

The pathway of digital learning environments in advancing Sustainable Development Goals (SDGs): A Bibliometric analysis covering three decades of research

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Abstract. A digital learning environment can play a pivotal role in advancing the objectives of Goal 4 and, in doing so, can contribute to several other SDGs. This study purposed to investigate the impact of digital learning on sustainable growth in institutions by emphasizing the educational procedures that were implemented in extended years (three decades) throughout the global and broader countries. Furthermore, this research also analyzes the challenges and opportunities for digital learning in educational institutions, primarily to support the SDGs. This research employs a descriptive bibliometric analysis, utilizing Scopus as the primary data source. The research findings indicate a consistent upward trend in publication rates each year, with articles being the most prevalent document type, followed by conference papers. Potential areas for future research include the integration of e-learning practices into various educational levels, from universities to high schools and early education. Additionally, there are opportunities to investigate the development of innovative learning techniques and the emergence of computer-assisted learning as an educational system. Notably, the most influential studies fall within the Q1 category. The implications of this research extend to providing a comprehensive overview of trends in DLE publications from 1993 to 2022 and their potential contributions to the SDGs. Furthermore, future researchers can build upon these findings to develop and enhance digital learning environments in educational contexts, ultimately contributing to the attainment of SDG goals.

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1 Introduction

The UN 2030 Sustainable Development Goal (SDGs) Goal 4 (Quality education) specifically focuses on education, while the concept of a digital learning environment can intersect with several of the targets and indicators associated with Goal 4. Digital technology can play a pivotal role in advancing the objectives of Goal 4 and, in doing so, can contribute to several other SDGs [1–3].

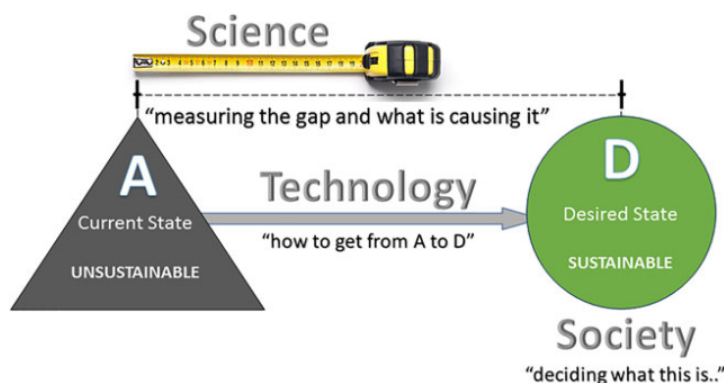


Fig. 1. Educational framework for sustainability transformation (Picture Source : [4]).

Fig. 1. shows that digital learning environments (DLE) support the goal's aims by enhancing access to education, improving the quality of education, promoting inclusivity, and offering lifelong learning opportunities, among other benefits [5]. DLE also supports economic growth, reduces inequalities, and fosters innovation and collaboration, making them a valuable tool for achieving a sustainable future [6]. Previous studies state that the digital transition [7], including e-learning [8], also highlights the importance of critically and practically engaging with what "transformational" education means in the context of the SDGs. Furthermore, previous studies [9,10] on the possibilities and necessities demonstrate an essential and beneficial connection between technological transformation achievement and global colleges and universities, including the opportunities for e-learning regarding SDGs, creative thinking, and organizational preparedness PRISMA statement. However, previous research [9] is still limited to a decade of metadata on DLE analysis and for specific countries. Hence, the purpose of this research is to investigate the impact of digital learning on sustainable growth in institutions by emphasizing the educational procedures that were implemented in extended years (three decades) through the global and broader countries. Furthermore, this research also analyzes the challenges and opportunities for digital learning in educational institutions, primarily to support the SDGs. This study, on the other hand, helps us comprehend the present condition of learning and instruction in universities. It is also crucial to comprehend how to improve the studied situation based on the recommendations offered in this study.

