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The Implementation of Education for Sustainable Development (ESD)-Based Natural Science Learning to Empower Critical Thinking Skills and Scientific Literacy

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Abstract: Education for Sustainable Development (ESD)-Based Science learning is important for strengthening students' scientific literacy and critical thinking skills. This study aims to analyze ESD-based science learning conducted by teachers affiliated with the Surakarta City's Subject Teacher Forum (MGMP) for Natural Science. This research uses a qualitative descriptive approach. The sample used in this research consisted of 25 teachers affiliated with the Surakarta City's MGMP for Natural Science. Data collection was carried out through observation, interviews, questionnaires and documentation. The data analysis technique used is Miles and Huberman's interactive analysis method. The results of research show that the majority of teachers understand the concept of ESD, are able to design contextual learning, and facilitate reflective activities and projects relevant to sustainability issues. Learning encourages the students to think critically, discuss, and develop scientific literacy in an applied manner. However, challenges are still encountered in teaching material preparation and limited learning resources. This study emphasizes the urgency of training, policy support, and institutional synergy to strengthen the sustainability of ESD implementation in Natural Science education.

Keywords: Critical thinking; Education for Sustainable Development (ESD); Natural science learning; Scientific literacy

Introduction

Natural Science (IPA) learning plays a strategic role in developing students who think critically and scientifically, and who care about environment and society (Darmaji et al., 2022; Jufrida et al., 2019; Suciati et al., 2023). However, in practice, natural science learning in Indonesia still faces many challenges, including a conventional approach, minimal integration of issues in learning, and a lack of reinforcement of students' Higher Order Thinking Skills (HOTS) and scientific literacy (Asyhari & Hartati, 2015; Ismawati et al., 2023; Susilawati et al., 2020). This condition encourages the need for innovative learning approaches that can connect science to real-life problems.

Education for Sustainable Development (ESD) encourages the integration of environmental, social, and economic sustainability principles into learning, aiming to develop students who not only understand science, but are also able to think systemically, make ethical decisions, and act responsibly (Grosseck et al., 2019; Laurie et al., 2016; Vioreza et al., 2023). ESD is an educational approach combining ecological, social, economic, and cultural perspectives to shape students who are aware of sustainability issues and able to take concrete actions for a better future (Araneo, 2024). In

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natural science learning, ESD can improve HOTS and scientific literacy through issue-based and project-based approaches, as well as learning oriented towards solving real problems (Bramastia et al., 2025; Primasti, 2021; Rini et al., 2024; Setiawan et al., 2020). This successful approach is greatly influenced by the teachers' role in designing and implementing participatory learning (Vare et al., 2007).

In the framework of ESD, critical thinking skills are defined as the ability of actively and systematically analyzing, evaluating, and synthesizing information to make logical and meaningful decisions (Fatimah et al., 2023). Critical thinking is, according to Ennis (2018), a reflective process focused on determining what is worth believing or doing. Science learning addressing sustainability issues provides students with the opportunity of honing these skills. Meanwhile, scientific literacy refers to students' ability of understanding and applying scientific concepts and processes in everyday life, including in social, economic, and environmental decision-making (Ariyatun et al., 2024; Fuadi et al., 2020; OECD, 2023; Shwartz et al., 2006). Strong scientific literacy enables the students to become informed citizens responsible for environment and society.

Natural Science learning in schools tends to be teacher-centered, based on memorization, and lacks active student involvement (Utami & Vioreza, 2021; Zubaidah, 2016). Teachers often fail to connect science material to real life, especially sustainability issues relevant to students' local experiences. As a result, learning becomes disconnected from socio-ecological realities, even though science is rooted in observation and reflection on life phenomena. For example, low scientific literacy is related not only to weak conceptual mastery but also to the lack of skills in processing, analyzing, and evaluating scientific information critically and responsibly (Tillah & Subekti, 2025).

