to the gap data, the results of interviews regarding the environmental science lecture process with IPL lecturers

were reported as follows; (1) lecturers use conventional learning methods such as lectures, questions and answers (discussions), and assignments (writing papers and presentations); (2) no measurement has been carried out on students' creative thinking skills; (3) no observation has been carried out on students' collaborative skills; and (4) no measurement has been carried out on students' environmental literacy (Nurwidodo et al., 2020).

Table 1. Student Competencies

No	Variables	Aspects	Percentage (%)	Category
1	Creative Thinking	Curiosity	54.65	Moderate
		Fluency of thought	53.76	Moderate
		Originality of thinking	55.97	Moderate
		Elaboration	52.21	Moderate
		Flexibility of thinking	52.88	Moderate
		Divergent thinking	54.42	Moderate
2	Skills Collaboration	Work productively	55.71	Moderate
		Show respect	54.29	Moderate
		Compromise	55.71	Moderate
		Responsibility	51.43	Moderate
3	Environmental Literacy	Ecological knowledge	55.71	Moderate
		Environmental sensitivity	54.29	Moderate
		Issue research	55.71	Moderate
		Issue analysis	53.47	Moderate
		Environmental behavior	51.43	Moderate

The results of interviews with IPL lecturers and the results of learning observations, students tend to learn individually. In addition, information was also obtained that during environmental science lectures, students work in a worksheet which is only an answering questions activity. In other hand, students need more interesting activities, such as direct observation, learning outside the classroom, or doing practicums. Moreover, students need experience in solving environmental problems collaboratively with their peers. This situation illustrates the performance gaps between student competency profiles and the learning process (Vallée, 2023).

Table 2. Results of confirmation of learning by lecturers

No	Confirmation Aspects	Percentage (%)	
		Agree	Disagree
1	Preparing lesson design	98	2
2	Determining learning outcomes	88	12
3	Providing learning materials	95	5
4	Student activity sheet	15	85
5	Instructional media	15	85
6	Evaluation	95	5
7	Need to develop new learning models	82	18
8	Interested in the DL-EMKONTAN integration model	85	15
9	Intend to implement the DL-EMKONTAN integration model	85	15

Analysis of the lecturers as research subjects showed that the majority of environmental learning preparations were well-executed. Several fundamental aspects were identified, including determining learning objectives, preparing lesson designs, and providing relevant teaching materials. From a learning perspective, learning quality can be

seen from how the design is implemented. Banihashem et al (2022), in their research, stated that fostering student engagement in learning requires sound learning to plan. One way to achieve this is by determining the extent to which students have mastered concepts after the learning process (Siva & Ershadi, 2025). Furthermore, deeper and more sustainable goals can be achieved through transformational learning to plan carried out by teachers, taking into account student characteristics (Rubilar, 2025). However, Table 2 also shows that the learning activities and media used were not optimally implemented. This indicates a gap between good planning and actual learning implementation, although the majority of subjects agreed that a relevant learning model is one based on inquiry-based reinforcement (Figure 1).

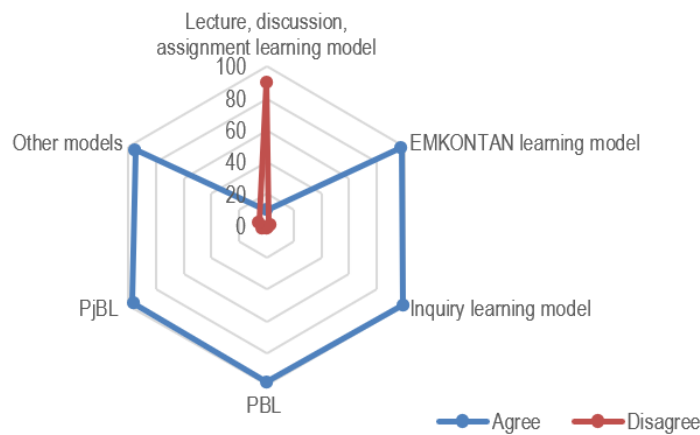


Figure 1. Gap Between Planning and Implementation: Support for Inquiry-Based Learning Model

The measurement of seventeen key aspects of learning for lesson planning (Table 3) shows that respondents strongly favored student-centered and constructivist learning over teacher-driven approaches. The findings also indicate that problem-based and project-based learning are considered essential in environmental learning because they connect conceptual understanding with practical implementation. In addition, most respondents agreed that such learning should remain meaningful, mindful, and enjoyable for students. Overall, the results suggest that integrating student-centered learning models focused on environmental problem analysis can support the development of environmental literacy, critical thinking, and collaboration skills.

