

Mapping Sustainable Development Goals in Secondary Education: Implications for Technical Education through Curriculum Integration

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Abstract—This study maps global research on sustainable development goals (SDGs), education for sustainable development (ESD), curriculum integration, and secondary education, and interprets the findings for technical education, including vocational education and training (VET). A bibliometric approach was applied using Publish or Perish for data retrieval and VOSviewer for keyword co-occurrence, overlay, density, and node-focused visualizations. The findings show that SDGs and education occupy central positions in the research field, higher education remains prominent, curriculum integration occupies an intermediate position, and secondary education remains comparatively peripheral. These patterns indicate a persistent research gap in school-level sustainability education. For technical education, the findings highlight the need to connect sustainability competencies with disciplinary knowledge, practical technical skills, teacher preparation, assessment, employability, and workplace practices. The study provides a transition perspective in which evidence from secondary sustainability education can inform a more systematic VET research agenda for preparing technical students for sustainable workplaces and societies.

Keywords—curriculum integration; education for sustainable development; sustainable development goals; sustainability competencies; technical education; technical students.

I. INTRODUCTION

The sustainable development goals (SDGs) emerged as a popular framework for research on sustainability and education. Education for sustainable development (ESD) is concerned with the development of knowledge, skills, values, and competencies to meet interrelated environmental, social, and economic challenges (Kioupi & Voulvoulis, 2019; Agbedahin, 2019). Bibliometric studies show a significant increase in the scholarship of ESD, with higher education, environmental education, sustainability, and teacher preparation being among the most prominent research themes (Hallinger & Chatpinyakoo, 2019; Yang & Xiu, 2023). Given the impact of formal education on learners' knowledge, environmental consciousness, and

preparedness for future social and occupational roles, it is of great importance to integrate sustainability into educational curricula. Learning for sustainability can strengthen learners. The importance of integrating sustainability into educational curricula is that formal education influences learners' knowledge, environmental awareness, and preparation for future social and occupational roles. By incorporating SDG-relevant content in a meaningful way into educational experiences, learner engagement and environmental awareness can be enhanced (Kelana et al., 2025; Papavasileiou et al., 2025; Nada et al., 2026). Educational reform consistent with the SDGs also requires attention to curriculum development and teacher preparation rather than viewing sustainability as an isolated subject. (Khakimova, 2025; Triyanto, 2026; Weerawong et al., 2025).

This gap is important because secondary education provides a transition between general education, higher education, and occupational preparation. The acquisition of sustainability-related competences in secondary education can build a basis for students going to technical education, influencing their engagement in professional learning, work practices, and environmental responsibility. However, curriculum integration remains an age-old problem. Sustainability is often added to existing subject areas rather than being systematically integrated into learning objectives, activities, and assessment (Lozano et al., 2015; Muhaimin et al., 2026; Gamage et al., 2022).

The link between secondary education and subsequent pathways in technical education, including vocational education and training (VET), is therefore important. Technical education offers an applied context to translate sustainability principles into technical competences, workplace practices, green skills and employability, linking formal learning with occupational and professional preparation. Research on technical education, including TVET contexts, has pointed to the importance of instructor competence as educational systems adapt to technological

and industrial change (Shahroni et al., 2022; Widaningsih et al., 2025). Sustainability-oriented educational models also demonstrate that occupational identity and self-efficacy can be aligned with SDG-oriented professional development (Fiandini et al., 2025).

Hence, sustainability should be linked to occupational knowledge and practical competence for technical students instead of only general environmental content. In VET, this involves the integration of sustainability into technical work, resource efficiency, workplace accountability, problem-solving, and professional preparedness. This incorporation also requires instructors who can bridge broad sustainability principles with occupation-specific learning experiences.

This study addresses this issue through a bibliometric mapping of research at the intersection of SDGs, ESD, curriculum integration, and secondary education. The dataset does not directly represent VET research. So, VET is treated as an interpretative extension of the bibliometric findings rather than as a characteristic of the dataset itself. This distinction preserves the empirical basis of the study while allowing the secondary-education findings to inform future research on technical education, vocational curricula, teacher preparation, sustainability competencies, and occupational learning.

This study aims to map the structure and development of sustainability-related education research and identify the position of secondary education within this literature. The findings are subsequently interpreted in relation to technical education, with particular attention to curriculum integration, sustainability competencies, teacher preparation, occupational learning, practical competence, and employability. By distinguishing direct bibliometric evidence from VET-oriented implications, the study provides a clearer foundation for future research on sustainability-oriented technical education and the preparation of technical students for sustainable professional and workplace environments.

II. LITERATURE REVIEW

A. Sustainable Development Goals (SDGs) and Education for Sustainable Development (ESD)

ESD links educational processes with the environmental, social and economic dimensions of sustainable development. Research on this topic has burgeoned, especially in the wake of the growing global interest in the SDGs. However, bibliometric evidence suggests that this development has been uneven across educational contexts, with considerably more attention being paid to higher education than to education at the school level (Hallinger & Chatpinyakoo, 2019; Yang & Xiu, 2023). Sustainability education is more than inserting environmental themes into current courses. It requires the development of competencies that enable learners to understand sustainability challenges and apply relevant knowledge in educational, social, and professional contexts. Sustainability-oriented learning can strengthen learner engagement and environmental awareness when sustainability principles are meaningfully

incorporated into learning activities (Kelana et al., 2025; Nandiyanto et al., 2026). Educational reform aligned with the SDGs therefore requires corresponding development in curriculum and teaching practices (Khakimova, 2025).