The implementation of ESD in science learning can also strengthen students' scientific literacy. The students are encouraged to understand scientific concepts not merely as theory but also as a means of analyzing and responding to environmental challenges at local and global levels. An ESD-based learning approach can significantly improve the students' understanding of environmental issues and encourage them to engage in real action in their communities (Sinaga et al., 2017). In Indonesia, this strategy aligns with the direction of Freedom Curriculum policy, prioritizing the reinforcement of Pancasila Student Profile, particularly in the dimensions of critical thinking, creativity, and global diversity (Kemendikbudristek, 2022a, 2022b).

The research evaluates the extent to which teachers are able to integrate ESD principles in understanding, planning, and implementing learning. The results of research are expected to provide conceptual and practical contributions to the development of more sustainable Natural Science learning. This study aims to analyze ESD-based science learning carried out by teachers affiliated with the Surakarta City's Subject Teacher Forum (MGMP) for Natural Science. The research question posed in this study is how the implementation of ESD-based Natural Science learning supports the empowerment of students' critical thinking skills and scientific literacy.

Method

This research employed a qualitative approach and was conducted from February to April 2025. The study involved 25 Natural Science teachers affiliated with the Surakarta City Subject Teacher Forum (MGMP) for Natural Science, representing both public and private junior high schools. The sample consisted of 76% female and 24% male teachers. In terms of age, 64% of the respondents were between 35 and 50 years old, while 36% were outside this range. Furthermore, 72% of the teachers had more than ten years of teaching experience, whereas 28% had ten years or less. All respondents held a bachelor's degree in Science Education with specializations in Biology, Physics, or Chemistry.

Data collection was conducted through observation, interviews, questionnaires, and documentation. Observations were conducted during teacher empowerment activities, including training sessions, discussions, and the development of teaching materials. Interviews were conducted with members of the MGMP. Documentation was made in the form of learning instruments and activity records. The main instrument used in data collection is a questionnaire designed to measure three main aspects: teachers' understanding of ESD concept, ability of designing ESD-based teaching instruments, and implementation of ESD-based Natural Science learning in the classroom. This instrument consists of 7 statement items equipped with a Likert scale 1 = Strongly Disagree (STS), 2 = Disagree (TS), 3 = Neutral (N), 4 = Agree (S), and 5 = Strongly Agree (SS). The questionnaire was then distributed to 25 samples and all of them were returned and could be analyzed.

Data deriving from the questionnaire were analyzed quantitatively and descriptively by calculating the percentage of response frequencies for each indicator, while qualitative data obtained from observations, interviews, and documentation were analyzed using the interactive model of analysis technique suggested by Miles and Huberman including data reduction, data presentation, and conclusion drawing/verification (Endarto & Martadi, 2022; Miles & Huberman, 1994; Yusmar & Fadilah, 2023). The triangulation process was carried out by matching data

obtained from various sources to increase the validity of results.

Result and Discussion

Result and discussion contain scientific research findings and discussions. This section writes down scientific findings obtained from the results of research that has been done but must be supported by adequate data. The scientific findings referred to here are not the results of research data obtained. The scientific findings must be explained scientifically including: What scientific findings were obtained? Why did that happen? Why are trend variables like that? All these questions must be explained not only descriptively but also scientifically, supported with adequate scientific basis phenomena if necessary. In addition, it should also be explained in comparison with the results of other researchers in similar topic. The results of research and the findings must be able to accommodate the research objectives as stated in the introduction.

A study on the implementation of Education for Sustainable Development (ESD) in Natural Science learning was conducted through an analysis of the responses of 25 teachers affiliated with the Surakarta City's Subject Teacher Forum for Natural Science to seven statements in a questionnaire instrument. Each statement was designed to represent key aspects in the implementation of ESD, including conceptual understanding, teaching instrument design, learning implementation, and pedagogical reflection. This analysis aims to provide an empirical picture of teachers' perceptions and practices in integrating sustainability principles into the science learning process in a meaningful and transformative manner. The results of the Education for Sustainable Development *(ESD)* questionnaire in Natural Science learning are shown in Table 1.