Table 3. Learning model requirements

No	Learning Crucial Aspects	Percentage (%)	
		Agree	Disagree
1	Teacher-Centered Learning (TCL) oriented, conventional	12	88
2	Orientation on Student-Centered Learning (SCL) or Student Active Learning (SAL)	87	13
3	Behaviorist	12	88
4	Constructivist	87	13
5	Transformative understanding	55	45
6	Having syntax (learning steps)	15	85
7	Has a nurturing impact	15	85
8	Problem-based	95	5
9	The integration model fulfills the requirements to enable students to learn meaningfully (meaningful)	82	18
10	The integration model fulfills the requirements to enable students to learn in a truly conscious (mindful)	85	15

No	Learning Crucial Aspects	Percentage (%)	
		Agree	Disagree
11	The integration model fulfills the requirements to enable students to learn in a joyful	85	15
12	The model integrates the deep learning approach at each step in the EMKONTAN syntax	87	13
13	The model has the flexibility to be applied to all topics in environmental science and/or ecology content	55	45
14	Models can improve students' environmental literacy	15	85
15	Models can improve students' creative thinking skills	15	85
16	Models can improve students' collaboration skills	95	5
17	The model is assumed to be able to build student competency as the main actors in solving environmental problems.	88	12

Discussion

The integration of the deep learning approach and the EMKONTAN model begins with identifying relevant learning syntax and activities. The planned syntax refers to inquiry learning as the basis of EMKONTAN and includes six stages: (1) observation of environmental problems, (2) analysis and identification of problems, (3) preparation of action plans, (4) implementation of action plans, (5) monitoring and evaluation, and (6) preparation of follow-up plans. This syntax has the potential to improve students' environmental literacy because it engages them in a structured sequence of learning experiences, from recognizing environmental issues to taking reflective follow-up action. Environmental literacy involves not only understanding environmental concepts, but also identifying problems, analyzing causes and consequences, evaluating solutions, and demonstrating responsible action (Mazar et al., 2026; Yildirim et al., 2025). In this regard, each stage of DL-EMKONTAN contributes systematically to the development of environmental literacy.

From the perspective of constructivist learning, the DL-EMKONTAN syntax positions students as active constructors of knowledge rather than passive recipients of information. Students are encouraged to observe environmental phenomena, formulate problems, develop predictions, gather evidence, and construct meaning through discussion and project activities. This is consistent with constructivist principles emphasizing that knowledge is built through experience, social interaction, and reflection (Wiyono et al., 2025). The syntax is also closely related to problem-based learning because it begins with authentic environmental problems relevant to students' surroundings and guides them through analysis, planning, implementation, and evaluation of solutions. Such a problem-oriented structure supports higher-order thinking, decision-making, and collaborative problem-solving. In relation to environmental education theory, the DL-EMKONTAN syntax reflects its core goals, namely developing environmental knowledge, awareness, positive attitudes, problem-solving skills, and participation in responsible action. Therefore, the model supports environmental literacy not only as knowledge acquisition, but also as the development of critical awareness and sustainable action competence.

In practice, DL-EMKONTAN learning begins with observing environmental issues around students, making learning highly contextual and dependent on the socio-scientific issues surrounding the school. If students have difficulty identifying such issues, teachers need to provide guidance by orienting the problem and relating it to students' lives or prior learning experiences. Students are then given space to analyze the problem deeply before formulating solutions, because appropriate action requires comprehensive

understanding. At this stage, teachers provide gradual and flexible assistance, for example by helping students study facts, make predictions, and identify causes. The results of this analysis become the basis for preparing action plans. In the next step, students formulate measurable solutions, consider how they will be implemented, and determine how their success will be evaluated, including relevant follow-up actions (Elendu et al., 2024). Thus, the DL-EMKONTAN syntax can be understood as a coherent pedagogical framework that combines constructivist learning, problem-based learning, and environmental education principles in higher education environmental science learning.

