

Integrating STEM based Education for Sustainable Development (ESD) to Promote Quality Education: A Systematic Literature Review

Irfan Fathurohman¹, Muhammad Fahriza Amri¹, Arifin Septiyanto¹, Riandi^{1*}

¹Science Education, Faculty Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

Received: June 23, 2023

Revised: September 14, 2023

Accepted: November 25, 2023

Published: November 30, 2023

Corresponding Author:

Riandi

riandi@upi.edu

DOI: [10.29303/jppipa.v9i11.4430](https://doi.org/10.29303/jppipa.v9i11.4430)

© 2023 The Authors. This open access article is distributed under a (CC-BY License)



Abstract: Promoting quality education through the integration of STEM-based Education for Sustainable Development (ESD) has become a significant area of interest. Integrating STEM-based ESD can enhance the quality of education by providing interdisciplinary learning opportunities that engage students in authentic, hands-on experiences. The objective of this study is to analyze existing empirical research on the utilization of STEM-ESD in order to investigate their effectiveness in fostering quality of education. The review process involved a systematic examination of journal papers published between 2018 and 2023, using both keyword search and snowballing techniques on the Scopus database. A total of 15 journal papers were selected for inclusion in this comprehensive review. The analysis indicates that STEM-ESD program is capable in increasing student self-efficacy and student engagement, STEM-ESD learning support student's critical thinking skills and system thinking, Implementing Local Wisdom Based ESD can increase student knowledge, STEM learning in Sustainable Food Program as an effort to increase sustainable literacy in student, ESD can increase student's environmental awareness. In this research there are a few implications such as that STEM-ESD need to be implemented in school curriculum in order to support education that is environmentally insightful.

Keywords: Literature Review; Quality Of Education; STEM-ESD

Introduction

Currently, our education system is required to be able to tackle current global challenges presented within our every aspect of life. Education that is in-line with the environmental, social, and economic conditions and needs are important in order to better prepare students in facing their future life (Alismail & McGuire, 2015; Marouli, 2021; OECD, 2018; WEF, 2023). Specifically, issues related to environmental damages and socio-scientific issues can be resolved by implementing sustainable education (Gunamantha, 2010; Lubis et al., 2022; Tytler, 2012; Wang et al., 2018). Thus, education will become an important priority by the government in order to reach the goals and targets of sustainable development in the era of Sustainable Development

Goals (SDGs). The increase in quality of education for the citizens of Indonesia can greatly help in achieving the goals and targets outlined in the 17 points that are declared, especially in increasing the developmental index of manpower in Indonesia. Thus, the role of education can hopefully increase the level of competitiveness of Indonesia in order to support SDGs 2030 (Mochtar et al., 2014).

Education for Sustainability Development (ESD) is an educational framework best suited in accommodating the achievement of sustainable development goals (Sutanto, 2017; UNESCO, 2019; Wolff et al., 2017). The implementation of ESD framework in science education can hopefully increase 21st century skills in order to fulfill the goal of SDGs about quality education (Hanifah et al., 2018; Olsson et

How to Cite:

Fathurohman, I., Amri, M. F., Septiyanto, A., & Riandi. (2023). Integrating STEM based Education for Sustainable Development (ESD) to Promote Quality Education: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, 9(11), 1052-1059. <https://doi.org/10.29303/jppipa.v9i11.4430>

al., 2022; Trott & Weinberg, 2020; Waltner et al., 2021). This is due to ESD having a number of pedagogical characteristics of which includes; collaborative and participative approach, holistic system thinking, exploration of knowledge, and focus on quality (Ofei-Manu & Didham, 2018). On the other hand, current STEM learning is considered to be the best approach in order to realize ESD program in schools. There are pedagogic principles in STEM that is in-line with the characteristics of ESD, of which to push student participation in developing solutions to real-life problems (Firda et al., 2021; Martín-Sánchez et al., 2022; Widarti & Roshayanti, 2021). By integrating ESD in STEM program, student will learn on how to invent technology using science and mathematics while still being in full consideration of the environmental sustainability and the practical use of said technology for the wider public (Rahman et al., 2023). This article reviews also uncover many discoveries which reveals that both ESD and STEM can increase student ability in literacy, system thinking skills, critical thinking skills, and attitude competence that points to sustainable practices.

