Visualization and analysis of mapping thinking skills to encourage Education for Sustainable Development (ESD)

Misbah Misbah[1,2], *Ida* Hamidah[3*], *Siti* Sriyati[4], *Achmad* Samsudin[5], *Binar Kurnia* Prahani[6] and *Nor Farahwahidah Abdul* Rahman[7]

[1]Department of Science Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia.
[2]Program of Physics Education, Universitas Lambung Mangkurat, 70123 Banjarmasin, Indonesia.
[3]Department of Mechanical Engineering Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia.
[4]Department of Biology Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia.
[5]Program of Physics Education, Universitas Pendidikan Indonesia, 40154 Bandung, Indonesia.
[6]Program of Physics Education, Universitas Negeri Surabaya, 60231 Surabaya, Indonesia.
[7]School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia.

Abstract. A bibliometric analysis maps thinking skills to support Education for Sustainable Development (ESD) in the last 6 years. The Scopus database was used to analyze 398 documents out of 762 documents. An important finding is that research on this topic generally increases in publication every year. Articles on this topic are mostly published by Scopus-indexed journals with quartile 1 (Q1). Similarly, the author with the most citations comes from articles published in Q1. The US became the most productive country on this topic. Several universities in Indonesia are included in the top 10 that research a lot on this topic. Found 5 clusters of visualization results, several thinking skills strengthen the realization of ESD, including critical thinking skills, problem-solving, design thinking, decision-making, systems thinking, creativity, and computational thinking. Some important findings were also obtained that can be used to conduct subsequent research.

1 Introduction

The Sustainable Development Agenda and Development Goals of the United Nations 2030 argue that to overcome the world's challenges in the 21st century, people need to develop various skills, including thinking skills [1]. Incorporating sustainable values through pedagogical strategies into the university curriculum helps future professionals improve their understanding of sustainability. This is one of the important steps to help achieve the Sustainable Development Goals (SDGs) through education [2].

* Corresponding author: idahamidah@upi.edu

ESD is essential in higher education, equipping students with the competencies needed for a sustainable future [3–5]. ESD allows students to think about three aspects (economic, environmental, and societal) of sustainability [6]. ESD provides an understanding of the relationship between sustainable development issues and competency development to create a sustainable future [7].

ESD seeks a holistic understanding of sustainability and encourages critical thinking (CT) and innovative approaches [3]. ESD has been addressed by professionals, authorities, and several studies in recent decades, but the results are not yet clear [8]. Little progress has been made in documenting the implementation of pedagogy that develops disciplinary and transversal competencies, such as complex thinking competencies, for mastering these competencies [1]. Teachers need to understand how to raise awareness of global challenges [8].

Analytical studies on ESD topics have been carried out, including those by Ateskan [9], Rasuman et al., [10], and Stakova. [8]. However, no analytical study of ESD and thinking skills (TS) has been conducted. Therefore, a bibliometric analysis was conducted to map thinking skills to support education for sustainable development (TS-ESD) in the 2018-2024 time frame. The problem formulation is as follows: (1) What is the number of publications each year? (2) Who are the top 10 sources publishing much about TS-ESD? (3) Who are the top 10 countries that have researched a lot about TS-ESD? (4) Who are the top 10 affiliates who are researching TS-ESD? (5) Who are the top 10 authors on this topic based on the number of citations? and (6) What thinking skills are related to ESD based on visualization from co-occurrence analysis?

2 Methods

This study is a bibliometric analysis [11, 12]. The data collection carried out [13] is shown in Figure 1.