2 Methods

This research is a descriptive analysis using bibliometrics. The primary source database used is Scopus [11–13]. However, Scopus has become a leading resource with a publication loading 70% higher than other database sources [14–16]. Bibliometrics is divided into four stages: (1) creating a research design, (2) gathering information using criteria, (3) data analysis, and (4) representing and displaying data [17–20]. The process of this research is to determine the use of DLE, as in Fig. 2.

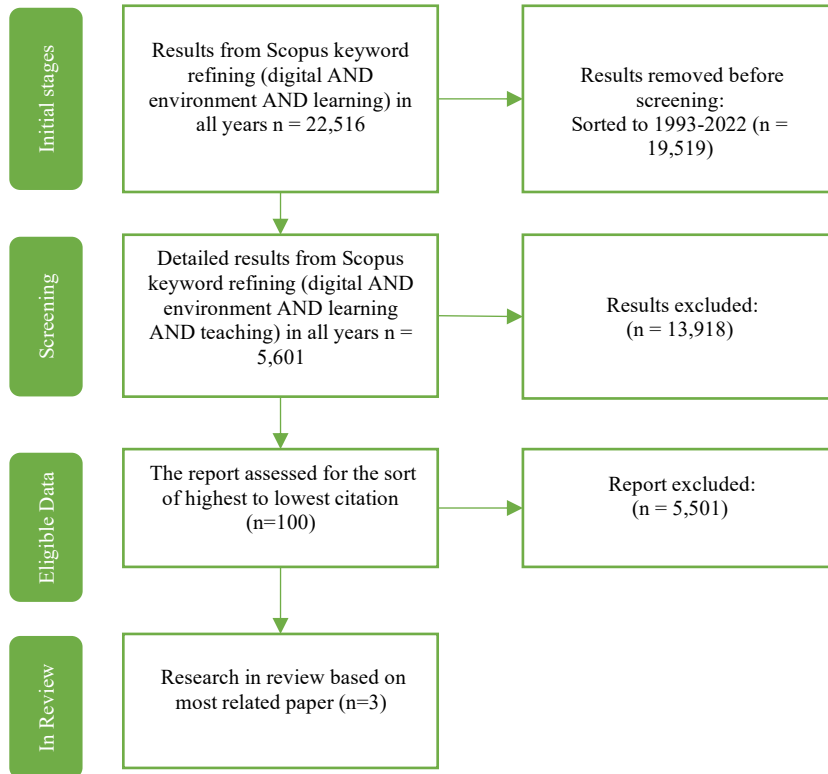


Fig. 2. Research Flowchart.

Gathering information on the metadata is conducted in October 2023. The results are chosen from the highest citation amount. Then, the metadata is saved as a .ris and .csv document types. Furthermore, the metadata are imported to assisted tools to relieve interpretation data analyzed. VOSViewer maps visualization to determine the link between published articles [18]–[21]. Then, selected articles are analyzed and reviewed to find the findings and recommendations to strengthen novelty besides mapping visualizations.

3 Results and discussion

3.1 DLE trendline during three decades

Based on the metadata gathered, the trend research of DLE during three decades is known. It is depicted in **Fig. 3**.