So, how does the value of deep learning to emerge in this integration? To answer this, teachers need to ensure that the first and second of DL-EMKONTAN that the issues discussed in the lesson are truly relevant to students (Marcinauskas et al., 2024; Santos et al., 2023). If this is achieved, the meaningful aspect can be achieved. For example, if a teacher in Malang wants to raise the issue of flooding, they don't need to stimulate and teach students about flooding in Semarang because the characteristics of flooding in the two areas are different. Flooding in Malang is often caused by land conversion and garbage accumulation in waterways, while flooding in Semarang is often caused by rising sea levels. This decision isn't about right or wrong, but rather about the meaningfulness of the concept being learned.

On the other hand, if the meaningful aspect is achieved, it's easier for teachers to stimulate students in more depth into a concept and problem simultaneously (Brady et al., 2021). Students will find it easier to conduct analysis, identification, and other scientific activities because they are confronted with the problem. Several experts agree that these activities can increase students' active participation and focus (Solé et al., 2020). Mindfulness can also develop in the activities of designing solutions and preparing assessment instruments. Students are faced with situations requiring them to find the best solutions. If this can be done effectively, it is certain that students' full awareness has developed integrally in DL-EMKONTAN learning (Sunderman, 2025). Furthermore, students can realize that the achievement of this learning is not merely cognitive achievement but also how beneficial the resulting solutions are in solving the problems they face.

Psychological perspective that when someone can make a real contribution to a process that impacts the wider community, a sense of personal joy emerges (Traini et al., 2025). Some researchers believe that this joyfulness can be assessed not only at the end of the learning process but also throughout the learning process, namely by how students explore a problem, formulate solutions, and take action. Furthermore, collaborative activities can also stimulate a sense of joy. However, at the same time, they also face paradoxical conditions. In this situation, teacher assistance is needed to bridge any potential problems that arise from student communication, such as by ensuring group heterogeneity. Some experts believe that heterogeneity within a group, if managed well, can foster student responsibility based on the strengths and characteristics of each individual so that their presence within the group community becomes an impactful presence.

This study implies that environmental learning in higher education should move beyond content delivery toward a contextual, problem-based, and action-oriented process. The DL-EMKONTAN model provides a practical framework for helping lecturers develop students' environmental literacy, critical thinking, and collaboration through meaningful, mindful, and joyful learning. More importantly, this integration strengthens the role of higher education in preparing students not only to understand environmental issues, but also to respond to them through responsible and sustainable action.

CONCLUSION

This study found that students' environmental literacy, creative thinking, and collaboration skills were still not optimal, while environmental science learning was still dominated by conventional methods. These findings indicate the need for a more innovative and student-centered learning model. In response to this need, this study proposes the DL-EMKONTAN model, which integrates deep learning with environmental-based learning through six main steps: observation of environmental problems, problem identification and analysis, action planning, action implementation, monitoring and evaluation, and follow-up planning. This model provides a relevant framework for supporting more active, contextual, and sustainability-oriented learning in higher education.

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REFERENCES

- Abina, A., Cestnik, B., Kovačič Lukman, R., Zavernik, S., Ogrinc, M., & Zidanšek, A. (2023). Transformation of the RESPO decision support system to higher education for monitoring sustainability-related competencies. *Sustainability (Switzerland)*, 15(4). <https://doi.org/10.3390/su15043477>
- Afifah, S. N., Muhdhar, M. H. I. Al, Aisyah, D. F. N., & Udiarti, E. (2024). The linkage between problem solving skills and social attitudes with environmental literacy of 10 th grade students at SMAN 7 Malang. *BIOEDUKASI: Jurnal Biologi Dan Pembelajarannya*, 22(1), 102–111. <https://doi.org/10.19184/bioedu.v22i1.43776>
- Alfaeni, D., Nurkanti, M., & Halimah, M. (2022). Kemampuan kolaborasi siswa melalui model project-based learning menggunakan zoom pada materi ekosistem. *BIOEDUKASI (Jurnal Pendidikan Biologi)*, 13(2), 143. <https://doi.org/10.24127/bioedukasi.v13i2.6330>
- Arwidiyarti, D., Khaerudin, K., & Wibawa, B. (2022). Improving the learning effectiveness of information system analysis and design courses with collasion learning. *International Journal of Information and Education Technology*, 12(5), 456–462. <https://doi.org/10.18178/ijiet.2022.12.5.1641>
- Banihashem, S. K., Farrokhnia, M., Badali, M., & Noroozi, O. (2022). The impacts of constructivist learning design and learning analytics on students' engagement and self-regulation. *Innovations in Education and Teaching International*, 59(4), 442–452. <https://doi.org/10.1080/14703297.2021.1890634>
- Barnett, S., & Francis, H. D. (2023). The four studio structures and deep learning. *PDS Partners: Bridging Research to Practice*, 18(1), 34–42. <https://doi.org/10.1108/pdsp-01-2023-0007>
- Bentz, J., & O'Brien, K. (2019). ART for CHANGE: Transformative learning and youth empowerment in a changing climate. *Elementa*, 7(1). <https://doi.org/10.1525/elementa.390>
- Brady, N., McVeigh, J. G., McCreesh, K., Rio, E., Dekkers, T., & Lewis, J. S. (2021).