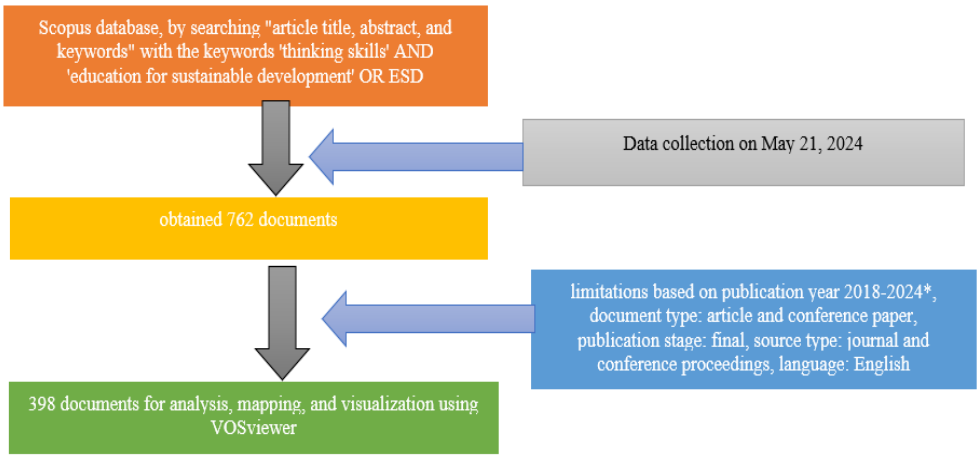


Fig. 1. Flowchart of data collection on the topic TS-ESD

3 Result and Discussion

The number of TS-ESD publications in each year is depicted in Figure 2.

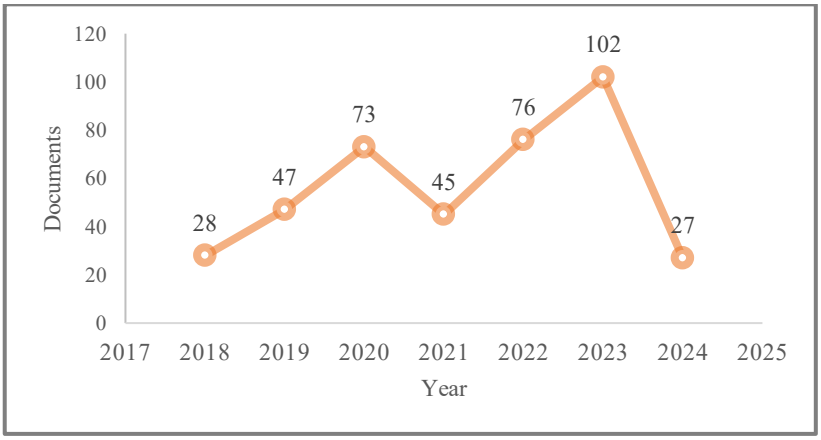


Fig. 2. Number of TS-ESD publications each year

Figure 2 shows the number of TS-ESD publications from 2018-2024*. There is an increase in the number of publications every year, except in 2021. The largest number of publications will occur in 2023. This happens because the topic of ESD is becoming one of the research trends, especially in science education [10], [14], [15].

The top 10 sources in both proceedings and journals on TS-ESD are provided in Figure 3.

Fig. 3. Top 10 resources about TS-ESD

Figure 3 shows the widely published topic on TS-ESD in Sustainability Switzerland, with quartile 1 (Q1). Several studies on TS-ESD have been published in this journal, such as Strakova [8], which examines critical thinking skills-ESD, and Baroudi [16], which discusses models of developing sustainable professional programs in the field of education. The published journals on this topic mostly come from Scopus-indexed journals with quartile 1 (Q1). The top 10 countries that research a lot about TS-ESD are listed in Figure 4.

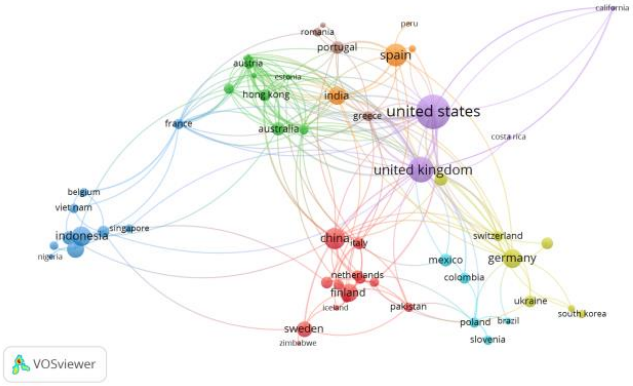


Fig. 4. Top 10 countries that research a lot about TS-ESD

Figure 4 shows the US as the most productive country on this topic, with 65 documents. Then, the UK came in second place. Indonesia is in fifth place. This corresponds to the visualization results using VOSviewer, where the UK ranks first. There are researchers from Indonesia, such as Dawana et al., [17], who researched the impact of the use of Augmented Reality on SDG and Rahmawati et al., [18], who discussed the value-based learning environment in ESD.