B. Curriculum Integration and Secondary Education

Curriculum integration provides a means of translating generic sustainability goals into learning outcomes, activities, and assessment. However, the infusion of sustainability is often piecemeal or ancillary rather than systematically infused throughout the curriculum (Lozano et al., 2015). This limitation is especially important at the secondary level because secondary education provides the basis for further academic and occupational pathways. Research also indicates an imbalance between secondary and higher education. Higher education has a much more developed research base for sustainability than secondary education (Hallinger & Chatpinyakoo, 2019; Kusumaningrum et al., 2023). This difference suggests a need to examine not only the volume of sustainability research but also how curriculum-related themes are connected with different educational levels.

C. Implications for Technical and Vocational Education

The secondary-education gap is particularly relevant to vocational education and training (VET), as VET is the education that links education with occupational preparation. Sustainability-oriented VET requires that technical students achieve occupational competence and understand how technical activities relate to resource efficiency, environmental responsibility and sustainable workplace practices. In this process, the competence of instructors is important, because teachers have to translate technological and industrial changes into relevant technical learning. Studies on TVET teachers have identified competencies required to respond to a changing industrial environment. (Shahroni et al., 2022; Jafar et al., 2020; Rajamanickam et al., 2024). Sustainability-oriented professional development can also support occupational identity and self-efficacy, illustrating how technical learning can connect professional preparation with broader sustainability objectives (Fiandini et al., 2025; Tarlochan et al., 2025; Doğan et al., 2025). Curriculum integration is therefore particularly relevant for technical students. Sustainability should not be treated as an isolated topic but connected with technical knowledge, practical activities, problem-solving, assessment, and workplace preparation. This approach provides a basis for examining how sustainability competencies developed during secondary education can subsequently support more specialized technical and occupational learning.

D. Research Gap and Conceptual Position

Research on sustainability education shows an increase in this area, but also indicates an uneven development at different educational levels. Secondary education is relatively neglected, and higher education remains the main

focus. Curriculum integration is an important but underdeveloped aspect of sustainability education. This study fills this gap by investigating the bibliometric relationships between SDGs, ESD, curriculum integration, and secondary education. Significantly, the dataset does not directly reflect VET research. The implications of the secondary-education findings are thus discussed in terms of their relevance for VET rather than as direct evidence about VET. This distinction provides a basis for identifying future research priorities concerning technical students, sustainability competencies, teacher preparation, occupational learning, and curriculum development.

III. METHOD

A. Research Design

This study employed a bibliometric approach to examine global publication patterns related to sustainability and education, with particular attention to secondary education and curriculum integration. The original dataset was retained so that the bibliometric results and visualizations remained consistent with the underlying analysis. The implications for VET were interpreted after the bibliometric analysis rather than incorporated into or used to modify the dataset.

B. Data Collection

Bibliographic data were retrieved using Publish or Perish (PoP). Four search terms were used: Sustainable Development Goals, Education for Sustainable Development, curriculum integration, and secondary education. These terms represented the broad sustainability framework and the educational and curricular concepts examined in the study. The retrieved dataset contained publication years, citation information, journals, publishers, and author information for subsequent bibliometric analysis. Figure 1 presents an overview of the dataset retrieved

through PoP and used as the basis for subsequent bibliometric mapping.

C. Data Processing and Visualization

The dataset was imported into VOSviewer to construct and visualize the bibliometric networks. Three main visualizations were generated: keyword co-occurrence, overlay, and density visualizations. The keyword co-occurrence network was used to examine relationships among terms, the overlay visualization provided a temporal perspective based on average publication year, and the density visualization indicated concentrations of scholarly attention within the network. In addition, four node-focused overlay maps were generated for sustainable development goal, education, higher education, and curriculum. These maps enabled more detailed examination of the network surrounding each major term. Together, the analyses produced seven VOSviewer visualizations representing the structural and temporal characteristics of the research field.

D. Methodological Scope and Limitations

The bibliometric approach enables systematic examination of relationships, trends, and gaps within the retrieved literature. However, keyword-based retrieval depends on the terminology used in publications. Relevant studies using alternative terms, such as “eco-schools,” “green schools,” or country-specific curriculum terminology, may therefore not have been captured. In addition, co-occurrence and overlay analyses identify relationships among terms but do not explain the underlying causes of those relationships. The dataset specifically represents the four search terms used in the retrieval process and does not directly map VET scholarship. Consequently, interpretations concerning VET and technical students are treated as implications of the bibliometric findings rather than direct bibliometric evidence about VET.

