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Review Article

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Assessment instruments for sustainability competences in applied biology: A systematic literature review

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ABSTRACT

Sustainability competences are essential for addressing complex global environmental, social, and economic challenges. However, tools to accurately assess these competences remain varied and underexplored, necessitating a comprehensive review of existing instruments. This study aims to systematically identify and analyze assessment instruments for sustainability competences through a systematic literature review (SLR). This type of research is a systematic literature review (SLR). The research instrument is an inclusion and exclusion criteria form. Using the Scopus database, articles published between 2010 and 2023 were screened based on inclusion criteria such as relevance to sustainability competences assessment, peer-reviewed status, and language (English). From an initial 234 articles, 11 met the criteria and were analyzed using bibliometric tools and qualitative synthesis guided by five research questions focusing on publication trends, subject areas, geographic distribution, keywords, and instrument characteristics. The results show dominance of Social Sciences in this field, with notable multidisciplinary inputs from Energy and Environmental Sciences. Key themes include teacher self-efficacy, institutional commitment, and educational tailoring, alongside challenges like weak theoretical foundations and limited curricular integration. The study concludes that culturally adapted and context-specific instruments are critical to effectively evaluate sustainability competences. It recommends further research to develop validated, comprehensive tools to support education and policy. This work provides a structured foundation for advancing sustainability competence assessment globally.

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INTRODUCTION

Sustainability competences have gained increasing importance in recent years as the world faces unprecedented environmental, social, and economic challenges (Demssie et al., 2023; Dzhengiz & Niesten, 2020). These competences are essential for equipping individuals with the knowledge, skills, and attitudes necessary to address complex sustainability issues (Duda, 2022; Heldal et al., 2023). Education institutions, industries, and policymakers have recognized the need for reliable instruments to assess these competences as part of their efforts to foster sustainable development goals/SDGs (Bianchi, 2020; Caeiro et al., 2013; Singh et al., 2023). However, despite the growing recognition of sustainability competences, systematic reviews of the tools and frameworks used to evaluate them remain limited. This article seeks to fill that gap by exploring the current state of research on instruments for assessing sustainability competences through a systematic literature review (SLR) in global databases.

Previous reviews and bibliometric studies have primarily focused on sustainability education and its integration into curricula, with less emphasis on the specific tools used to measure sustainability competences (Kusumaningrum et al., 2023; Umar et al., 2024). While some bibliometric analyses have mapped trends in sustainability education, they have often lacked a detailed examination of the instruments themselves. Some other SLRs focus on action competencies for sustainability (Husamah et al., 2022), environmental education research trend (Husamah et al., 2022), and sustainable development research trend (Husamah et al., 2022). Similarly, SLR studies have predominantly explored broader aspects of sustainability or education for sustainable development (ESD), leaving a gap in understanding the practical methodologies and tools for assessing competences (Albuquerque & dos Santos, 2024; Singh et al., 2023). This lack of focused analysis makes the evaluation and reflection on important information about the instrument less comprehensive, especially its strengths and limitations.

In particular, this study addresses the critical gap concerning instruments designed to assess sustainability competences within the field of biology and applied biology, encompassing knowledge, skills, and attitudes relevant to sustainable practices in biological sciences and their applications. Sustainability competences assessed in this research include ecological literacy, environmental stewardship, socio-environmental responsibility, and integration of sustainability principles in biological and applied biological contexts.

The primary research question guiding this study is: “What are the characteristics, strengths, and limitations of existing assessment instruments for sustainability competences in biology and applied biology, and how can these tools be improved to better support education and practice in these fields?”. To answer this, this article adopts a systematic literature review (SLR) approach following the PRISMA framework to rigorously identify, analyze, and synthesize relevant studies from global databases. This method distinguishes the current research from previous bibliometric studies by focusing specifically on the instruments themselves rather than general trends.