The top ten affiliations on this topic are provided in Figure 5.

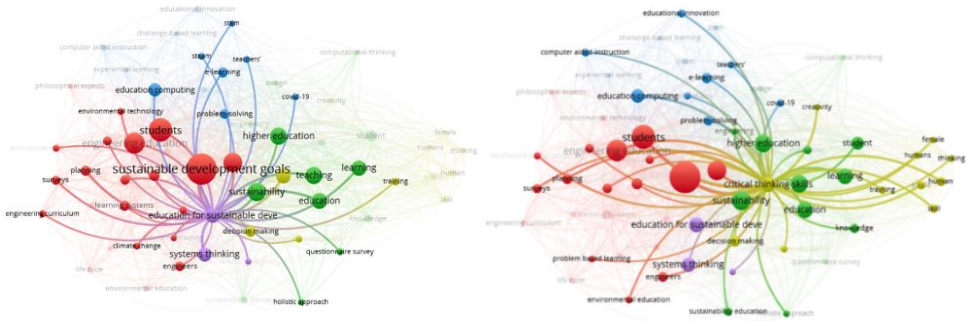
Fig. 5. Top ten affiliations in this topic TS-ESD

Figure 5 shows that the authors who researched extensively on the topic of TS-ESD came from the Tecnológico de Monterrey affiliate. Two campuses originated in Indonesia, including the Universitas Pendidikan Indonesian (UPI) and Universitas Negeri Jakarta (UNJ). For example, Rahmawati et al., [18] discussed a value-based learning environment in ESD from UNJ, and Rustaman [19] discussed system thinking as a sustainable competence derived from UPI. The top 10 authors researching TS-ESD topics, are based on the number of citations listed in Table 1.

Table 1. Top ten authors in the field of TS-ESD

Authors	Cited/ Quartile/ SJR	Findings
Gatti et al., (2019)	125/ Q1/ 1.981	Action learning approaches, especially simulations and games, can potentially influence students' CT growth.
Mian et al., (2020)	98/ Q1/ 0.664	Curriculum, human resources, finance, infrastructure, workshops, and industry partnerships are some of the factors that influence sustainability education at the tertiary level.
York et al., (2019)	95/ Q1/ 0.555	Systems thinking (ST) in STEM education disciplines has the potential to be applied in chemistry education.
Homeyer et al., (2018)	85/ Q2/ 0.769	Skills in interprofessional communication and role understanding will be key prerequisites for enhancing patient-centered, collaborative care.
Filho et al., (2020)	83/ Q1/ 0.664	Implementing sustainability leadership in higher education institutions is challenging because university administrators and some academic community members lack interest, as well as expertise, materials, and resources.
Membrillo-Hernández et al., (2019)	72/ Q1/ 0.429	An industry partner in the Challenge-Based Learning experience is critical to increasing the challenge's complexity and uncertainty. This helps expose students to real-life professional problems that need to be solved.
Straková & Cimermanová (2018)	72/ Q1/ 0.664	Teacher education institutions must incorporate comprehensive ESD-focused training into all teacher programs to ensure the achievement of the SDGs.
Zhang et al., (2020)	66/ Q1/ 0.664	Implementing the seven levels of professional and personal development can improve students' skills in ESD.
Molderez & Ceulemans, (2018)	52/ Q1/ 1.981	There is an extra dimension to the cognitive understanding of ST, namely that it enriches the person as a whole and strengthens critical and creative thinking skills.
Abookire et al., (2020)	50/ Q2/ 1.125	Design thinking (DT) increases efficiency and collaboration in intervention development.