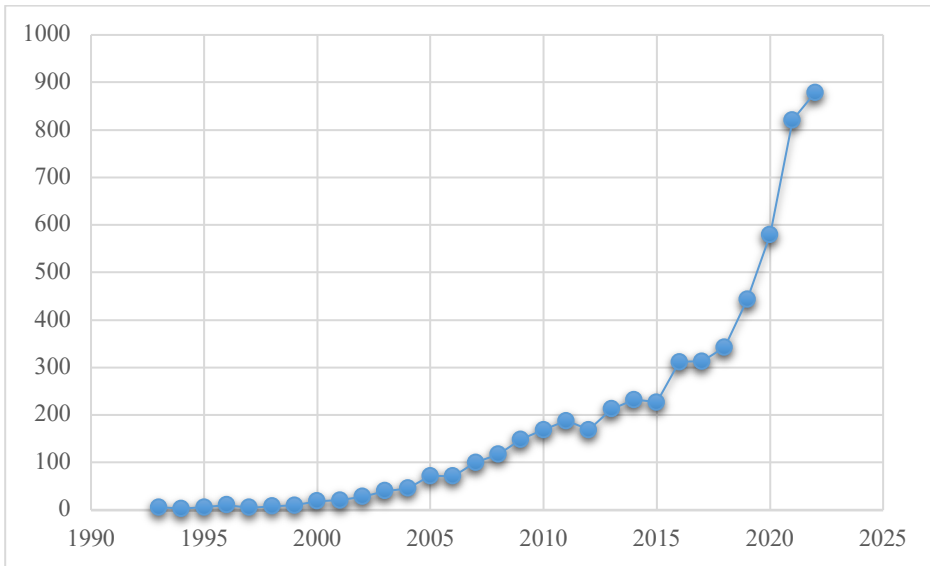


Fig. 3. Publication Trendline of DLE.

According to the research findings, as depicted in **Fig. 3**, there is an evident and stimulating annual growth trend in publication rates. This surge can be attributed to the growing interest among researchers in standardizing broadband cellular networks, particularly DLE. DLE is currently under consideration and is rapidly gaining prominence in the realms of research and education [25–27]. This shift led to a new set of DLE services characterized by diverse and technologically advanced design demands.

The pattern of DLE publications encompasses a wide array of available materials. According to the collected data, various document types were issued between 1993 and 2022, providing valuable insight for prospective researchers. **Fig. 4** illustrates the assortment of published documents related to DLE.

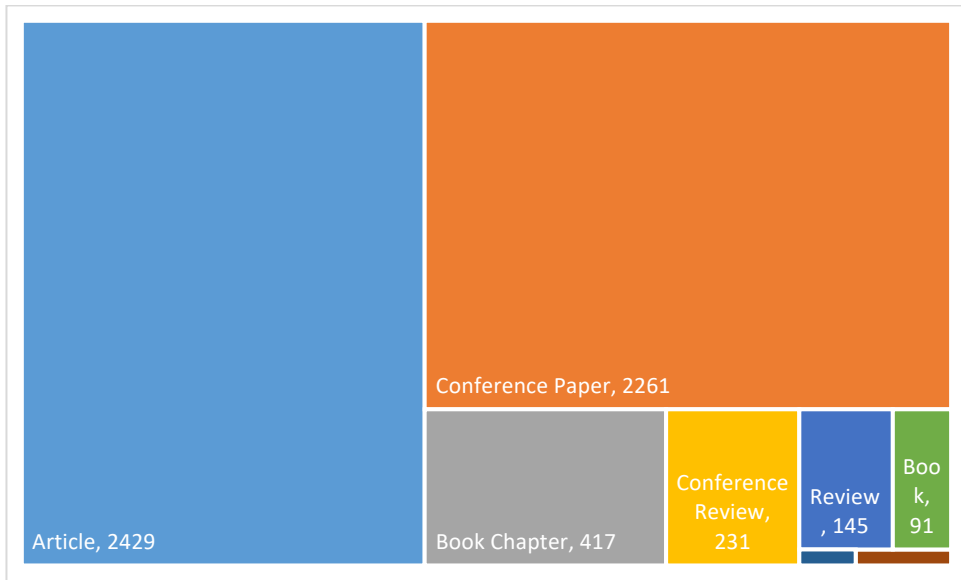


Fig. 4. Document Type of DLE Publications.