Table 1. Results of the Education for Sustainable Development (ESD) questionnaire of natural science learning

Indicator of Statement	Scale (%)				
	STS	TS	N	S	SS
Teachers' understanding of the basic concepts of Education for Sustainable Development (ESD)	0	0	0	80	20
ESD with HOTS reinforcement	0	0	8	60	32
Scientific literacy through ESD approach	0	0	4	72	24
Natural Science learning materials and media used	0	0	8	52	40
Implementation of critical thinking and problem solving related to sustainability issues.	0	0	0	52	48
Discussions and reflections encouraging environmental and social impacts	0	0	4	56	40
The impact of learning carried out	0	0	0	48	52

Table 1 shows that teachers affiliated with the Surakarta City's Subject Teacher Forum (MGMP) for Natural Science have understood, implemented, and understood the impact of ESD learning in Natural Science learning. When examined per statement indicator, in the statement "the teachers' understanding of the basic concepts of Education for Sustainable Development (ESD)" 80% of respondents agree and 20% strongly agree that teachers have understood the basic concepts of ESD. No respondents answered neutral or disagreeing, indicating that training and mentoring have successfully built a strong conceptual understanding. This is an important foundation for the development of transformative learning based on sustainability issues.

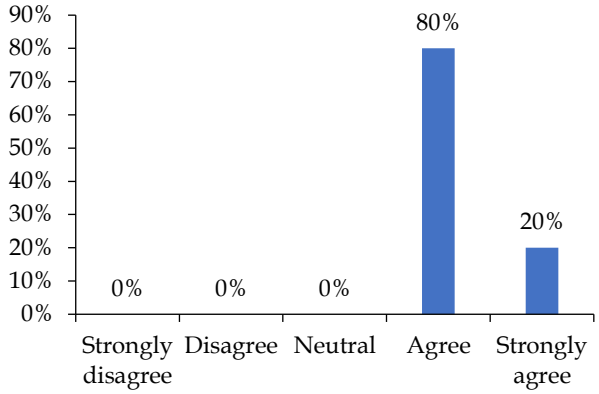

Figure 1. Result of questionnaire

Teachers have recognized the relationship between ESD and higher-order thinking skills (HOTS) reinforcement. Sixty percent of respondents agreed, 32% strongly agreed, and 8% were neutral. These findings indicate that the majority of teachers recognize the relationship between ESD approach and HOTS development. Teachers are beginning to understand that integrating sustainability issues can encourage learning activities involving analysis, evaluation, and solution creation. However, the presence of neutral responses indicates that a small number of respondents still need to deepen their understanding of the relationship between ESD and HOTS dimensions in applied Natural Science learning.

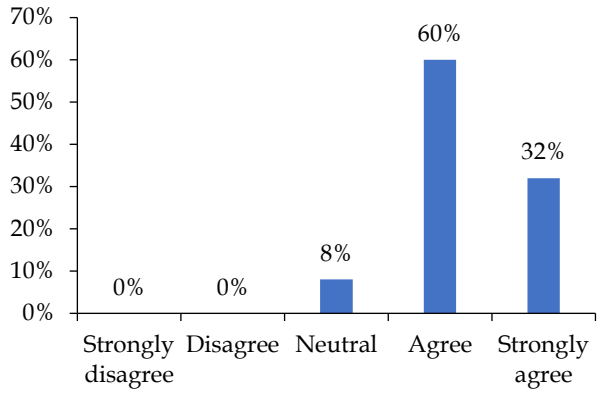

Figure 2. Result of questionnaire

Teachers understand that scientific literacy can be improved through an ESD approach to Natural Science learning. Seventy-two percent of teachers agreed, 24% strongly agreed, and 4% were neutral. These results indicate that most teachers have understood that ESD-based learning not only enriches learning, but also improves students' abilities of understanding, interpreting, and applying science concepts in everyday life. Scientific literacy fostered through current issues such as environmental and socio-ecological issues is an effective medium to make science more meaningful to the students.