Based on Table 1, authors whose articles are widely cited are published in reputable international journals with quartile 1 (Q1), such as Gatti [5], Mian et al., [20], and York et al., [21]. Figure 6 lists the results of co-occurrence analysis in the form of network visualization using VOSviewer on the topic of TS-ESD.



(a) (b)

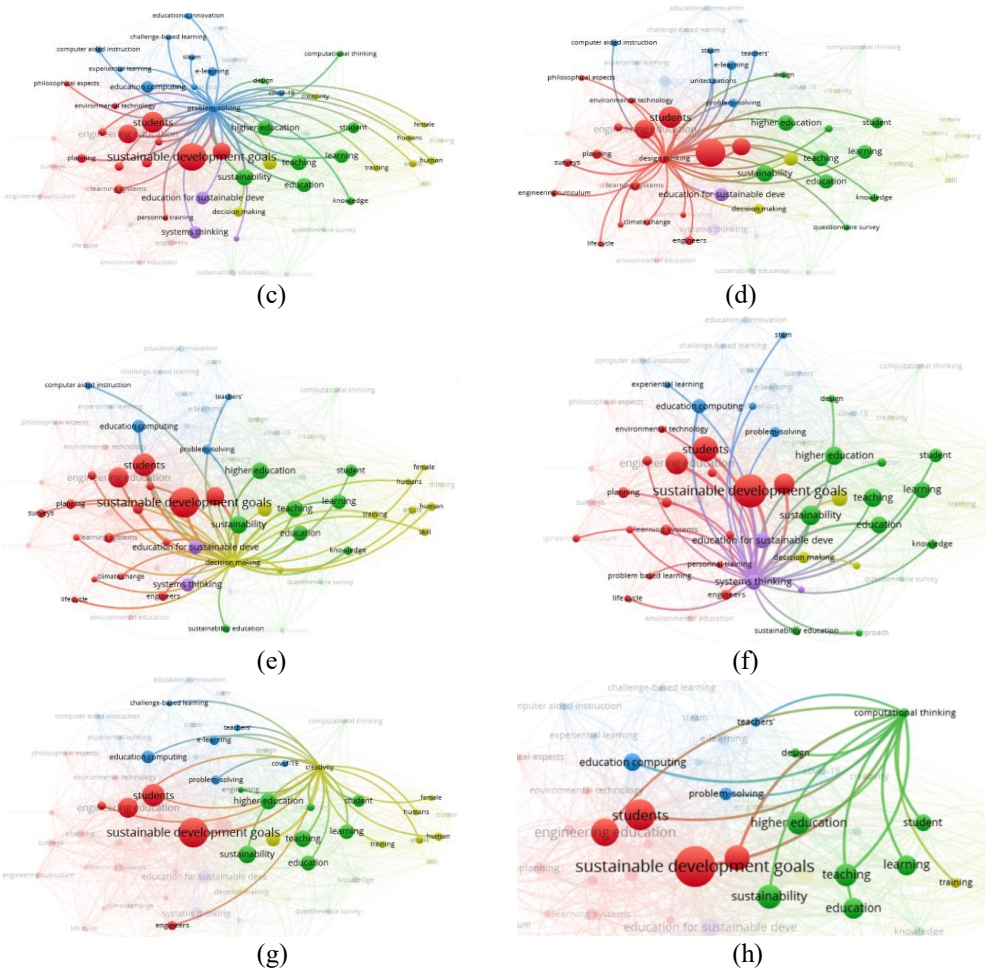


Fig. 6. Keyword mapping results are more specific to the topics of a) ESD, b) CT skills, c) problem-solving (PS), d) design thinking (DT), e) decision making (DM), f) ST, g) creativity, and h) computational thinking.

Figure 6 shows five clusters. The top 10 keywords in the five clusters are listed in Table 2.