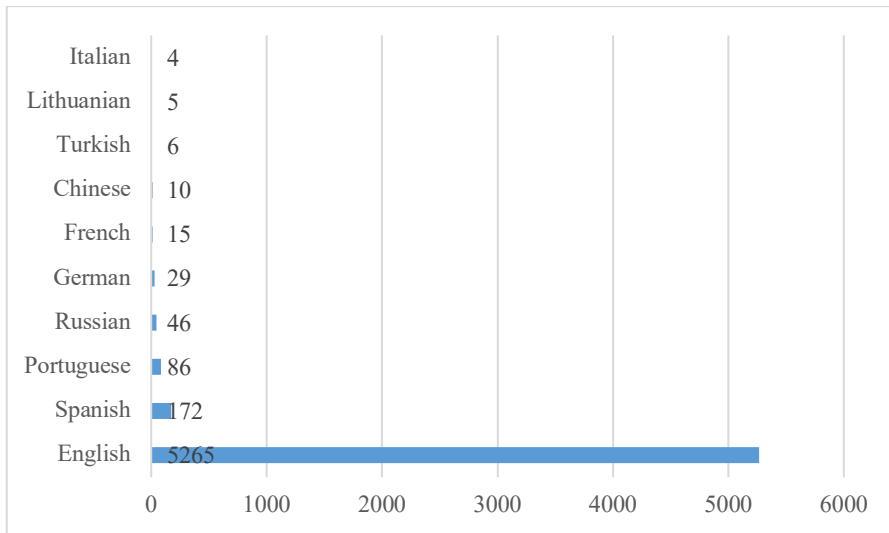


Fig. 5. Top Publications Language of DLE.

Fig. 3 reveals that articles are the most frequently employed publication format, accounting for 2,429 documents. Conference papers are the second most prevalent type with a count of 2,261. Furthermore, the predominant language for DLE publication research is English, as demonstrated by the data presented in **Fig. 5**. The information collected over the span of three decades indicates that English is the most commonly utilized language for disseminating DLE research in educational contexts [31,32].

3.2 Novelties of the DLE publications during three decades

Fig. 6. delves into the mapping visualization of metadata, which aims to explore the connections between relatively fewer keywords, thereby discerning the research's novelty from the mapping outcomes.

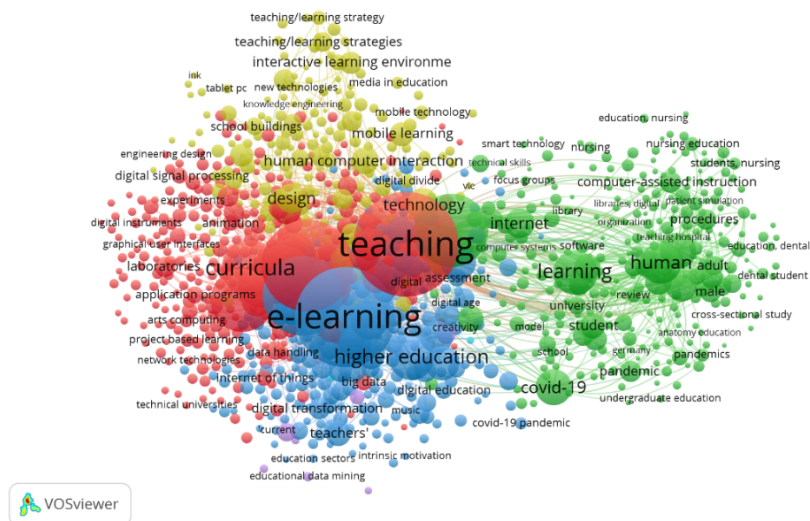


Fig. 6. Mapping Visualisation of DLE Publications.

Based on **Fig. 6.** it is known that six clusters, namely 1) Cluster 1 (n=308) with red node, consist of e-learning systems, platforms, teaching, teaching systems, virtual reality, virtual laboratory, university education, and so on. 2) Cluster 2 (n=284) with green node consists of COVID-19, digital technology, education, health education, high school, online systems, postgraduate students, school students, etc. 3) Cluster 3 (n=240) with blue node consists of collaborative learning, DLE, digital teaching, gamification, ICT, LMS, MOOCs, online environments, virtual education, and so on. 4) Cluster 4 (n=158) with the yellow node consists of active learning, practical learning, learning achievement, learning outcomes, mobile learning, web-based learning, and so on. 5) Cluster 5 (n=7) with purple node consists of data mining, educational data mining, primary education, learning analytics, etc. 6) Cluster 6 (n=3) with cyan node consists of PBL (problem based-learning), research question, and secondary school. Hence, from the DLE during three decades, the novelties are found in **Fig. 7** and **Fig. 8**.