Cites	Per year	Rank	Authors	Title	Year	Publication	Publisher
✓ 44	44.00	83	Y Orman	Understanding how to develop a...	2026	Globalisation, Societies and...	Taylor &Francis
✓ 1	1.00	1	S KUMAR, S ARORA	INTEGRATION OF SUSTAINABLE D...	2025	TPM-Testing, Psychomet...	tpmap.org
✓ 4	4.00	4	NT Do, MP Thinh	Integrating sustainable developm...	2025	... in Geographical and En...	Taylor &Francis
✓ h 257	257.00	57	C N Ugwu, OPC U...	Sustainable development goals (S...	2025	Medicine	journals.lww.com
✓ 2	2.00	62	AF Maluleke	Educational technology for sustai...	2025	Journal of Educational Le...	noyam.org
✓ h 250	250.00	79	GW Mbijaszek	Ecopedagogy: Teaching critical fl...	2025	Ecopedagogy and the Glo...	api.taylorfrancis.com
✓ h 481	481.00	91	A Ziai	Development discourse and glob...	2025		taylorfrancis.com
✓ 22	11.00	8	C Guo, Y Huang, ...	Research on integration of the su...	2024	Sustainability	mdpi.com
✓ h 161	80.50	9	ME Angelaki, F Be...	Towards more sustainable higher ...	2024	Education and ...	Springer
✓ h 280	140.00	13	A Zickafosse, O IL...	Barriers and challenges affecting ...	2024	Sustainability	mdpi.com
✓ h 268	134.00	18	E Yetti	Pedagogical innovation and curri...	2024	Journal of Open Innovatio...	Elsevier
✓ h 170	85.00	23	OAG Opešemowo...	Harnessing artificial intelligence f...	2024	..., Teaching and Education...	academia.edu
✓ h 113	56.50	38	C Işık, S Ongan, H ...	A new pathway to sustainability: I...	2024	Journal of Ekonomi	dergipark.org.tr
✓ 79	39.50	63	PA Solihah, I Kania...	... problem-solving skills in scienc...	2024	Indonesian Journal of ...	ijost.upi.edu
✓ 64	32.00	90	OG Nwachukwu	Human capital development: A d...	2024	British Journal of education	academia.edu
✓ h 167	83.50	92	Y Yu, D Appiah, B ...	Integrating rural development, ed...	2024	Sustainability	mdpi.com
✓ 3	1.00	2	AS Albuquerque, ...	Integration of Sustainable Develo...	2023	EDULEARN23 ...	library.iated.org
✓ h 177	99.00	11	S Baena-Morales...	Physical education for sustainabl...	2023	Sport, Education and ...	Taylor &Francis
✓ h 369	123.00	25	MI Saini, E Sengup...	Sustainable Development Goal fo...	2023	Education and Informatio...	Springer
✓ h 230	76.67	28	W Leal Filho, AL S...	An overview of the engagement ...	2023	Journal of Cleaner Produc...	Elsevier
✓ h 152	50.67	34	N Vioreza, W Hilya...	Education for Sustainable Develo...	2023	... Journal of Educational ...	ejerp.id-ise.org
✓ h 159	53.00	44	A Catlacutan, OK K...	Competence based curriculum d...	2023	... Journal of Education ...	researchgate.net
✓ h 158	52.67	46	SM Jamal, N Ala E...	The role of STEM Education in im...	2023	... Technology and Design...	Springer
✓ h 187	62.33	50	P Kumar, J Sahani...	Using empirical science educatio...	2023	... and Sustainable Energy ...	Elsevier
✓ h 253	84.00	64	P Berrone, HE Rou...	How can research contribute to t...	2023	International Journal ...	Wiley Online Library
✓ h 115	38.33	66	F Rosati, VP Rodri...	Business model innovation for th...	2023	Business strategy and ...	Wiley Online Library
✓ 55	18.33	68	W Sass, S De Mery...	Honing action competence in su...	2023	... Development and ...	Springer
✓ 47	15.67	72	B Martinione, S Di...	A conceptual framework for sust...	2023	... for Sustainability	reference-global.com
✓ h 127	42.33	84	A Alam, A Mohanty	Developing 'happiness mgneme...	2023	Qubahan Academic Journal	journal.qubahan.com
✓ 52	17.33	86	B LI, I Sjøtrom, B ...	Education for sustainability meet...	2023	Science &Education	dive-portal.org
✓ h 288	96.00	89	D Buhalis, XY Leu...	Tourism 2030 and the contributio...	2023	Tourism ...	emerald.com
✓ h 210	70.00	93	KL Whittingham, ...	The impact of the United Nations...	2023	BRQ Business ...	journals.sagepub.com
✓ h 216	72.00	98	O Deubaniuk, M I...	Learning and teaching sustainabl...	2023	... Journal of Educational ...	Springer

Fig. 1. Overview of the bibliometric dataset retrieved using the selected keywords, including publication years, citation information, journals, and publishers.

IV. RESULTS AND DISCUSSION

A. Keyword Co-Occurrence Network

Figure 2 presents the keyword co-occurrence network and shows the overall structure of sustainability-education research. SDGs and education occupy the most central positions, indicating strong connectivity with other major themes. Higher education also appears as a prominent node, whereas curriculum occupies an intermediate position and secondary education remains comparatively small and peripheral. The pattern confirms that sustainability research has developed more strongly around broad educational themes and higher education than around secondary education. This result is consistent with previous bibliometric studies showing the strong concentration of ESD scholarship in higher education (Hallinger & Chatpinyakoo, 2019; Kusumaningrum et al., 2023; Yang & Xiu, 2023). The weak connectivity of secondary education indicates a structural research gap rather than evidence that sustainability education is absent from secondary-school practice.