Promoting quality education through the integration of STEM-based Education for Sustainable Development (ESD) has become a significant area of interest. The concept of STEM education emphasizes the integration of science, technology, engineering, and mathematics in a holistic approach to learning (Kushnir, 2018; Sanders, 2009; White, 2014). By incorporating ESD principles into STEM education, there is a potential to foster sustainable development practices, empower students with critical thinking skills, and address real-world challenges (Helmi & Herliani, 2021; Yalçın, 2022). Quality education plays a vital role in equipping students with the knowledge and skills necessary to thrive in a rapidly evolving global society (ILC, 2021). Integrating STEM-based ESD can enhance the quality of education by providing interdisciplinary learning opportunities that engage students in authentic, hands-on experiences (Abdurrahman et al., 2023; Gamage et al., 2022; Margot & Kettler, 2019; Martín-Sánchez et al., 2022). Through this approach, students can develop a deep understanding of the interconnectedness between STEM disciplines and their applications in addressing sustainability issues.

However, the successful implementation of STEM-based ESD requires a comprehensive understanding of effective pedagogical strategies, curriculum development, teacher training, and supportive learning environments (Kioupi & Voulvoulis, 2019; Laurie et al., 2016). It is essential to explore research and best practices in this field to inform policy and practice, ensuring that the integration of STEM-based ESD effectively promotes

quality education and contributes to sustainable development goals. Considering these limitations, our research aims to systematically review STEM-ESD in more detail than previous reviews and its effects on school teaching. In particular, our review focuses specifically on empirical studies that apply STEM-ESD to educational levels from preschool to corporate organizational levels. Research investigating ESD implementation during STEM education is also limited. Meanwhile, knowledge on program implementation should also be considered in the future program (Ferrer-Estévez & Chalmeta, 2021). Based on the results of a systematic review of 25 articles, it was found that implementing ESD in the high school context is still needed in future research (Hoque et al., 2022), especially ESD project that emphasize on real action in bthe daily life.

Method

A systematic literature review typically involves conducting thorough and comprehensive searches to clearly understand a specific topic by identifying, evaluating, and summarizing all relevant studies (Uman, 2011). In this particular review, electronic search databases were utilized to obtain data from five sources: SCOPUS, Science Direct, Taylor & Francis, and Springer. The databases were searched using a combination of keywords: "STEM AND EDUCATION FOR SUSTAINABLE DEVELOPMENT," resulting in 7,209 articles (n = 7,209). Duplicate articles were removed, and the dataset was further reduced based on specific eligibility criteria. The review included three main criteria for article eligibility.

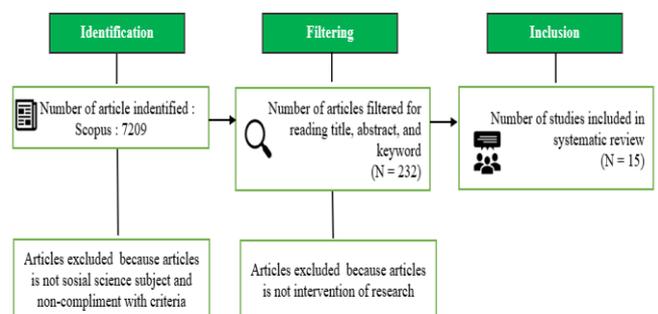


Figure 1. Article selection procedure

The following are the criteria (Figure 1) that can be included in the selection of articles. First, we focused on gathering journal articles indexed in Scopus from the first and second quartiles (Q1-Q2) based on the Scimago Journal Rankings. Our search included articles where the terms "STEM," and "Education for sustainable development" were present in either the title, abstract, or

keywords (Septiyanto, Ashidiq, et al., 2023). The selected articles encompassed educational interventions implemented within formal and non-formal educational settings, with a specific emphasis on fostering STEM based sustainable for education development (ESD). Lastly, the article presents its findings and concludes application of STEM-ESD. Following the application of these eligibility criteria, only 15 articles were selected as samples for the study.