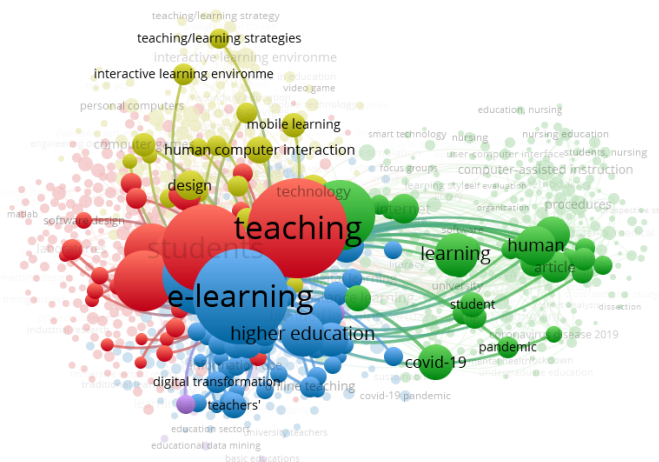


Fig. 7. The Top Occurance Keywords.

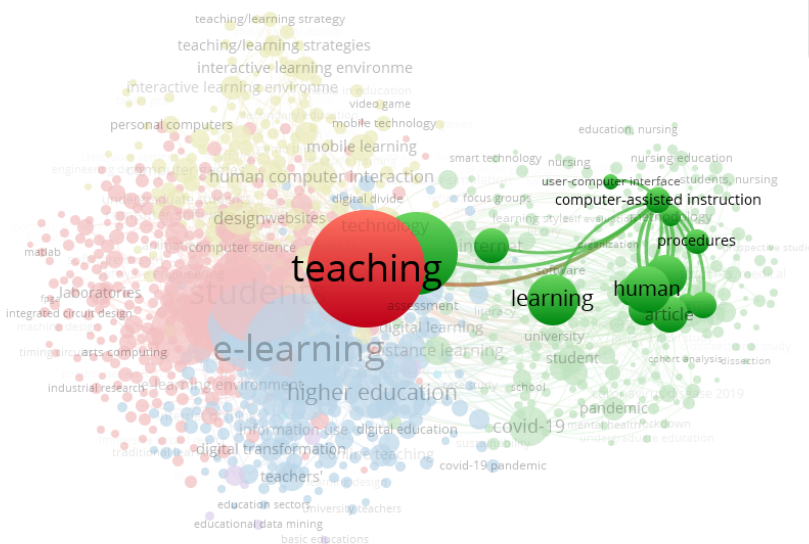


Fig. 8. The Few Occurance Keywords.

In order to identify the originality of prior research, an examination of metadata keywords through mapping is conducted [33]. Therefore, within the realm of DLE publications spanning three decades, the novel aspects are depicted in **Fig. 7** and **8**. As shown in **Fig. 7**, there is a noticeable research interest in e-learning and teaching, as evidenced by its substantial total link strength. Consequently, forthcoming research endeavors could focus on enhancing e-learning methods, such as integrating e-learning activities into universities, high schools, and early education. Alternatively, researchers could explore the application of e-learning across all educational institutions and evaluate its impact. On the other hand, **Fig. 8**, with its more limited set of keywords, highlights research opportunities related to developing learning techniques and the emergence of computer-assisted learning as an instructional system. These keywords can be utilized to

uncover novel approaches and recommend actions such as implementation, development, enhancement, installation, or further research.

3.3 Review of DLE's most cited papers from 1993 to 2022

Table 1 provides an evaluation of the three most frequently cited publications considered to be highly influential in the field of DLE from 1993 to 2022. Each of these articles underwent analysis based on their citations, Scimago Journal and Country Rank (SJR) data retrieved from www.scimagojr.com as well as CiteScore data accessed on www.scopus.com as of October 2023. This analysis includes a review of the findings and recommendations presented in each publication [34–37].

Table 1. Review of Most Cited Papers on DLE Publication from 1993 to 2022.