- Exploring the effectiveness of immersive Virtual Reality interventions in the management of musculoskeletal pain: a state-of-the-art review. *Physical Therapy Reviews*, 26(4), 262–275. <https://doi.org/10.1080/10833196.2021.1903209>
- Cheng, V. M. Y. (2019). Developing individual creativity for environmental sustainability: Using an everyday theme in higher education. *Thinking Skills and Creativity*, 33, 100567. <https://doi.org/https://doi.org/10.1016/j.tsc.2019.05.001>
- Davidson, J., Ryberg, T., & Bernhard, J. (2020). “Everything comes together”: Students’ collaborative development of a professional dialogic practice in architecture and design education. *Thinking Skills and Creativity*, 37(June), 100678. <https://doi.org/10.1016/j.tsc.2020.100678>
- Elendu, C., Amaechi, D. C., Okatta, A. U., Amaechi, E. C., Elendu, T. C., Ezech, C. P., & Elendu, I. D. (2024). The impact of simulation-based training in medical education: A review. *Medicine*, 103(27), e38813. <https://doi.org/10.1097/MD.00000000000038813>
- Eskiyurt, R., & Özkan, B. (2024). Exploring the impact of collaborative learning on the development of critical thinking and clinical decision-making skills in nursing students: A quantitative descriptive design. *Heliyon*, 10(17), e37198. <https://doi.org/10.1016/j.heliyon.2024.e37198>
- Fitriana, D. E. N. (2023). Analisis collaborative skill mahasiswa calon guru biologi melalui pembelajaran project based learning. *Jurnal Pendidikan Tambusai*, 7(1), 4607–4612. <https://doi.org/10.31004/jptam.v7i1.5965>
- Graesser, A. C., Fiore, S. M., Greiff, S., Andrews-Todd, J., Foltz, P. W., & Hesse, F. W. (2019). Advancing the science of collaborative problem solving. *Psychological Science in the Public Interest*, 19(2), 59–92. <https://doi.org/10.1177/1529100618808244>
- Hudha, M. N., Putri, E. V. R., & Kumala, F. N. (2021). Analysis of student understanding related to environmental literature in elementary school with science technology community approach. *Paedagogia*, 24(2), 144. <https://doi.org/10.20961/paedagogia.v24i2.54232>
- Husamah, H., Rahardjanto, A., Permana, T. I., & Lestari, N. (2025). The relationship between environmental literacy, ecological literacy, and science for sustainability: A systematic literature review. *Research and Development in Education (RaDEn)*, 5(1), 351–364. <https://doi.org/10.22219/raden.v5i1.39957>
- Irawati, H., Aprilia, N., Saifuddin, F., & Biologi, P. (2024). Environmental literacy of teaching students. *Jurnal Penelitian Pendidikan Biologi*, 7(2), 91–97.
- Kaya, V. H., & Elster, D. (2019). A critical consideration of environmental literacy: Concepts, contexts, and competencies. *Sustainability (Switzerland)*, 11(6). <https://doi.org/10.3390/su11061581>
- Kemendikdasmen, K. (2025). *Konsep dan implementasi deep learning oleh Robert Randall*.
- KemenPan-RB, K. (2025). *Mendikdasmen paparkan penerapan deep learning untuk tingkatan mutu pendidikan*.
- Kurniawan, E., Saputra, Z. S., & Akhyar, M. (2024). Environmental literacy and responsibility level of students in the Geography Education Study Program in Universitas Negeri Semarang as prospective teachers. *International Journal of Environmental Impacts*, 7(2), 221–232. <https://doi.org/10.18280/ijei.070207>
- Maas, T., Jochim, A., & Gross, B. (2018). Mind the gap: Will all students benefit from 21st Century learning? *Center on Reinventing Public Education*, October, 1–17.
- Magaji, A. (2021). Promoting problem-solving skills among secondary science students through problem based learning. *International Journal of Instruction*, 14(4), 549–