The analysis was conducted in two stages. The first stage involved case analysis (Miles & Huberman, 1994), where each article was individually examined and summarized. In the second stage, a cross-case analysis was performed (Miles & Huberman, 1994). The extracted application of STEM-ESD from all the articles was reorganized, and similar elements were grouped, resulting in four distinct categories, as presented in Table 1. The classification of teaching and learning practices for each category was based on the categories established by Thibaut et al. (2018). Subsequently, the proposed teaching and learning practices for STEM-ESD were developed by focusing on the instructional categories most commonly employed in the articles reviewed in the systematic review.

Result and Discussion

A thorough systematic literature review was conducted, encompassing articles published from 2017 to 2023. The selection of articles was based on specific inclusion criteria, with a focus on international journals indexed in Scopus and categorized as Q1 and Q2. The research undertaken on STEM-ESD explored various aspects, including its impact on self-efficacy, critical thinking skills, and system thinking. The results of cross-case analysis of STEM-ESD to promote quality education from various journals can be seen in Table 1.

STEM-ESD Program is Capable in Increasing Student Self-efficacy and Student Engagement

Sustainable education, better known as ESD, and STEM approach are both interrelated towards each other (Turner et al., 2021). Besides that, the implementation of STEM learning can have positive impact towards student self-efficacy and student engagement. As one of the indicators that student self-efficacy experience increase is shown by their motivation and eagerness in STEM learning. Besides that, a noticeable observation shown by using STEM is the high level of engagement and interaction between students while working in groups (Turner et al., 2021; Vallera & Bodzin, 2020), with student are also shown practicing peer teaching, especially when learning about technology in groups, thus resolving the issue of skill differences in students

(Turner et al., 2021). The increase in student engagement in science learning is also believed to be achievable by implementing ESD (Olsson et al., 2022; Qureshi, 2020; Trott & Weinberg, 2020; Zelenika et al., 2018). Student engagement is shown in science learning, which brought up issues that happens in student’s immediate environment (Setiawan et al., 2023; Trott & Weinberg, 2020), also in the form of pro-environment actions, such as waste reduction, water conservation, wildlife conservation, and their ability to participate in a variety of sustainable practices (Qureshi, 2020; Zelenika et al., 2018).

Table 1. Cross-case analysis

Category	Specific coding	Source
Impact STEM-ESD	Self-efficacy and student engagement	Turner et al. 2021; Vallera & Bodzin. 2020; Zelenika et al. 2018; Olsson et al. 2022; Qureshi. 2020; Zidny & Eilks. 2022; Trott & Weinberg. 2020; Bosevska & Kriewaldt. 2020; Zowada et al. 2021
	Critical thinking and system thinking skills	Turner et al. 2021; Vallera & Bodzin. 2020; Shepard et al. 2021; Agirreazkuenaga & Martinez. 2021; Qureshi. 2020; Kucuk & Saysel. 2018; Zidny & Eilks. 2022; Trott & Weinberg. 2020; Bosevska & Kriewaldt. 2020
STEM-ESD based local wisdom	Student knowledge	Turner et al. 2021; Zelenika et al. 2018; Agirreazkuenaga & Martinez. 2021; Qureshi. 2020; Zidny & Eilks. 2022; Trott & Weinberg. 2020; Bosevska & Kriewaldt. 2020
STEM-ESD program	Environmental literacy	Vallera & Bodzin. 2020; Agirreazkuenaga & Martinez. 2021; Sass et al. 2021; Olsson et al. 2022; Qureshi. 2020; Repanovici et al. 2021
ESD	Environmental awareness	Shepard et al. 2021; Zelenika et al. 2018; Qureshi. 2020; Saleh et al. 2022; Zidny & Eilks. 2022; Trott & Weinberg. 2020

Student engagement in the implementation of sustainable education and STEM learning began from their own self-induced interest and internal motivation. This is outlined on several research which states that sustainable education can increase student interest and motivation to study (Bosevska & Kriewaldt, 2020; Zidny & Eilks, 2022; Zowada et al., 2021). Motivation that

develop during learning session can then help student in developing new ideas which can be used to support the idea of sustainability and better relate them with day-to-day real-life issues (Qureshi, 2020). Besides that, STEM learning can also stimulate student in developing connections between topics that are presented and environmental issues that they assume to be related to each other (Turner et al., 2021). Thus, we can conclude that in order to help student in finding their motivation, interest, and up to their engagement in learning activities require the implementation of STEM-ESD as a strategy in education that is effective in achieving said goals.