Author(s)	Citation	SJR	CiteScore	Findings & Recommendations
Papastergiou, (2009) [38]	1,111	Q1 (3.68)	23.8	The findings indicate that educational computer games can serve as practical and motivating learning environments in high school computer science, regardless of the student's gender.
Rapanta et al. (2020) [39]	888	Q1 (2.45)	16.5	The creation of learning tasks possessing specific attributes, the integration of three presence types (social, cognitive, and facilitatory), and the necessity to adjust assessments to meet the evolving learning demands.
Robin & Robim (2008) [40]	608	Q1 (1.25)	4.6	In recent years, digital storytelling has gained prominence as an effective educational tool that captivates both educators and their students. Even so, up until recently, there has been a need for more emphasis on the development of a theoretical framework

Author(s)	Citation	SJR	CiteScore	Findings & Recommendations
				that could enhance the efficacy of technology as a classroom tool.

Furthermore, based on **Table 1**, these publications become fundamental for future research, so they have outstanding citations and impact DLE development. As of October 2023, a list of the most highly cited publications in Quartile 1 (Q1) ranked journals, with CiteScores ranging from 23.8 to 4.6, is provided. This indicates that these publications hold significant influence and unquestionable credibility, mainly due to the reputable nature of the publishers. The analysis of the SJR indicator assigns varying scores to citations based on the significance of the source journal from which the citation originates. Consequently, citations from influential journals hold more significant value, and the journals receiving such citations tend to gain increased recognition and prominence.

4 Conclusion and remarks

Based on the findings and subsequent discussion, it is evident that there is a consistent upward trajectory in publication trends on an annual basis. Articles represent the most prevalent document type, with conference papers following as the second most common form of publication. Opportunities for future research include the exploration of novel approaches through the integration of e-learning into educational institutions, ranging from universities to high schools and early education. On the other hand, a more limited set of keywords points to prospects for research in the realm of developing innovative learning techniques and the establishment of computer-assisted learning as an instructional framework. Notably, the most influential studies belong to the Q1 category.

The research's broader implication is to provide a comprehensive understanding of the trends in DLE publications from 1993 to 2022 and their potential contributions to the Sustainable Development Goals (SDGs). Moreover, future researchers can leverage this knowledge to refine and advance research in the field of educational DLE, ultimately contributing to the attainment of SDG objectives. This research framework enables subsequent researchers to establish a document profile that serves as a focal point for further exploration. By identifying the most pertinent topics within Scopus' DLE, researchers can effectively narrow down the emerging trends in this research domain.

References

1. S. Clark, M. Maclachlan, K. Marshall, N. Morahan, C. Carroll, K. Hand, N. Boyle, K. O'Sullivan, *Sustain.* **14** (2022)
2. M. Akintolu and C. Uleanya, *Univ. J. Educ. Res.* **9**, 713 (2021)
3. D. Rad, A. Redeş, A. Roman, S. Ignat, R. Lile, E. Demeter, A. Egerău, T. Dughi, E. Balaş, R. Maier, C. Kiss, H. Torkos, G. Rad, *Front. Psychol.* **13** (2022)