566. <https://doi.org/10.29333/iji.2021.14432a>
- Marcinauskas, L., Iljinas, A., Čyviene, J., & Stankus, V. (2024). Problem-Based Learning versus traditional learning in physics education for engineering program students. *Education Sciences*, 14(2). <https://doi.org/10.3390/educsci14020154>
- Mazar, L., Rakhshanderou, S., Mohseni-Bandpei, A., & Ghaffari, M. (2026). Environmental health literacy: an exploratory conceptual redefinition and explanation structuralized from comprehensive multidisciplinary expert perspectives along with public insights. *City and Environment Interactions*, 29, 100285. <https://doi.org/https://doi.org/10.1016/j.cacint.2025.100285>
- Meitayani, M., Elvianasti, M., Maesaroh, M., Irdalisa, I., & Amirullah, G. (2022). Analysis of students creative thinking ability in environmental problem solving. *AL-ISHLAH: Jurnal Pendidikan*, 14(2), 1983–1994. <https://doi.org/10.35445/alishlah.v14i2.1629>
- Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methodes sourcebook* (3rd Ed.). Sage.
- Nasution, R. (2021). Analisis tingkat literasi lingkungan mahasiswa FKIP Universitas Mulawarman dengan transformasi skor NELA (National Environmental Literacy Assessment). *Jurnal Ilmiah BioSmart (JIBS)*, 7(1), 38–51. <https://doi.org/10.30872/jibs.v1i1.423>
- Nguyen, T. T., Grote, U., Neubacher, F., Rahut, D. B., Do, M. H., & Paudel, G. P. (2023). Security risks from climate change and environmental degradation: implications for sustainable land use transformation in the Global South. *Current Opinion in Environmental Sustainability*, 63, 101322. <https://doi.org/https://doi.org/10.1016/j.cosust.2023.101322>
- Nurwidodo, N., Amin, M., Ibrohim, I., & Sueb, S. (2020). The role of eco-school program (Adiwiyata) towards environmental literacy of high school students. *European Journal of Educational Research*, 9(3), 1089–1103. <https://doi.org/10.12973/eu-er.9.3.1089>
- Nurwidodo, N., Hadi, S., Ibrohim, I., & Sueb, S. (2021). Validity and practicality of the EMKONTAN learning model to improve creative thinking, collaborative and literacy environment of prospective biology teacher students. *The 12th International Conference on Lesson Study*, 221–232.
- Nurwidodo, N., & Hindun, I. (2024). EMKONTAN learning model to improve creativity, collaborative skills, and environmental literacy of prospective biology teachers. *Jurnal Biolokus*, 7(2), 143. <https://doi.org/10.30821/biolokus.v7i2.3814>
- Nurwidodo, N., Ibrohim, I., Sueb, S., Abrori, F. M., & Darajat, T. A. (2023). Improving the creative thinking and collaborative skills of prospective biology teachers using the EMKONTAN learning model in environmental science courses. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 9(1), 15–25. <https://doi.org/10.22219/jpbi.v9i1.24382>
- Ørngreen, R., Knudsen, S. P., Kolbæk, D., & Jensen, R. H. S. (2021). Moodle and problem-based learning: Pedagogical designs and contradictions in the activity system. *Electronic Journal of E-Learning*, 19(3), 133–146. <https://doi.org/10.34190/ejel.19.3.2218>
- Owusu, B. A., Ofori-Boateng, P., & Doku, D. T. (2023). Coping and adaptation strategies among young persons living with type 1 diabetes and their caregivers: textual and photovoice analyses. *BMC Public Health*, 23(1), 1–12. <https://doi.org/10.1186/s12889-023-16573-z>
- Palmgren-Neuvonen, L., Littleton, K., & Hirvonen, N. (2021). Dialogic spaces in divergent and convergent collaborative learning tasks. *Information and Learning Science*, 12(5–6), 409–431. <https://doi.org/10.1108/ILS-02-2020-0043>