STEM-ESD Learning Support Student's Critical Thinking Skills and System Thinking

STEM approach can always be relied upon in order to stimulate student in developing their critical thinking skills, especially if used in-tandem alongside sustainable education. Furthermore, it is revealed that STEM can help student develop different thought patterns and thought processes, which includes critical thinking skills, problem-solving skills, and sustainable thinking skills demonstrated by students in their analysis and conclusion of which they develop from the result of their observation (Sagita et al., 2023; Turner et al., 2021; Vallera & Bodzin, 2020). STEM learning can also be readily implemented in learning process using group learning, which can help trigger student to practice peer teaching, of which can be a solution to the issue of skill differences in students (Turner et al., 2021). In-line with the thinking competencies developed in students by using STEM approach, are several research results which states that in its implementation, sustainable education can, in reality, help push the increase of student's critical thinking skills, which is revealed within science learning process that is conducted by students in groups (Bosevska & Kriewaldt, 2020; Trott & Weinberg, 2020). Aside from increasing their critical thinking skills, ESD can also increase their critical thinking disposition, which is said that critical thinking disposition help give students positive influence in the form of their displayed level of sustainability concerns (Bosevska & Kriewaldt, 2020; Shephard et al., 2021).

Aside from the critical thinking aspect, system thinking skills is also an indicator widely used as a benchmark in determining the success of implementing ESD in learning. Sustainable living practices are effective in helping students in developing new skills, of which is system thinking (Kucuk & Saysel, 2018; Qureshi, 2020; Zidny & Eilks, 2022). Besides that, System Thinking Skill (STS) is said to be able to help students in developing their own ideas in order to better solve complex and dynamic environmental issues (Kucuk & Saysel, 2018).

System thinking help student in developing sustainable perspectives and sustainable knowledge in approaching problems through social, economic, and environmental aspects (Agirreazkuenaga & Martinez, 2021).

Implementing Local Wisdom Based ESD can Increase Student Knowledge

Science learning conducted outside of class can help student gain knowledge from their environment. Student concept understanding can be developed through Local Wisdom-based learning within sustainable education (Turner et al., 2021; Zidny & Eilks, 2022). Learning activities conduction outside can help broaden student knowledge and student attitude towards science (Septiyanto, Oetomo, et al., 2023). These learning activities can be conducted in the form of visits to the zoo, farm, or from activities such as exploring school garden (Bosevska & Kriewaldt, 2020; Trott & Weinberg, 2020; Zelenika et al., 2018). Various natural phenomena happening in the surrounding environment have the advantage of being a real-life source of learning for students, of which analyzing these phenomenon have been proven to increase student system thinking skills after students undergo outdoor activities as a part of sustainable education (Agirreazkuenaga & Martinez, 2021; Qureshi, 2020).

Outdoor activities in science learning using the context of local wisdom require the involvement of public communities which actively promotes sustainable behavior (Bosevska & Kriewaldt, 2020; Trott & Weinberg, 2020; Zelenika et al., 2018). The role of communities involved in the field of living environment add to student knowledge in growing their concerns towards the environment (Trott & Weinberg, 2020; Zelenika et al., 2018). This means that schools need to better cooperate with various communities in the surrounding area in order to strengthen the implementation of sustainable education. In-line with above statement, the presence of locals while conducting outdoor learning activities need to be increased as a form of literacy that cannot be obtained inside of classroom (Zidny & Eilks, 2022).

STEM Learning in Sustainable Food Program as an Effort to Increase Sustainable Literacy in Student

Discussions related to STEM learning has been done many times due to the fact that STEM approach has been proven to discover various competencies found in students. The transformation of educational processes using STEM has been seen as the key to advancement and innovation. Besides that, STEM learning has been proven to play a significant role in increasing literacy skills and help support sustainable lifestyle (Qureshi, 2020; Repanovici et al., 2021; Vallera & Bodzin, 2020).

This have been proven through a project with the theme of sustainable food which resulted in positive effect in increasing agricultural literacy and sustainable literacy (Qureshi, 2020; Vallera & Bodzin, 2020). Then, competencies related to information literacy found in students can support the development of student's sustainable thinking skills (Repanovici et al., 2021). On that note, sustainable literacy and sustainable action can also be increased through sustainable living practices (Qureshi, 2020). For example, students can now decide which daily routine that they can implement at home in order to be more energy efficient or minimizing environmental pollution. Sustainable living practice create an opportunity in creating a society that is educated and responsible in preserving the environment (Repanovici et al., 2021).