4. N. Voulvoulis, M. A. Burgman, *Crit. Rev. Environ. Sci. Technol.* **49**, 1079 (2019)
5. M. Laufer, A. Leiser, B. Deacon, P. Perrin de Brichambaut, B. Fecher, C. Kobsda, and F. Hesse, *Int. J. Educ. Technol. High. Educ.* **18** (2021)
6. A. Amran, I. Jasin, M. Perkasa, et al., *Journal of Physics: Conference Series* **1521**, 4 (2020)
7. J. Holmes, O. R. Moraes, L. Rickards, W. Steele, M. Hotker, A. Richardson, *Int. J. Sustain. High. Educ.* **23**, 503 (2022)
8. S. Ghanem, *Int. Sustain. Resil. Conf. Technol. Innov. Build.* **12** (2020)
9. N. S. Alotaibi, *Sustain.* **14** (2022)
10. V. Vázquez-Verdera, J. Domingo, E. Dura, D. Gabaldón-Estevan, E. López-Baeza, S. M. López, F. Meco-Tébar, S. Rueda, J. J. Serrano-Lara, I. Signes-Soler, M. L. V. de Á. Pascual, and E. Martínez-García, *Sustain.* **13**, 1 (2021)
11. Y. J. Utama, B. Setiyono, M. Tauviquirrahman, and H. Susanto, *E3S Web Conf.* **125**, 1 (2019)
12. Z. Hakimova, *E3S Web Conf.* **413**, 1 (2023)
13. H. Purnaweni, A. Roziqin, S. P. Hadi, *E3S Web Conf.* **317** (2021)
14. R. Prancuté, *Publications* **9**, (2021)
15. F. J. Agbo, S. S. Oyelere, J. Suhonen, M. Tukiainen, *Smart Learn. Environ.* **8**, 1 (2021)
16. M. Shareefa, V. Moosa, *Eur. J. Educ. Res.* **9**, 331 (2020)
17. P. Song and X. Wang, *Asia Pacific Educ. Rev.* **21**, 473 (2020)
18. Z. Liu, J. Moon, B. Kim, and C. P. Dai, *Educ. Technol. Res. Dev.* **68**, 1931 (2020)
19. C. T. Ha, T. T. P. Thao, N. T. Trung, L. T. T. Huong, N. Van Dinh, T. Trung, *Eurasia J. Math. Sci. Technol. Educ.* **16** (2020)
20. H. L. T. Thu, T. Tran, T. T. T. Phuong, T. L. T. Tuyet, H. Le Huy, T. V. Thi, *Educ. Sci.* **11**, (2021)
21. D. F. Al Husaeni, A. B. D. Nandiyanto, R. Maryanti, *Indones. J. Teach. Sci.* **3**, 1 (2023)
22. S. M. A. H. Gillani, A. B. A. Senin, J. Bode, Muniba, S. M. A. H. Gillani, *Int. J. Interact. Mob. Technol.* **16**, 48 (2022)
23. Y. Hou and Z. Yu, *Educ. Sci.* **13**, 125 (2023)
24. H. Soegoto, E. S. Soegoto, S. Luckyardi, A. A. Rafdhi, *Indones. J. Sci. Technol.* **7**, 89 (2022)
25. I. Rodr and N. Shirvanizadeh, *Int. J. Environ. Res. Public Health* **18**, (2021)
26. X. Cheng, Y. Wu, S. Member, G. Min, A. Y. Zomaya, *IEEE J. Sel. AREAS Commun.* (2020)
27. V. Seters, *Comput. Educ. Artif. Intell.* **1**, 1 (2020)
28. R. Davidson, Y. Liu, *Lang. Cult. Curric.* **33**, 32 (2020)
29. S. N. Sari, D. Aminatun, *J. English Lang. Teach. Learn.* **2**, 16 (2021)
30. R. Rabiman, P. Sudira, H. Sofyan, M. Nurtanto, *Int. J. Interact. Mob. Technol.* **15**, 130 (2021)
31. S. Hussain, *Alford Counc. Int. English Lit. J.* **2**, 6 (2019)
32. V. Ramírez-Castañeda, *PLoS One* **15**, 1 (2020)
33. S. H. P. W. Gamage, J. R. Ayres, M. B. Behrend, *Int. J. STEM Educ.* **9**, (2022)
34. M. Torres-Samuel, C. L. Vázquez, A. Viloría, N. Varela, L. Hernández-Fernandez, R. Portillo-Medina, *Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)* **10943 LNCS**, 188 (2018)

35. L. Sun, *Learn. Publ.* **32**, 207 (2019)
36. I. Ianoş, A. I. Petrişor, *Publications* **8**, (2020)
37. S. Kasper, *Int. J. Psychiatry Clin. Pract.* **25**, 1 (2021)
38. M. Papastergiou, *Comput. Educ.* **52**, 1 (2009)
39. C. Rapanta, L. Botturi, P. Goodyear, and L. Guàrdia, *Postdigital Sci. Educ.* **2**, 923 (2020)
40. B. R. Robin, B. R. Robin, *Theory Pract.* **37** (2009)