B. Temporal Development of Research Themes

Figure 3 presents the overlay visualization and shows the temporal development of the major research themes. SDG-related terms are associated with more recent research activity, while higher education reflects an earlier and more

established research trajectory. Curriculum occupies an intermediate position, suggesting that attention to curriculum integration has increased but remains less developed than the broader sustainability and education themes. Secondary education appears comparatively recent and weakly connected. These findings suggest that increasing interest in sustainability education has not yet produced equivalent research development across all educational levels.

C. Research Density

Figure 4 presents the density visualization and indicates where scholarly attention is concentrated within the network. The highest density of research is observed around SDGs, sustainable development, and education. It is fairly dense for higher education and curriculum. Secondary education is a much less dense area. The convergence of the network, overlay, and density visualizations supports the interpretation that secondary education is still underrepresented in the mapped literature. Also, curriculum integration is less central than the broader sustainability concepts. This finding is consistent with evidence that sustainability is often introduced as supplementary content rather than systematically embedded across curricula (Lozano et al., 2015). Educational activities oriented toward sustainability need a better alignment between the curriculum content, learning experiences, and sustainability competencies (Kelana et al., 2025; Wilhelm et al., 2019).

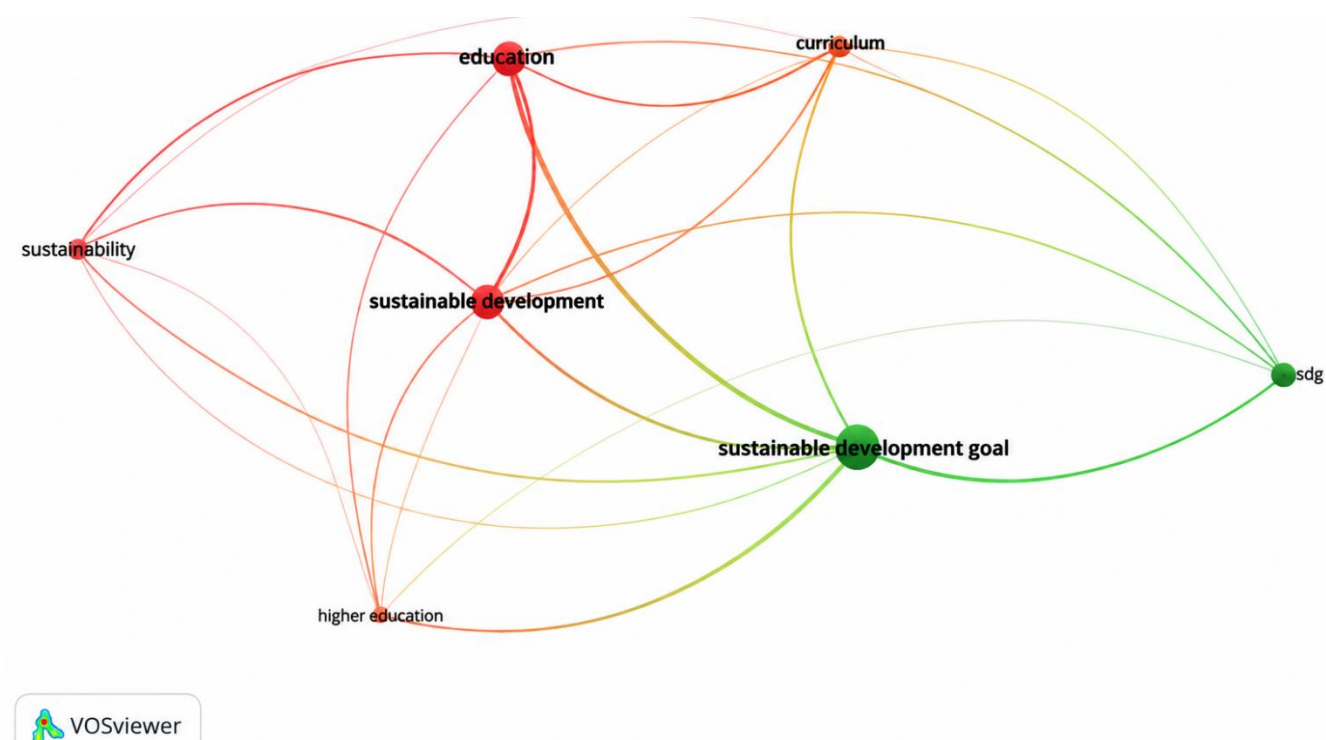


Fig. 2. Keyword co-occurrence network of sustainability and education research created using VOSviewer, highlighting the centrality of SDGs and education and the relative periphery of secondary education.