Sustainable food program gives a prospective context for ESD learning, and can become an integral part in school curriculum (Vallera & Bodzin, 2020). Issues related to agriculture which includes GMO, food production, food security, and usage of pesticide can become topics that is taught to students. Topics related to food and its production process, along with its consumption have a very broad relationship with the concept of sustainability (Agirreazkuenaga & Martinez, 2021). Aside from that, in the context of daily life, sustainable food program can bring up topics related to cooking with clean fuel, consumption of organic food, and vegetables from local farmers (Qureshi, 2020).

ESD can Increase Student's Environmental Awareness

The responsibility that comes with environmental issues need to be developed as early as possible in students through learning process. Sustainable education is an educational concept which try to answer these challenges while also support sustainable development goals and programs. Learning intervention using Field School (Zelenika et al., 2018) and environmental knowledge (Saleh et al., 2022) both can have positive impact towards student's willingness towards sustainability. Aside from that, the improvement in attitude gained from ESD-based learning can be observed in student's awareness towards environmental issues (Setiawan et al., 2023; Shephard et al., 2021), involvement in pro-environment actions (Trott & Weinberg, 2020; Zelenika et al., 2018), or decisions made in order to support sustainable lifestyle (Qureshi, 2020).

Student knowledge related to environmental issues are interrelated with changes in behavior reflective of sustainable indicators (Trott & Weinberg, 2020). Aside from that, student knowledge towards the environment have the potential to increase student awareness towards knowledge in their surroundings in order to

increase their scientific and cultural literacy (Setiawan et al., 2023; Zidny & Eilks, 2022). Thus at the end, the implementation of ESD holistically can help to grow student willingness (Saleh et al., 2022), behavior (Zelenika et al., 2018), and awareness (Agirreazkuenaga & Martinez, 2021) in sustainable living practices.

Conclusion

According to the result of analysis and discussion above, it can be concluded that the implementation of STEM-ESD learning can improve the quality of education. The improvement in quality through STEM-ESD learning can be conducted by introducing students to environmental issues. By introducing environmental issues through STEM-ESD, this can help student in engagement so that student will be able to think critically, and systematically to solve those environmental issues. In this literature review, are gathered a few points that includes the effects of STEM-ESD towards self-efficacy and student encouragement, impact of STEM-ESD on critical thinking and system thinking skills, STEM-ESD based on local wisdom influence student knowledge, and impact STEM-ESD towards environmental literacy and environmental awareness. Because of this, STEM-ESD learning can become an integral part of school curriculum. And thus, this research recommends that the implementation of STEM-ESD learning have to be implemented in every level of education, starting from elementary school to university level with the goal to support SDGs 2030 program especially in the context of the quality of education.

Acknowledgments

I'd like to extend my gratitude to everyone involved in this research. I would also give my utmost gratitude towards Dr. Riandi, M.Si as my overseeing lecturer, and also towards the Science Education study program in Universitas Pendidikan Indonesia which have given the opportunity for students to always be active in the world of scientific writing.

Author Contributions

Irfan Fathurohman, Muhammad Fahriza Amri: writing—original draft preparation, result, discussion; Arifin Septiyanto: methodology, analysis, proofreading, and editing; Riandi: supervision, conclusion, and review.

Funding

This research was funded by personal funding.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