Table 2. Co-occurrence analysis of keywords (top 10 keywords in the 5 clusters)

No	Cluster 1 (red)	Cluster 2 (green)	Cluster 3 (blue)	Cluster 4 (yellow)	Cluster 5 (purple)
1	SDGs (904)	Teaching (317)	education computing (212)	CT skills (176)	ST (139)
2	Students (627)	Sustainability (295)	e-learning (111)	DM (123)	ESD (128)
3	engineering education (488)	Education (244)	PS (108)	Human (96)	Teacher education (15)
4	Curriculum (412)	higher education (239)	Computer-aided instruction (62)	Article (88)	

No	Cluster 1 (red)	Cluster 2 (green)	Cluster 3 (blue)	Cluster 4 (yellow)	Cluster 5 (purple)
5	Planning (116)	Learning (237)	covid-19 (50)	Skill (76)	
6	learning systems (115)	Student (178)	teachers' (49)	Training (59)	
7	DT (95)	Knowledge (73)	United Nations (49)	Female (52)	
8	Engineers (83)	Innovation (50)	educational innovation (39)	Thinking (50)	
9	product design (77)	Design (46)	challenge-based learning (37)	professional development (36)	
10	professional aspects (73)	questionnaire survey (41)	experiential learning (36)	Creativity (34)	

Based on Figure 6, it is concluded that ESD has a direct relationship with thinking skills, such as CT skills, PS, DT, DM, and ST. On the other hand, creativity and computational thinking are not directly related. This could be an opportunity for the next morning's researcher to discuss the relationship between creativity and computational thinking with ESD.

SDGs require elements of CT, creativity, innovation, awareness, and integrity to be included in the curriculum so that these traits can be applied and internalized to students [22]. CT strategically develops complex thinking and sub-competencies [23]. CT skills are needed to ensure environmental sustainability in the era of the SDGs [24]. Teachers have an important role in using CT as an aspect of ESD [25]. CTS is the integration of sustainability into education, promoting the most important values in community life [26] and equipping individuals to overcome complex environmental challenges [27].

An innovative program that integrates creative personality development and strategic planning effectively supports sustainability education with creative and CT skills [28]. Creativity, CT, collaborative DM, and communication skills can be fostered through design-based learning [29]. Optimization of critical reflective social thinking, collaborative DM skills, and increased awareness of the need to protect the environment to support sustainable development can be trained through the STEAM teaching model [30]. PS is a complex skill, and it is an important one for students to have [31]. The application of Socio-Scientific Issues in learning encourages ESD and improves students' communication and collaboration skills [18].

ST is a holistic approach to studying complex problems and systems, which aims to develop higher-order thinking skills and address complex, interdisciplinary, real-world problems [21]. Improving students' ST skills can be done through project-based learning [32] and STEM-Engineering Design Process learning [33]. DT focuses on producing ideas when addressing a design problem and turning them into a solution [34]. DT is problem-solving in the form of prototypes and iterative refinements [35]. To achieve the Fourth SDG of providing quality education and promoting lifelong learning opportunities for all, developing computational thinking skills is essential. Computational thinking is usually related to coding or programming and computational thinking enables the usage of new technology [36], [37]. The results of the co-occurrence analysis in the form of overlay visualization using VOSviewer on the TS-ESD topic are listed in Figure 7.