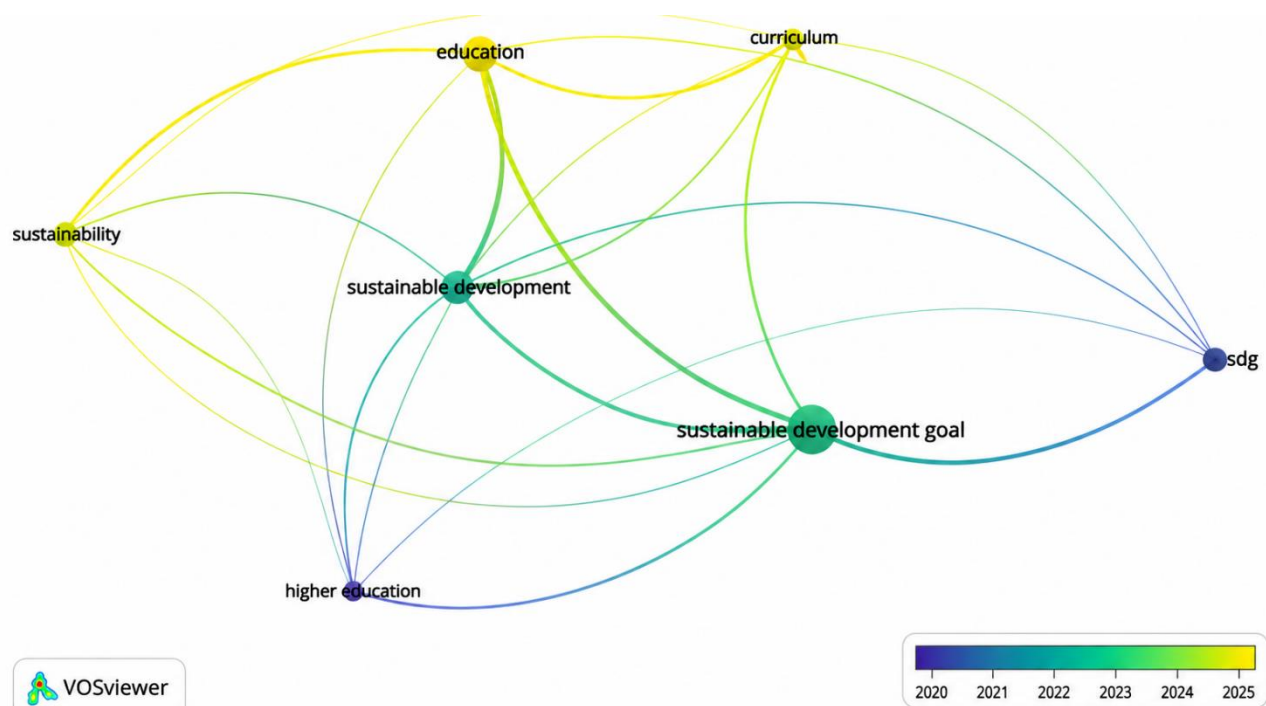


Fig. 3. Overlay visualization of sustainability and education research, produced with VOSviewer, showing the temporal development of the main research themes.

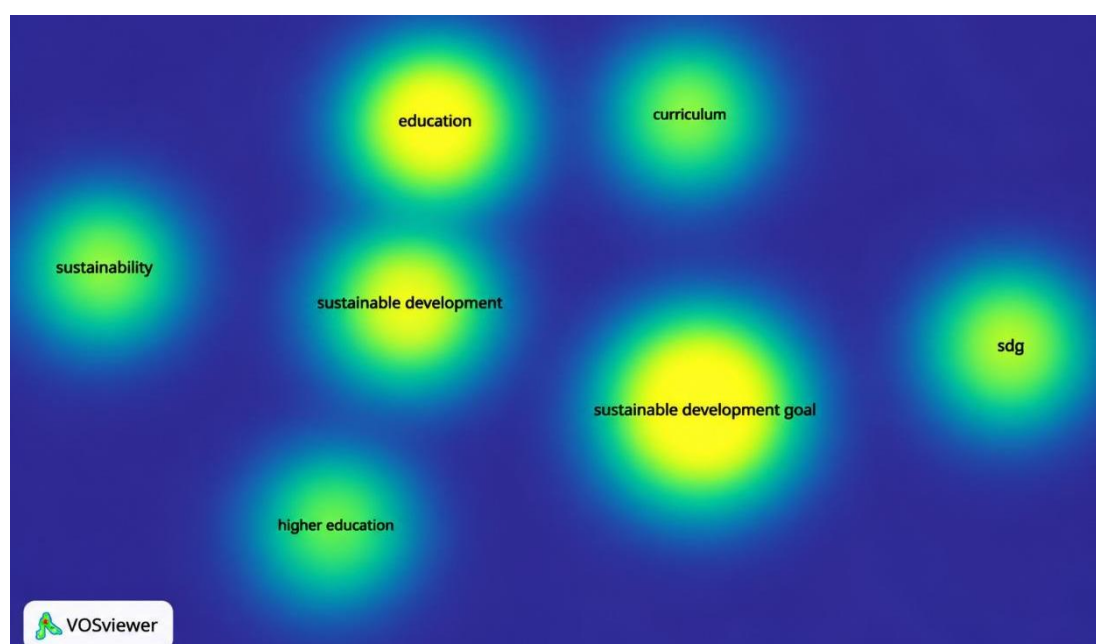


Fig. 4. Density visualization of sustainability and education research produced with VOSviewer showing the concentration of scholarly attention in the bibliometric network.

D. Node-Focused Analysis of the Main Research Themes

To examine the network relationships in greater detail, Figures 5–8 present node-focused visualizations, respectively, for SDGs, education, higher education, and curriculum. From Figure 5, it can be seen that SDGs have a strong relationship with education, while secondary education is relatively distant and weakly related. Figure 6 Concerned with education, this figure also shows strong associations with sustainability-related themes. Again, secondary education seems less closely tied. Figure 7 confirms the established position of higher education within

sustainability research. Its network presence is considerably stronger than that of secondary education, reinforcing the concentration of ESD scholarship at the tertiary level. Figure 8 deals with curriculum. The curriculum is connected to the wider discourse of sustainability, but its connection to secondary education is relatively weak. Figures 5–8 show a consistent hierarchy, with SDGs and education at the core of the research field, higher education well established, curriculum in an intermediate position, and secondary education consistently the weakest and most peripheral theme. This pattern is repeated in different node-focused views, so it is less likely that the observed gap is due to a single visualization configuration.