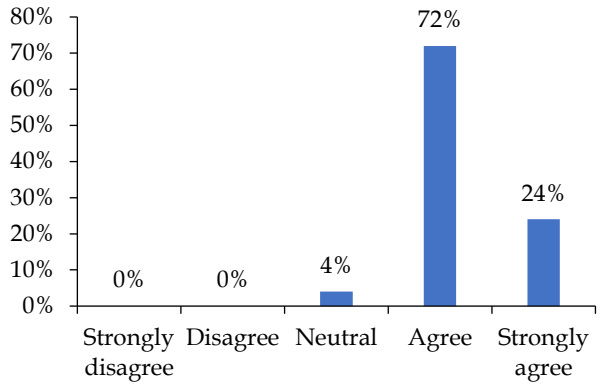

Figure 3. Result of questionnaire

Natural Science learning materials and media used support the improvement of students' scientific literacy. Forty percent of respondents strongly agree, 52% agree, and 8% are neutral. This means that most teachers have used materials and media connected to students' daily lives. This approach is in line with the spirit of ESD and is important to improve students' ability of understanding and using scientific information in addressing sustainability issues. However, the small number of respondents who were neutral could be an indicator of the need for further training in selecting and developing contextual-based learning media.

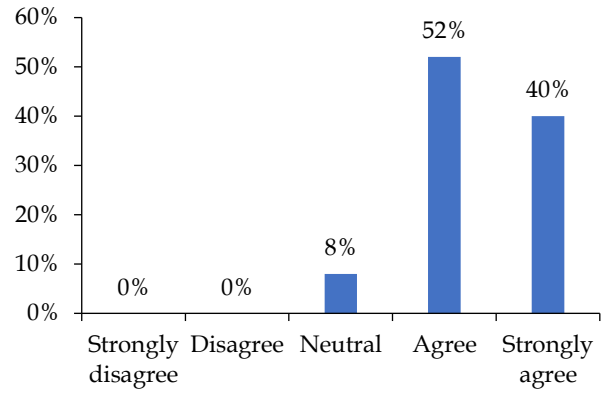

Figure 4. Result of questionnaire

During Natural Science learning, the students are encouraged to think critically and solve problems related to sustainability issues**.** All respondents responded positively, with 52% agreeing and 48% strongly agreeing. This indicates that teachers have successfully encouraged learning practices develop students' critical thinking skills, in line with the characteristics of HOTS-based learning. Encouraging students to address sustainability issues such as environmental degradation or resource scarcity is a crucial practice in developing students' scientific awareness and capacity.

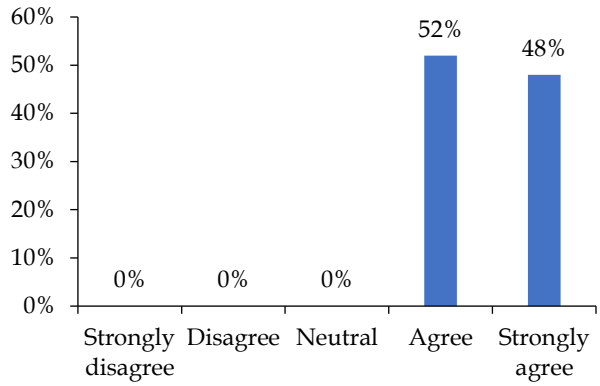

Figure 5. Result of questionnaire

Teachers facilitate discussions and reflections encourage the students to think systematically about environmental and social impacts. Fifty-six percent of respondents agreed, 40% strongly agreed, and 4% were neutral. This reflects that most teachers have engaged students in reflective dialogue and structured discussions, enabling them to see the interconnectedness of factors in sustainability issues. This systemic approach is at the heart of ESD pedagogy, as it fosters critical awareness and cross-disciplinary understanding. The presence of neutral responses indicates that some teachers may need further support in facilitating in-depth reflective activities.

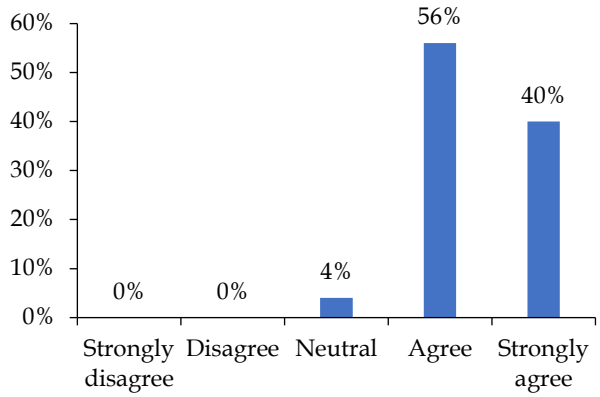

Figure 6. Result of questionnaire

Having participated in the learning, the students are expected to demonstrate increased scientific literacy skills and awareness of sustainable issues. Fifty-two percent of teachers strongly agreed, and 48% agreed, that ESD-based Natural Science learning can improve scientific literacy while building awareness of sustainability issues. The overwhelmingly positive response from all teachers demonstrates the belief that this approach effectively develops the students not only understanding science but also demonstrate social and environmental awareness as responsible global citizens.