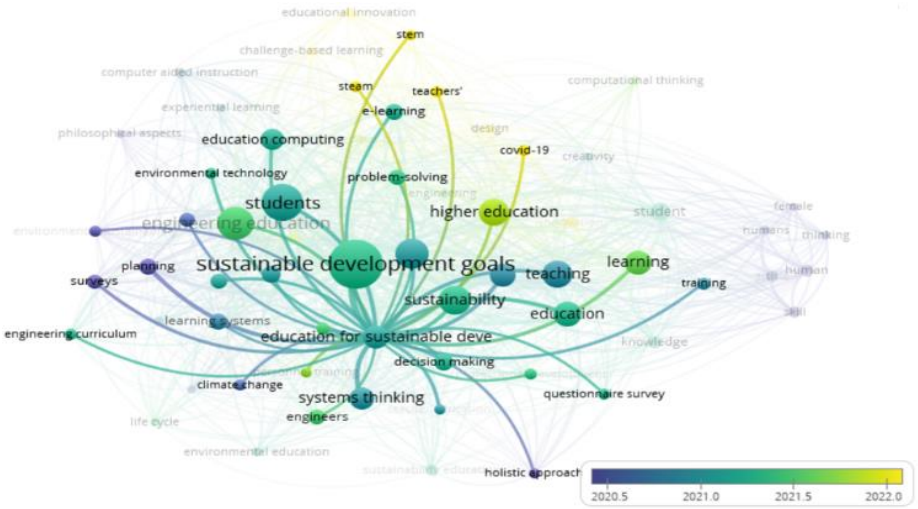


Fig. 7. Overlay visualization on topic TS-ESD

Figure 7 shows that research on TS-ESD in the last two years is associated with STEM and STEAM. However, many circles or keywords are still not directly related to ESD, such as computational thinking, creativity, challenge-based learning, experiential learning, educational innovation, etc. This is also an opportunity for future researchers.

ESD emphasizes the need to train teachers to implement effective approaches to achieve the SDGs [38]. ESD demands teachers use an interdisciplinary teaching style while promoting skills to deal with sustainability issues [6]. Among them are STEM and STEAM. Environment-based and STEM-based approaches are relevant to the real world to achieve the SDGs [17], [39]. STEM education provides opportunities for learners to develop CT, PS, and analytical skills. The STEM approach can realize SDGs in learning [40], [41]. STEM and STEAM approaches involve integrating different subjects and encouraging creative thinking, PS, and innovation. Applying these approaches can create a more engaging and interactive learning environment, resulting in a better understanding of the living world [42]. Developing these thinking skills can contribute to advancing SDG 4 goals for quality education.

4 Conclusion

Publications on TS-ESD topics have generally increased. Articles published in the Q1 Journal have the potential to be more widely cited and published articles on this topic. Indonesia is the fifth country to do a lot of research of this topic. UPI and UNJ are included in the top 10 universities that do a lot of research of this topic. From the visualization results, the researchers found five several thinking skills that strengthen the realization of ESD, including critical thinking skills, problem-solving, design thinking, decision-making, and systems thinking. However, creativity and computational thinking are not directly connected to ESD. This is an opportunity for further research.

Acknowledgements

This publication is part of dissertation research funded by the Beasiswa Pendidikan Indonesia (BPI) through the Higher Education Funding Center, the Indonesian Ministry of Education and Culture, and LPDP.