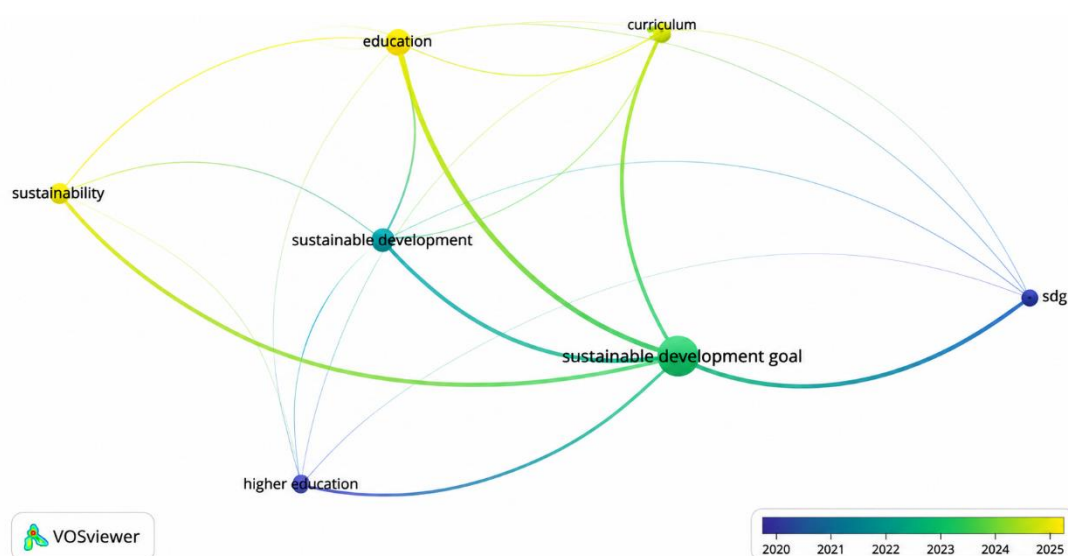


Fig. 5. Node-centered overlay visualization on SDGs, depicting their links with education, higher education, curriculum, and secondary education.

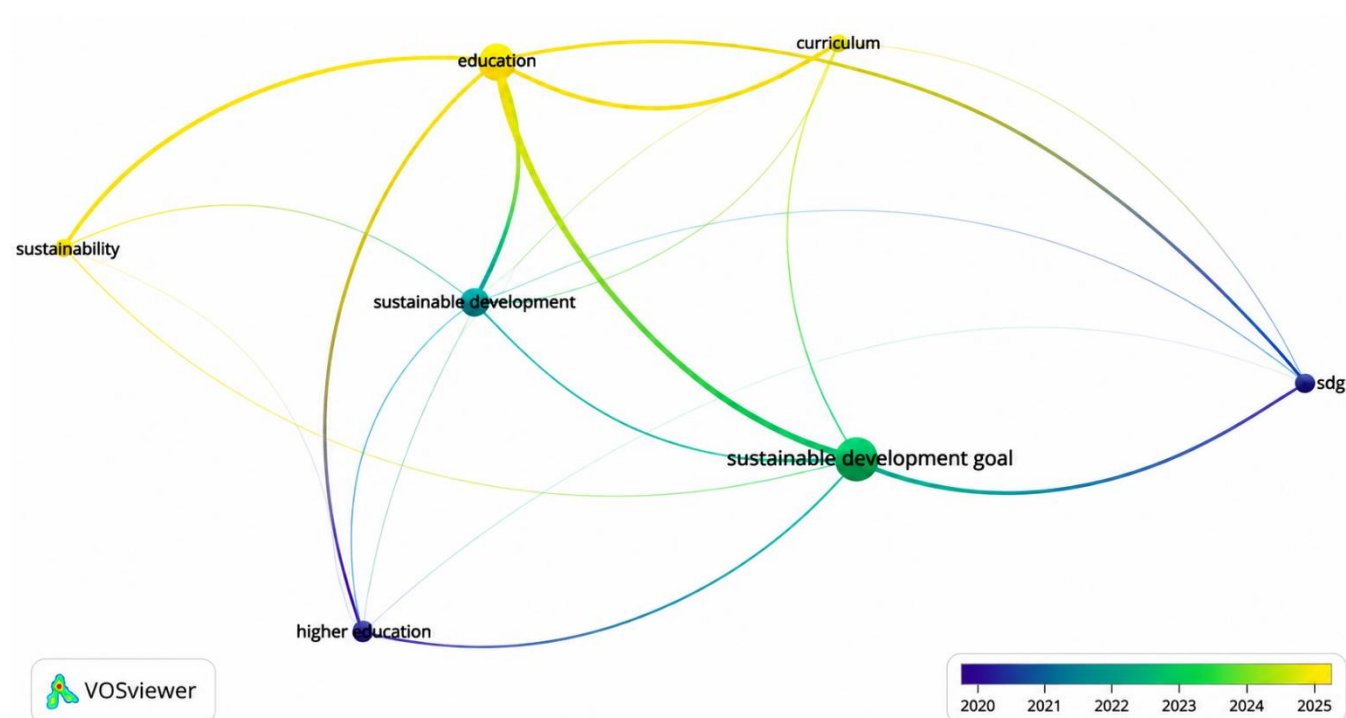


Fig. 6. Node-focused overlay visualization centered on education, showing its relationships with sustainability-related themes and the comparatively weaker connection with secondary education.