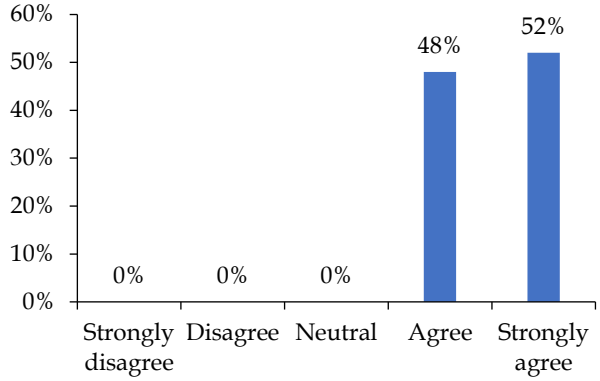

Figure 7. Result of questionnaire

Natural Science learning based on Education for Sustainable Development (ESD) among teachers affiliated with MGMP of Surakarta shows positive implementation in terms of understanding, planning, and implementation. The majority of teachers have understood the basic concepts of ESD and its relationship to the reinforcement of higher-order thinking skills (HOTS) and scientific literacy. They are able to connect sustainability values to their learning, both theoretically and practically, although a small number still show a neutral attitude towards a deeper integration of ESD and HOTS. Furthermore, the use of contextual learning materials and media is also starting to be implemented widely, enabling the students to connect scientific knowledge with the social and environmental realities around them. This strengthens the function of Natural Science education as a means of developing students who are not only academically intelligent but also aware of and concerned with environmental sustainability.

In classroom practice, teachers actively encourage students to think critically, discuss, and engage in reflection on sustainability issues, demonstrating the implementation of ESD-based transformative learning. The students are facilitated to solve problems systematically and undergo meaningful learning experiences, such as projects relevant to sustainable life. The overwhelmingly positive response from all teachers to improving students' scientific literacy and awareness of global issues confirms the effectiveness of this approach in shaping a scientific, critical, and socially and ecologically responsible generation. Nevertheless, these results also indicate the importance of further reinforcement through reflective training, development of local learning media, and systemic support from educational institutions so that the implementation of ESD in science learning can take place sustainably and in-depth.

The impact of the implementation and the challenges of ESD-based education sustainability, namely ESD-based learning, have evidently been able to strengthen the students' scientific literacy through an approach emphasizing the relationship between science, technology, society, and the environment. Teachers previously tending to focus on cognitive aspects are beginning to understand the importance of affective and psychomotor dimensions in Natural Science learning. The implementation of the Education for Sustainable Development (ESD) approach in Natural Science learning has demonstrated a positive impact on the reinforcement of teachers' pedagogical capacity and improved the quality of science learning in schools (Tahmid et al., 2024). One of the main impacts identified is an increase in teachers' ability of designing contextual, collaborative, and problem-based learning. Most teachers stated that they were able to connect Natural Science material to environmental issues around students, such as waste management, water pollution, and energy conservation.

This shows that ESD approach encourages a paradigm shift from content-based learning to the one rooted in the students' socio-ecological realities (Amyyana et al., 2017). By implementing ESD, education focuses not only on academic aspects but also on sustainable development issues relevant to environment, society, and economy. The students are encouraged to understand the complexity of problems occurring in local, national, and global contexts (Vioreza et al., 2023). Furthermore, positive impacts are also seen

in the empowerment of critical thinking skills and scientific literacy. Student engagement in data analysis, discussions, and evidence-based decision-making is a key indicator that science learning has led to the development of 21st-century skills. Teachers are beginning to adopt project-based learning strategies and collaborative discussions to foster students' awareness of sustainability issues while equipping them with scientific reasoning and reflective skills. These findings align with ESD principles, emphasizing active participation, systemic thinking, and ethical decision-making in addressing global challenges.