References

1. A. Medina Vidal, C. Nerantzi, and P.E. Alonso Galicia, in *Proceeding Int. Conf. Res. Educ. Sci.* (ISTES Organization, Cappadocia, Turkey, 2023)
2. B. Karmakar, R.J. Joga, R. Thangavel, D. Thakuria, and R.H. Begum, J. Chem. Educ. **100**, 1296 (2023)
3. N.D.J. Colón-Flores, M.R. Vargas-Martínez, J.C. Tavarez-De Henríquez, and C.M. Domínguez-Valerio, Sustainability **15**, 13537 (2023)
4. P. Fors, T.T. Lennerfors, and J. Woodward, Digit. Chem. Eng. **9**, 100129 (2023)
5. L. Gatti, J. Clean. Prod. **207**, 667 (2019)
6. M. Saimon, Z. Lavicza, and T. Prodromou, J. Inf. Technol. Educ. Res. **22**, 481 (2023)
7. T. Zhang, Sustain. **12**, (2020)
8. Z. Straková, Sustain. **10**, (2018)
9. A. Ateskan and J.F. Lane, J. Clean. Prod. **172**, 4348 (2018)
10. M.A. Rasuman, N. Nandi, A.J. Astari, and A.B. Ashie, Indones. J. Multidiciplinary Res. **4**, 109 (2024)
11. I. Zupic and T. Čater, Organ. Res. Methods **18**, 429 (2015)
12. M. Misbah, I. Hamidah, S. Sriyati, and A. Samsudin, J. Eng. Sci. Technol. **17**, 118 (2022)
13. B. Jiang, N. Hong, F. Zhao, and F. Dong, Int. Ophthalmol. **44**, 57 (2024)
14. P. Glavič, Sustainability **12**, 6500 (2020)
15. G. Grosseck, L.G. Țîru, and R.A. Bran, Sustainability **11**, 6136 (2019)
16. S. Baroudi, Sustainability **15**, (2023)
17. I.R. Dawana, B.K. Prahani, E. Hariyono, M.A. Ghofur, F.C. Wibowo and M.A.H. Bunyamin. *E3S Web Conf.* **4006** (2024)
18. Y. Rahmawati, M.J. Akbar, S. Budi, and A. Ridwan, AIP Conf. Proc. **2540**, (2023)
19. N.Y. Rustaman, J. Phys. Conf. Ser. **1806**, 12223 (2021)
20. S.H. Mian, B. Salah, W. Ameen, K. Moiduddin, and H. Alkhalefah, Sustainability **12**, 6100 (2020)
21. S. York, R. Lavi, Y.J. Dori, and M. Orgill, J. Chem. Educ. **96**, 2742 (2019)
22. N. Ahmad, Z.A. Sayadi, N. Danuri, and S. Ismail, AIP Conf. Proc. **2544**, (2023)
23. J.A. Talamás-Carvajal, H.G. Ceballos, and M.S. Ramírez-Montoya, J. Learn. Anal. **11**, 37 (2024)
24. M. R. Uddin, K. Shimizu, H. Sharmin, and A. Widiyatmoko, AIP Conf. Proc. **2614**, (2023)
25. S.M. Felix, Educ. Sci. **13**, 666 (2023)
26. D. Quiroz-Martinez, Environ. Educ. Res. **30**, 432 (2024)
27. A. Shutaleva, Sustainability **15**, 13492 (2023)
28. K. Haim and W. Aschauer, Sustainability **16**, 2257 (2024)
29. C. Gupta and V. Gupta, IEEE Trans. Educ. (2023)
30. Y. Rahmawati, E. Taylor, P.C. Taylor, A. Ridwan, and A. Mardiah, Sustain. **14**, (2022)
31. A. Duyver, J. Keyzer, E. Wieers, K. Henrioulle, and K. Aerts, in *SEFI 2023 - 51st*

Annu. Conf. Eur. Soc. Eng. Educ. Eng. Educ. Sustain. Proc. (2023)

32. I. Molderez, J. Clean. Prod. **186**, 758 (2018)
33. A. Abdurrahman, H. Maulina, N. Nurulsari, I. Sukamto, A.N. Umam, and K.M. Mulyana, Heliyon **9**, (2023)
34. S.A. Soomro, H. Casakin, and G. V Georgiev, Sustainability **13**, 1196 (2021)
35. S. Abookire, C. Plover, R. Frasso, and B. Ku, Front. Public Heal. **8**, 559030 (2020)
36. C. Boya-Lara, D. Saavedra, A. Fehrenbach, and A. Marquez-Araque, Int. J. Educ. Technol. High. Educ. **19**, 7 (2022)
37. Á. Molina-Ayuso, N. Adamuz-Povedano, R. Bracho-López, and M. Torralbo-Rodríguez, Sustainability **16**, 110 (2023)
38. B. Radulović, M. Džinović, D. Mandić, M. Zukorlić, and G. Starijaš, Sustainability **15**, 5196 (2023)
39. S. Chansaengsee, Kasetsart J. Soc. Sci. **45**, 11 (2024)
40. R. AlAli, K. Alsoud, and F. Athamneh, Sustainability **15**, 12542 (2023)
41. J. Han, T. Kelley, and J.G. Knowles, Int. J. Technol. Des. Educ. **33**, 1499 (2023)
42. T.T.K. Nguyen, D. Nguyen, and T.T. Dang, Simul. Gaming **55**, 51 (2024)