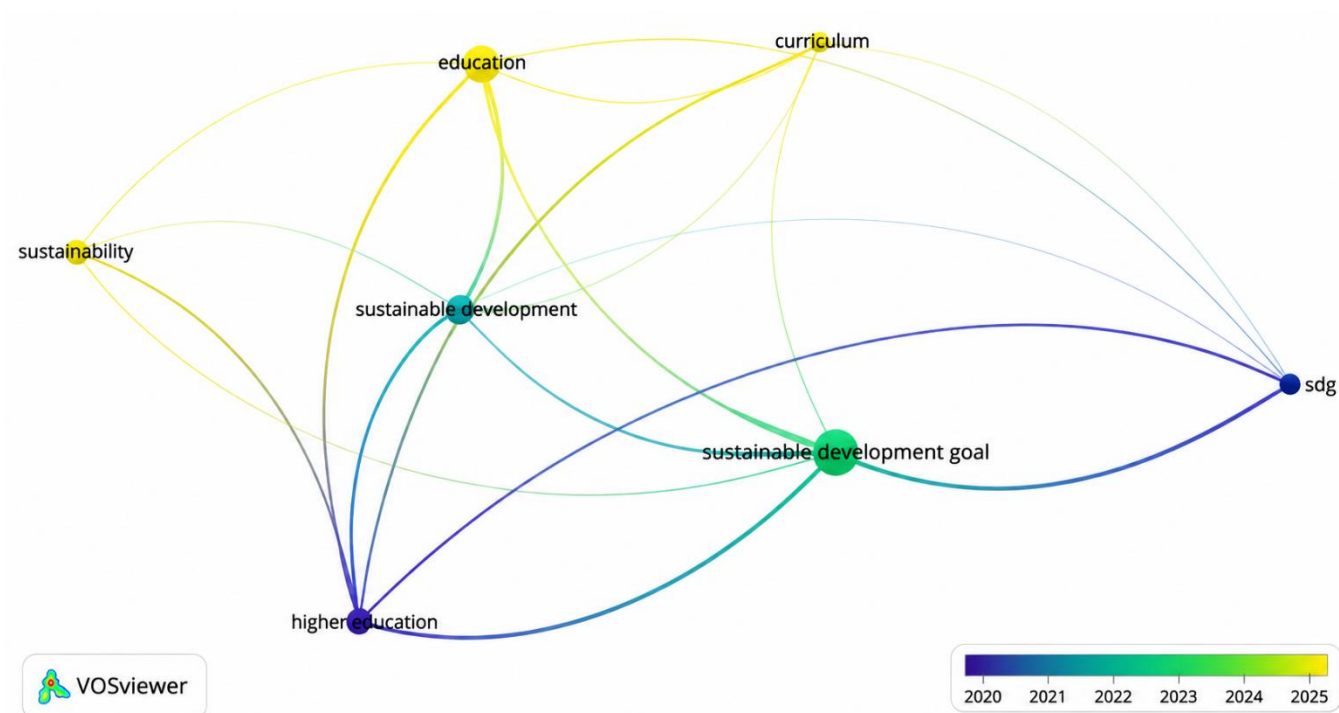


Fig. 7. Node-focused overlay visualization centered on higher education, showing its established position and stronger network connectivity within sustainability research.