- Abdurrahman, A., Maulina, H., Nurulsari, N., Sukamto, I., Umam, A. N., & Mulyana, K. M. (2023). Impacts Of Integrating Engineering Design Process Into STEM Makerspace On Renewable Energy Unit To Foster Students' System Thinking Skills. *Heliyon*, 9(4), e15100. <https://doi.org/10.1016/j.heliyon.2023.e15100>
- Agirreazkuenaga, L., & Martinez, P. M. (2021). Secondary Students' Perception, Positioning And Insight On Education For Sustainability. *International Research in Geographical and Environmental Education*, 30(3), 218-237. <https://doi.org/10.1080/10382046.2021.1877952>
- Alismail, H. A., & McGuire, D. P. (2015). 21st Century Standards and Curriculum: Current Research and Practice. *Journal of Education and Practice*, 6(6), 150-155. <https://doi.org/10.3390/bs12020038>
- Bosevska, J., & Kriewaldt, J. (2020). Fostering A Whole-School Approach To Sustainability: Learning From One School's Journey Towards Sustainable Education. *International Research in Geographical and Environmental Education*, 29(1), 55-73. <https://doi.org/10.1080/10382046.2019.1661127>
- Kucuk, Z.D., & Saysel, A. K. (2018). Developing Seventh Grade Students' Understanding of Complex Environmental Problems with Systems Tools and Representations: a Quasi-experimental Study. *Research in Science Education*, 48(2), 491-514. <https://doi.org/10.1007/s11165-017-9620-8>
- Ferrer-Estévez, M., & Chalmeta, R. (2021). Integrating Sustainable Development Goals in educational institutions. *International Journal of Management Education*, 19(2). <https://doi.org/10.1016/j.ijme.2021.100494>
- Firda, R., Kaniwati, I., & Sriyati, S. (2021). STEM Learning in Sustainability Issues to Improve Sustainability Consciousness of Junior High School Students. *Paedagogia*, 24(1), 53. <https://doi.org/10.20961/paedagogia.v24i1.54212>
- Gamage, K. A. A., Ekanayake, S. Y., & Dehideniya, S. C. P. (2022). Embedding Sustainability in Learning and Teaching: Lessons Learned and Moving Forward-Approaches in STEM Higher Education Programmes. *Education Sciences*, 12(3). <https://doi.org/10.3390/educsci12030225>
- Gunamantha, I. M. (2010). Pendidikan Untuk Pembangunan Berkelanjutan: Mengapa, Apa dan Bagaimana. *Jurnal Pendidikan Dan Pengajaran*, 43(3), 215-221. <https://doi.org/10.23887/jppundiksha.v43i3.125>
- Hanifah, M., Mohmadisa, H., Yazid, S., Nasir, N., & Saiyidatina Balkhis, N. (2018). Developing Low Carbon Schools Model through Students Involvement in Sustainability Activities. *International Journal of Asian Social Science*, 8(8), 591-602. <https://doi.org/10.18488/journal.1.2018.88.591.602>
- Helmi, M. H., & Herliani, E. (2021). Developing Sustainability Literacy Through STEM Learning: A Review. *SEAQIS Journal of Science Education*, 1(1), 36-43. <https://doi.org/10.58249/sjse.v1i1.23>
- Hoque, F., Yasin, R. M., & Sopian, K. (2022). Revisiting Education for Sustainable Development: Methods to Inspire Secondary School Students toward Renewable Energy. *Sustainability (Switzerland)*, 14(14), 1-18. <https://doi.org/10.3390/su14148296>
- ILC. (2021). *Shaping skills and lifelong learning for the future of work*. International labour conference. Retrieved from https://www.ilo.org/ilc/ILCSessions/109/report/s/reports-to-the-conference/WCMS_813696/lang-en/index.htm
- Kiupui, V., & Voulvoulis, N. (2019). Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes. *Sustainability (Switzerland)*, 11(21). <https://doi.org/10.3390/su11216104>
- Kushnir, N. (2018). Experience of foundation STEM-school. In *CEUR Workshop Proceedings*, 2104, 431-446. Retrieved from https://api.elsevier.com/content/abstract/scopus_id/85048355103
- 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>
- Lubis, S. P. W., Suryadarma, I. G. P., Paidi, & Yanto, B. E. (2022). The Effectiveness of Problem-based learning with Local Wisdom oriented to Socio-Scientific Issues. *International Journal of Instruction*, 15(2), 455-472. <https://doi.org/10.29333/iji.2022.15225a>
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, 6(1). <https://doi.org/10.1186/s40594-018-0151-2>
- Marouli, C. (2021). Sustainability education for the future? Challenges and implications for education and pedagogy in the 21st century. *Sustainability (Switzerland)*, 13(5), 1-15. <https://doi.org/10.3390/su13052901>
- Martín-Sánchez, A., González-Gómez, D., & Jeong, J. S.