- Putri, M. D. S., Muhdhar, M. H. I. Al, Mardiyanti, L., Suradi, S., Idayati, I., & Utami, S. (2023). Relationship between problem-solving skills and environmental literacy of students. *AIP Conference Proceedings*, 2569(January). <https://doi.org/10.1063/5.0112734>
- Rubilar, K. H. (2025). Design for learning: teacher educators as policymakers? *School-University Partnerships*, 18(2), 200–214. <https://doi.org/10.1108/sup-10-2024-0023>
- Safira, S., & Astuti, P. (2025). Conceptualizing the Implementation of Deep Learning in ELT through Cooperative Learning for Teaching Speaking Skills at the High School Level. *Jurnal Penelitian Pendidikan*, 42(2), 269–277.
- Santos, C., Rybska, E., Klichowski, M., Jankowiak, B., Jaskulska, S., Domingues, N., Carvalho, D., Rocha, T., Paredes, H., Martins, P., & Rocha, J. (2023). Science education through project-based learning: A case study. *Procedia Computer Science*, 219(March), 1713–1720. <https://doi.org/10.1016/j.procs.2023.01.465>
- Siva, J., & Ershadi, M. (2025). Fostering leadership in sustainability: insights from transformational learning in the built environment. *Smart and Sustainable Built Environment*, September, 1–18. <https://doi.org/10.1108/SASBE-09-2024-0387>
- Sliwka, A., Klopsch, B., Beigel, J., & Tung, L. (2024). Transformational leadership for deeper learning: shaping innovative school practices for enhanced learning. *Journal of Educational Administration*, 62(1), 103–121. <https://doi.org/10.1108/JEA-03-2023-0049>
- Solé, L., Sole-Coromina, L., & Poole, S. E. (2020). Mind the gap: identifying barriers to students engaging in creative practices in higher education. *Journal of Work-Applied Management*, 12(2), 207–220. <https://doi.org/10.1108/JWAM-03-2020-0017>
- Sunderman, H. M. (2025). *Growth-based grading : a non-traditional approach to grading in leadership education*. September. <https://doi.org/10.1108/JOLE-06-2025-0060>
- Tiantong, M., & Teemuangsai, S. (2013). The four scaffolding modules for collaborative problem-based learning through the computer network on moodle lms for the computer programming course. *International Education Studies*, 6(5), 47–55. <https://doi.org/10.5539/ies.v6n5p47>
- Traini, H., McKee, K., Smist, J., & Rosch, D. M. (2025). Exploring the role of positive emotions in leadership learning. *Journal of Leadership Education*, September. <https://doi.org/10.1108/jole-10-2024-0123>
- Vallée, M. (2023). How and why US universities fail to impart environmental literacy to all students. *International Journal of Sustainability in Higher Education*, 25(9), 60–77. <https://doi.org/10.1108/IJSHE-07-2022-0241>
- Wiyono, B. B., Imron, A., Sumarsono, R. B., Musa, K., & Binti Mohd. Saat, R. (2025). The effect of constructivist learning and project-based learning model on students' entrepreneurial competence in higher education. *Cogent Education*, 12(1), 2557606. <https://doi.org/10.1080/2331186X.2025.2557606>
- Yildirim, M. S., Elkoca, A., Gökçay, G., Yilmaz, D. A., & Yıldız, M. (2025). The relationship between environmental literacy, ecological footprint awareness, and environmental behavior in adults. *BMC Public Health*, 25(1), 551. <https://doi.org/10.1186/s12889-025-21340-3>
- Young, O. R., & Stokke, O. S. (2020). Why is it hard to solve environmental problems? The perils of institutional reductionism and institutional overload. *International Environmental Agreements: Politics, Law and Economics*, 20(1), 5–19. <https://doi.org/10.1007/s10784-020-09468-6>