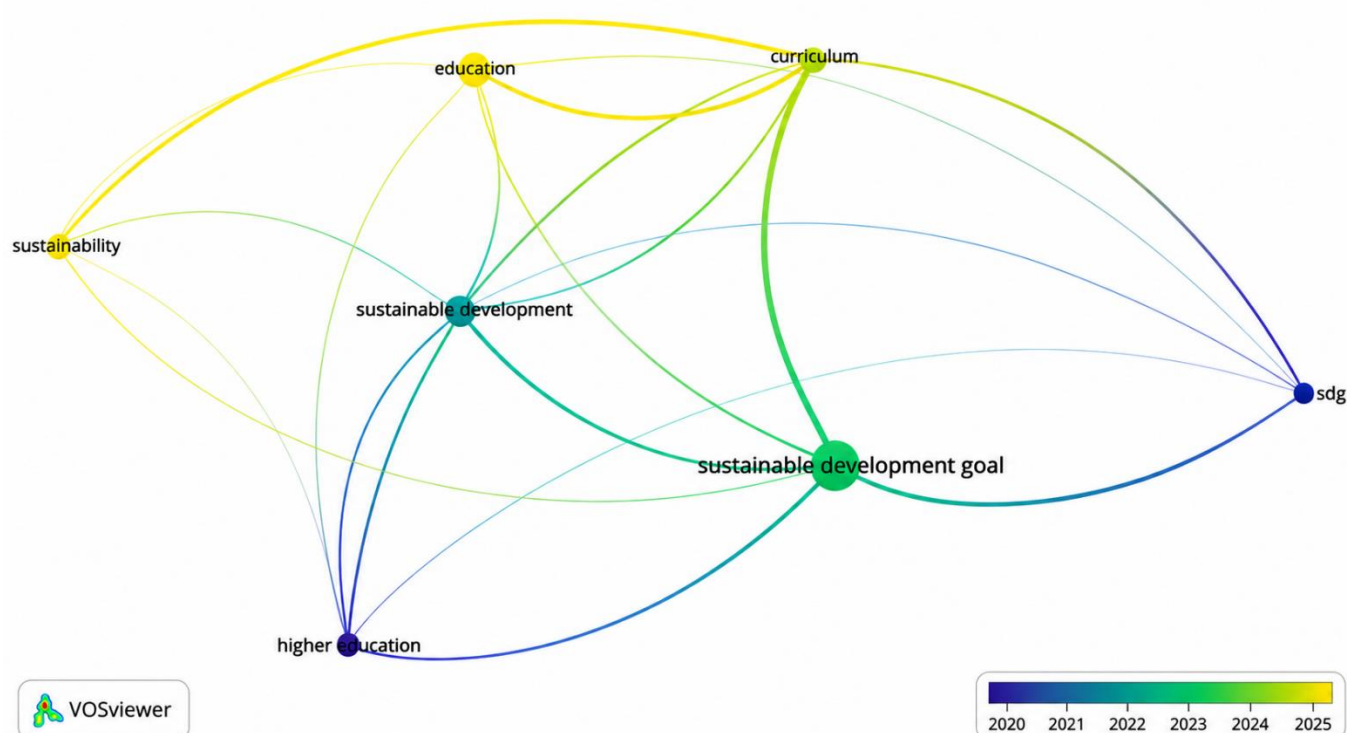


Fig. 8. Curriculum and its relation to SDGs and education, and relatively limited relation to secondary education: A node-centric overlay visualization.

E. Curriculum Integration and Technical Education

The intermediate position of curriculum has important implications for technical education. Sustainability competencies cannot be developed effectively if they remain separate from technical knowledge, practical learning, and assessment. Instead, curriculum integration should connect sustainability with occupational problem-solving, resource efficiency, workplace responsibility, and professional competence. Research on TVET instructors highlights the importance of educator competence in responding to technological and industrial change (Shahroni et al., 2022; Jafar et al., 2020; Hani et al., 2024). SDG-oriented educational approaches also indicate that occupational identity and self-efficacy can be developed alongside professional preparation (Fiandini et al., 2025; Kwee, 2021). For technical students, sustainability can therefore be positioned as part of technical competence rather than as an additional theoretical topic.

F. Implications for Technical and Vocational Education

The bibliometric dataset does not directly measure VET scholarship. Therefore, the following implications should be interpreted as an extension of the secondary-education findings rather than as direct evidence about the structure of VET research. The persistent marginal position of secondary education suggests a need for stronger research on the transition from general sustainability education to occupation-specific learning. In VET, this transition can involve integrating sustainability competencies with technical tasks, workplace practices, green skills, assessment, and employability.

Teacher preparation is also important. Sustainability-oriented curriculum reform requires instructors who can translate broad SDG principles into practical technical learning. Research on educational reform and the SDGs similarly emphasizes the importance of teacher development and curriculum change (Khakimova, 2025; Grobler & Dittrich, 2024; Collazo & Granados, 2020), while studies of TVET instructor competencies emphasize professional readiness for changing industrial requirements (Shahroni et al., 2022; Jafar et al., 2020; Omar et al., 2021).

G. Research and Practical Implications

The findings suggest three priorities for future research. First, bibliometric studies should directly map sustainability-related VET scholarship to determine whether the patterns identified here also occur within technical and occupational education. Second, empirical studies should examine how sustainability competencies are integrated into specific technical programs and occupational fields. Third, teacher preparation should be investigated because curriculum integration depends on instructors' capacity to translate sustainability objectives into practical learning. Future studies should also examine relationships between technical education and industry. Sustainability competencies taught to technical students should correspond with emerging workplace expectations, green practices, and changing occupational standards. Such research would broaden the present bibliometric findings to a better evidence base for sustainability-oriented technical education. However, the results should be viewed in light of the limitations of the dataset. Keyword-based retrieval can miss studies with alternative terminology, and bibliometric mapping identifies patterns of scholarly attention rather than actual curriculum

implementation. The findings therefore point to a gap in research within the mapped literature rather than a direct measure of sustainability practice in individual schools or VET institutions.

CONCLUSION

This study mapped research on SDGs, ESD, curriculum integration, and secondary education and interpreted the findings for vocational education and training (VET). Across the bibliometric visualizations, SDGs and education emerged as the central themes, higher education remained prominent, curriculum occupied an intermediate position, and secondary education consistently appeared as a comparatively peripheral and weakly connected theme. Such research would broaden the present bibliometric findings to a better evidence base for sustainability-oriented technical education. However, the results should be viewed in light of the limitations of the dataset. Keyword-based retrieval can miss studies with alternative terminology, and bibliometric mapping identifies patterns of scholarly attention rather than actual curriculum implementation. The findings therefore point to a gap in research within the mapped literature rather than a direct measure of sustainability practice in individual schools or VET institutions. Curriculum and its relation to SDGs and education, and relatively limited relation to secondary education: A node-centric overlay visualization.

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