However, the implementation of ESD in the field still faces a number of challenges affecting the sustainability of program. Several teachers stated that there were obstacles in compiling ESD-based teaching instruments.

"We still often encounter obstacles in developing ESD-based instruments, particularly in designing Student Worksheet (LKPD) and research instruments in accordance with the appropriate critical thinking indicators."

Time limitations, lack of reference sources, and heavy administrative demands also hinder the consistent implementation of ESD learning. Furthermore, not all schools have adequate learning environments to support project-based learning, such as access to open laboratories, contextualized teaching materials, or collaboration with local communities.

On the other hand, program sustainability is largely determined by the availability of advanced training, teacher reflection forums (such as MGMP), and policy support from education stakeholders. To ensure the systematic and sustainable implementation of ESD approach, synergy between schools, local governments, and universities is required. This includes providing ESD-based learning resources, continuously strengthening teacher capacity, and developing evaluation models capturing sustainability dimension comprehensively.

Thus, although the implementation of ESD in science learning has shown positive impacts in strengthening the students' scientific literacy and critical thinking, sustainable efforts are needed to address the structural and pedagogical challenges remaining. The long-term success of ESD depends not only on the readiness of individual teachers, but also on the empowerment of education system to make it an integral and transformative pedagogical framework.

Conclusion

The implementation of Education for Sustainable Development (ESD)-based science learning by teachers affiliated with Surakarta's Subject Teacher Forum (MGMP) for Natural Science has demonstrated success in integrating sustainability principles into learning, and fostering students' scientific literacy and critical thinking skills. The majority of teachers are able to understand ESD concepts, design contextual, and issue-based learning, and facilitate reflective activities and real-life projects relevant to sustainable life. Students are actively involved in the systemic, analytical, and collaborative thinking processes being the characteristics of ESD approach. However, challenges remain in the development of teaching materials, the assessments, and the provision of learning resources. Therefore, the sustainability of ESD implementation requires institutional support, ongoing training, and cross-stakeholder collaboration so that Natural Science learning can keep developing as a transformative educational vehicle that is responsive to global challenges.

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Author Contributions

The conceptualization was carried out by Suciati and Bramastia; methodology was designed by Suciati; validation was conducted by Suciati, Bramastia, and Budi Utami; formal analysis was performed by Suciati; investigation was undertaken by Suciati; resources were provided by Budi Utami; data curation was managed by Kadek Dwi Hendratama Gunawan; the original draft was prepared by Suciati; writing, review, and editing were contributed by Bramastia and Budi Utami; visualization was prepared by Kadek Dwi Hendratama Gunawan; supervision was provided by Bramastia, Budi Utami, and Endah Febri Setiya Rini; project administration was managed by Suciati; and funding was acquired by Bramastia. All authors have reviewed and approved the final version of this article for publication.

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Conflicts of Interest

The authors declare that there is no conflict of interest in this research. Funders played no role in study design, data collection, analysis, or interpretation; manuscript writing; or decision to publish the results of research.

References

Amyyana, A. H., Paristiowati, M., & Kurniadewi, F. (2017). Pirolisis Sederhana Limbah Plastik dan Implementasinya sebagai Sumber Belajar Berbasis ESD pada Pembelajaran Kimia. *Jurnal Riset Pendidikan Kimia*, *7*(1), 14–21. Retrieved from journal.unj.ac.id/unj/index.php/jrpk/article/view/3093/2491

Araneo, P. (2024). Exploring Education for Sustainable Development (ESD) Course Content in Higher Education; A Multiple Case Study Including What Students Say They Like. *Environmental Education Research*, *30*(4), 631–660. https://doi.org/10.1080/13504622.2023.2280438

Ariyatun, A., Winarto, W., Syaifuddin, S., & Krityaningrum, D. H. (2024). Profile of Students' Scientific Literacy Competence and Attitudes toward Online Learning Using Microsoft Teams. *European Journal of Education and Pedagogy*, *5*(4), 55–61. http://dx.doi.org/10.24018/ejedu.2024.5.4.853