- (2022). Service Learning as an Education for Sustainable Development (ESD) Teaching Strategy: Design, Implementation, and Evaluation in a STEM University Course. *Sustainability (Switzerland)*, 14(12). <https://doi.org/10.3390/su14126965>
- Mochtar, N. E., Gasim, H., Hendarman, Indrastuti, N., Wijiasih, A., Suryana, C., Restuningsih, K., & Tartila, S. L. (2014). *Pendidikan untuk Pembangunan Berkelanjutan (Education for Sustainable Development) di Indonesia*. Jakarta: Kementerian Pendidikan dan Kebudayaan.
- Saleh, M. S. M, Mehellou, A., Huang, M., & Briandana, R. (2022). The influence of sustainability knowledge and attitude on sustainable intention and behaviour of Malaysian and Indonesian undergraduate students. *Research in Comparative and International Education*, 17(4), 677–693. <https://doi.org/10.1177/17454999221126712>
- OECD. (2018). *The Future of Education and Skills: Education 2030*. In OECD Education Working Papers. Retrieved from [http://www.oecd.org/education/2030/E2030%0APosition%0APaper%0A\(05.04.2018\).pdf](http://www.oecd.org/education/2030/E2030%0APosition%0APaper%0A(05.04.2018).pdf)
- Ofei-Manu, P., & Didham, R. J. (2018). Identifying the factors for sustainability learning performance. *Journal of Cleaner Production*, 198, 1173–1184. <https://doi.org/10.1016/j.jclepro.2018.06.126>
- Olsson, D., Gericke, N., & Boeve-de Pauw, J. (2022). The effectiveness of education for sustainable development revisited—a longitudinal study on secondary students' action competence for sustainability. *Environmental Education Research*, 28(3), 405–429. <https://doi.org/10.1080/13504622.2022.2033170>
- Qureshi, S. M. Q. (2020). Learning by sustainable living to improve sustainability literacy. *International Journal of Sustainability in Higher Education*, 21(1), 161–178. <https://doi.org/10.1108/IJSHE-01-2019-0001>
- Rahman, A. A., Kaniawati, I., Riandi, R., & Hendayana, S. (2023). Secondary Science Teachers Perception on STEM Learning for Sustainable Development. *Jurnal Penelitian Pendidikan IPA*, 9(3), 1297–1303. <https://doi.org/10.29303/jppipa.v9i3.2776>
- Repanovici, A., Rotaru, C. S., & Murzea, C. (2021). Development of sustainable thinking by information literacy. *Sustainability (Switzerland)*, 13(3), 1–25. <https://doi.org/10.3390/su13031287>
- Sagita, S., Rahmat, A., Priyandoko, D., & Sriyati, S. (2023). Sustainability of Project-Based Learning: Challenge and Obstacles from Students Perception Point of View. *Jurnal Penelitian Pendidikan IPA*, 9(2), 810–816. <https://doi.org/10.29303/jppipa.v9i2.3044>
- Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, 68(4), 20–26. <https://doi.org/10.11340/skinresearch1959.41.49>
- Septiyanto, A., Ashidiq, R. M., Prima, E. C., & Riandi. (2023). Investigasi Tren Penelitian Pendidikan Stem : Analisis Bibliometrik dari Tahun 2018-2022. *Seminar Nasional IPA XIII*, 649-665. Retrieved from <https://proceeding.unnes.ac.id/index.php/snipa/article/view/2342/1823>
- Septiyanto, A., Oetomo, D., & Indriyanti, N. Y. (2023). Analysis of Students' Attitudes towards Engineering and Technology Viewed from School Area Differences. *AIP Conference Proceedings*, 2540. <https://doi.org/10.1063/5.0105949>
- Setiawan, H., Koosbandiah Surtikanti, H., Kusnadi, K., & Riandi, R. (2023). Sustainability Awareness, Engagement, and Perception of Indonesian High School Students during Sustainability Project Based Learning Implementation in Biology Education. *Jurnal Penelitian Pendidikan IPA*, 9(6), 4227–4236. <https://doi.org/10.29303/jppipa.v9i6.3971>
- Shephard, K., Kalsoom, Q., Gupta, R., Probst, L., Gannon, P., Santhakumar, V., Ndukwe, I. G., & Jowett, T. (2021). Exploring the relationship between dispositions to think critically and sustainability concern in HESD. *International Journal of Sustainability in Higher Education*, 22(5), 1166–1185. <https://doi.org/10.1108/IJSHE-07-2020-0251>
- Sutanto, H. P. (2017). Education For Sustainable Development In West Nusa Tenggara. *Cakrawala Pendidikan*, 3, 320–341. Retrieved from <https://journal.uny.ac.id/index.php/cp/article/view/13698>
- Trott, C. D., & Weinberg, A. E. (2020). Science Education for Sustainability: Strengthening Children's Science Engagement through Climate Change Learning and Action. *Sustainability*, 12(16), 6400. <https://doi.org/10.3390/su12166400>
- Turner, A., Logan, M., & Wilks, J. (2021). Planting food sustainability thinking and practice through STEM in the garden. *International Journal of Technology and Design Education*, 32(3), 1413–1439. <https://doi.org/10.1007/s10798-021-09655-9>
- Tytler, R. (2012). Socio-Scientific Issues, Sustainability and Science Education. *Research in Science Education*, 42(1), 155–163. <https://doi.org/10.1007/s11165-011-9262-1>
- UNESCO. (2019). *Sub-Education Policy Review Report: Education For Sustainable Development*. UNESCO, Paris France.
- Vallera, F. L., & Bodzin, A. M. (2020). Integrating STEM with AgLIT (Agricultural Literacy Through Innovative Technology): The Efficacy of a Project-Based Curriculum for Upper-Primary Students.