Asyhari, A., & Hartati, R. (2015). Profil Peningkatan Kemampuan Literasi Sains Siswa Melalui Pembelajaran Saintifik. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *04*(2), 179–191. https://doi.org/10.24042/jpifalbiruni.v4i2.91

Bramastia, B., Utami, B., Gunawan, K. D. H., Suciati, S., Rini, E. F. S., & Salsabila, T. H. (2025). The Empowerment of Science Teachers in Developing Education Sustainable Development (ESD)-Based Learning Instrument for Teachers Affiliated with Subject Teachers' Working Group (MGMP) for Science in Surakarta City. *Jurnal Pengabdian Magister Pendidikan IPA*, *8*(3), 691–698. https://doi.org/10.29303/jpmpi.v8i3.12353

Darmaji, D., Astalini, A., Kurniawan, D. A., & Rini, E. F. S. (2022). Gender Analysis in Measurement Materials: Critical Thinking Ability and Science Processing Skills. *JIPF Al-Biruni*, *11*(1), 113–128. https://doi.org/10.24042/jipfalbiruni.v11i1.11509

Endarto, I. A., & Martadi, M. (2022). Analisis Potensi Implementasi Metaverse pada Media Edukasi Interaktif. *Jurnal Barik*, *4*(1), 37–51. Retrieved from ejournal.unesa.ac.id/index.php/JDKV/

Ennis, R. H. (2018). Critical Thinking Across the Curriculum: A Vision. *Topoi*, *37*(1), 165–184. https://doi.org/10.1007/s11245-016-9401-4

Fatimah, H., Yamtinah, S., & Shidiq, A. S. (2023). Study of Ecology and Biodiversity Learning Based on Project Based Learning-Science Technology Engineering Mathematics (PjBL-STEM) in Empowering Students' Critical Thinking. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 729–736. https://doi.org/10.29303/jppipa.v9i9.3688

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), 2620–8326. https://doi.org/10.29303/jipp.v5i2.122

Grosseck, G., Tîru, L. G., & Bran, R. A. (2019). Education for Sustainable Development: Evolution and Perspectives: A Bibliometric Review of Research, 1992-2018. *Sustainability (Switzerland)*, *11*(21), 1992–2018. https://doi.org/10.3390/su11216136

Ismawati, E., Hersulastuti, H., Amertawengrum, I. P., & Anindita, K. A. (2023). Portrait of Education in Indonesia: Learning from PISA Results 2015 to Present. *International Journal of Learning, Teaching and Educational Research*, *22*(1), 321–340. https://doi.org/10.26803/ijlter.22.1.18

Jufrida, J., Basuki, F. R., Kurniawan, W., Pangestu, M. D., & Fitaloka, O. (2019). Scientific Literacy and Science Learning Achievement at Junior High School. *International Journal of Evaluation and Research in Education*, *8*(4), 630–636. https://doi.org/10.11591/ijere.v8i4.20312

Kemendikbudristek. (2022a). *Panduan Implementasi Kurikulum Merdeka*. Jakarta: Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Kemendikbudristek. (2022b). *Profil Pelajar Pancasila*. Jakarta: Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. Retrieved from puskur.kemdikbud.go.id/profilpelajarpancasila

Laurie, R., Nonoyama-Tarumi, Y., McKeown, R., & Hopkins, C. (2016). Contributions of Education for Sustainable Development (ESD) to Quality Education: A Synthesis of Research. *Journal of Education for Sustainable Development*, *10*(2), 226–242. https://doi.org/10.1177/0973408216661442

Miles, M. B., & Huberman, A. M. (1994). *Qualitatif Data Analysis*. SAGE Publications.