- International Journal of Science and Mathematics Education*, 18(3), 419–439.
<https://doi.org/10.1007/s10763-019-09979-y>
- Waltner, E. M., Scharenberg, K., Hörsch, C., & Rieß, W. (2021). What teachers think and know about education for sustainable development and how they implement it in class. *Sustainability*, 12(1690).
<https://doi.org/10.3390/su12041690>
- Wang, H. H., Hong, Z. R., Liu, S. C., & Lin, H. S. (2018). The impact of socio-scientific issue discussions on student environmentalism. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(12). <https://doi.org/10.29333/ejmste/95134>
- WEF. (2023). *The Global Risks Report 2023 - 18th Edition*. : World Economic Forum. Retrieved from <https://www.weforum.org/publications/global-risks-report-2023/in-full/>
- White, D. W. (2014). What Is STEM Education and Why Is It Important? *Florida Association of Teacher Educators Journal 2014*, 1(14), 1–9. Retrieved from https://www.ccc.edu/departments/Documents/STEM_labor.pdf
- Widarti, R., & Roshayanti, F. (2021). Potensi Implementasi STEAM (Science, Technology, Engineering, Art and Mathematic) berorientasi ESD (Education for Sustainable Development) dalam Pembelajaran Fluida. *Unnes Physics Education Journal*, 10(3), 291–295. Retrieved from <http://journal.unnes.ac.id/sju/index.php/upej>
- Wolff, L. A., Sjöblom, P., Hofman-Bergholm, M., & Palmberg, I. (2017). High performance education fails in sustainability? –a reflection on finnish primary teacher education. *Education Sciences*, 7(1).
<https://doi.org/10.3390/educsci7010032>
- Yalçın, V. (2022). Design-Oriented Thinking in STEM education: Exploring the Impact on Preschool Children’s Twenty-First-Century Skills. *Science & Education*, 0123456789.
<https://doi.org/10.1007/s11191-022-00410-7>
- Zelenika, I., Moreau, T., Lane, O., & Zhao, J. (2018). Sustainability education in a botanical garden promotes environmental knowledge, attitudes and willingness to act. *Environmental Education Research*, 24(11), 1581–1596.
<https://doi.org/10.1080/13504622.2018.1492705>
- Zidny, R., & Eilks, I. (2022). Learning about Pesticide Use Adapted from Ethnoscience as a Contribution to Green and Sustainable Chemistry Education. *Education Sciences*, 12(4).
<https://doi.org/10.3390/educsci12040227>
- Zowada, C., Belova, N., & Eilks, I. (2021). Enhancing Education for Sustainable Development Through Geographical Perspectives in Chemistry Teaching. *International Journal of Science and Mathematics Education*, 19(1), 87–109.
<https://doi.org/10.1007/s10763-019-10043-y>