OECD. (2023). *PISA 2022 Assessment and Analytical Framework*. OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en

Primasti, S. G. (2021). Implementasi Program Education for Sustainable Development di SMA Tumbuh. *Jurnal Spektrum Analisis Kebijakan Pendidikan*, *10*(3), 80–100. http://dx.doi.org/10.21831/sakp.v10i3.17465

Rini, E. F. S., Rahardjo, S. B., & Bramastia, B. (2024). Analisis Bibliometrik: Bagaimana Tren Penelitian Literasi Sains dalam Pembelajaran Sains Tahun 2014-2024? *Seminar Nasional Pembelajaran Matematika, Sains dan Teknologi*, *4*, 242–251. Retrieved from http://e-jurnal.fkip.unila.ac.id/index.php/SINAPMASAGI/article/view/821/387

Setiawan, B., Susatyo, E. B., & Wibowo, E. (2020). Pengembangan Model Pendidikan Lingkungan

Hidup Berbasis ESD pada Sekolah Adiwiyata. *Jurnal Pendidikan Lingkungan dan Pembangunan Berkelanjutan*, *21*(2), 89–101.

Shwartz, Y., Ben-zvi, R., & Hofstein, A. (2006). The Use of Scientific Literacy Taxonomy for Assessing the Development of Chemical Literacy Among High-School Students. *Chemistry Education Research and Practice*, *7*(4), 203–225. https://doi.org/10.1039/B6RP90011A

Sinaga, P., Kaniawati, I., & Setiawan, A. (2017). Improving Secondary School Students' Scientific Literacy Ability Through the Design of Better Science Textbooks. *Journal of Turkish Science Education*, *14*(4), 92–107. https://doi.org/10.12973/tused.10215a

Suciati, S., Silvita, S., Prasetyo, O., Fauziah, M. D., Santika, K. D., Norawi, A. M., & Rahman, H. T. (2023). Problem-Based Learning Models: Their Effectiveness in Improving Creative Thinking Skills of Students. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 672–683. https://doi.org/10.15294/jpii.v12i4.44752

Susilawati, E., Agustinasari, A., Samsudin, A., & Siahaan, P. (2020). Analisis Tingkat Keterampilan Berpikir Kritis Siswa SMA. *Jurnal Pendidikan Fisika dan Teknologi*, *6*(1), 11–16. https://doi.org/10.29303/jpft.v6i1.1453

Tahmid, T., Nurkhoiri, N., & Syaiful, M. (2024). Peningkatan Literasi Sains dan Berpikir Kritis Melalui ESD di SMPN 2 Bojong. *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi*, *8*(2), 235–245. https://doi.org/10.33369/diklabio.8.2.235-245

Tillah, N. F., & Subekti, H. (2025). Analisis Kemampuan Literasi Sains Siswa SMP Berdasarkan Indikator dan Level Literasi Sains. *Edusaintek: Jurnal Pendidikan, Sains, dan Teknologi*, *12*(1), 137–154. https://doi.org/10.47668/edusaintek.v12i1.1271

Utami, P. P., & Vioreza, N. (2021). Teacher Work Productivity in Senior High School. *International Journal of Instruction*, *14*(1), 599–614. Retrieved from http://files.eric.ed.gov/fulltext/EJ1282134.pdf

Vare, P., Scott, W., Vare, P., & Scott, W. (2007). Learning for a Change: Exploring the Relationship between Education and Sustainable Development. *Journal of Education for Sustainable Development*, *1*(191). https://doi.org/10.1177/097340820700100209

Vioreza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for Sustainable Development: Bagaimana Urgensi dan Peluang Penerapannya pada Kurikulum Merdeka? *PUSAKA: Journal of Educational Review*, *1*(1), 34–48. https://doi.org/10.56773/pjer.v1i1.11

Yusmar, F., & Fadilah, R. E. (2023). Analisis Rendahnya Literasi Sains Peserta Didik Indonesia: Hasil PISA dan Faktor Penyebab. *Lentera (Lentera Sains): Jurnal Pendidikan IPA*, *13*(1), 11–19. https://doi.org/10.24929/lensa.v13i1.283

Zubaidah, S. (2016). Keterampilan Abad ke-21: Keterampilan yang Diajarkan Melalui Pembelajaran. *Seminar Nasional Pendidikan dengan Tema "Isu-Isu Strategis Pembelajaran MIPA Abad 21*, *2*(2), 1–17. Retrieved from https://www.researchgate.net/publication/318013627