This article aimed to conduct a systematic literature review of global databases to identify, analyze, and synthesize existing research on instruments for assessing sustainability competences. Specifically, it seeks to uncover patterns, highlight underexplored areas, and propose recommendations for advancing the development and implementation of these instruments. By adopting a rigorous and structured approach, this study will provide valuable insights into the current landscape of sustainability competence assessment tools. The contribution of this article lies in its focus on bridging the gap between existing research and practical applications. By mapping the current state of knowledge, identifying research trends, and highlighting opportunities for future exploration, this study offers a comprehensive overview of the field. Furthermore, the findings will serve as a resource for educators, researchers, and

policymakers seeking to develop or refine instruments that promote sustainability competences in various contexts. Ultimately, this article can contribute to advancing the discourse on sustainability education and contribute to the broader goal of achieving sustainable development.

RESEARCH METHODS

This study was conducted using a systematic literature review (SLR), a research approach that follows a structured and detailed process to identify, assess, and synthesize relevant studies on a specific topic. Its purpose is to address a well-defined research question by applying clear inclusion criteria and conducting a critical evaluation. This method aims to reduce bias and ensure the review's reliability and reproducibility, ultimately offering a comprehensive summary of the current knowledge within a particular field through the systematic analysis of existing research literature (Munn et al., 2018; Page et al., 2021).

SLR is a qualitative research method aimed at systematically identifying, assessing, and synthesizing relevant studies to answer clearly defined research questions. The purpose of this SLR is to comprehensively explore existing instruments for assessing sustainability competences, particularly in biology and applied biology contexts, in order to identify their characteristics, strengths, limitations, and research trends. The research sample consisted of peer-reviewed journal articles retrieved from the Scopus database. The search query focused on the phrase "sustainability competence AND instrument OR measurement" across all fields. A total of 359 articles were initially identified using the official Universitas Muhammadiyah Malang subscription.

The research instrument in this context is the search string combined with clearly defined inclusion and exclusion criteria to select relevant studies. The inclusion criteria included articles focusing on sustainability competence assessment instruments, published in English, final published articles (excluding preprints or conference abstracts), and relevance to biology or applied biology fields. Exclusion criteria filtered out articles unrelated to assessment tools or sustainability competences, or those not fitting biological contexts. Regarding the publication year, this study did not limit the search by year to capture both foundational and recent developments comprehensively. This decision was made to ensure a holistic view of the evolution and current state of assessment instruments without arbitrarily excluding older but relevant studies.

The research procedure followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility. The process included identification 359 records were retrieved from Scopus, screening duplicate records and non-article types were removed & resulting in 15 records, eligibility full-text articles were assessed against inclusion/exclusion criteria, leading to 12 articles, and inclusion after detailed review, 11 articles met all criteria and were included for analysis as illustrated in Figure 1.

For data analysis, this study combined bibliometric analysis and qualitative thematic analysis. Bibliometric analysis, performed using VOSviewer, provided visualization of publication trends, keyword co-occurrences, and geographic distributions. Qualitative thematic analysis was applied to systematically categorize and interpret the content related to the instruments' characteristics, their applications, strengths, and limitations. This mixed-method approach allows a comprehensive and nuanced understanding aligned with the research questions.

To achieve the stated objective, we set several research questions (RQ). RQ 1, what is the temporal distribution and the rate of growth of publications focusing on instruments for assessing sustainability competences?. RQ 2, which subject areas are most commonly used as starting points by researchers focusing on instruments for assessing sustainability competences?. RQ 3, which countries are leading in

publications focusing on instruments for assessing sustainability competences?. RQ 4, what is the distribution and relevance of keywords in publications focusing on instruments for assessing sustainability competences?. RQ 5, what instruments do researchers use to assess sustainability competences and what are their interesting findings that can serve as a reflection on this theme?.

The search was focused on the phrase “sustainability competence AND instrument OR measurement” in the search within all fields”, as many as 359 articles were found. The search was carried out using the official subscription account owned by the Universitas Muhammadiyah Malang. Data simulation uses "Analyze search results" which is available on the Scopus system. To enrich data and analysis, the data was exported to *CSV format for visualizing data process with VOSviewer. The search history and article inclusion-exclusion process is as follows: TITLE-ABS-KEY ("sustainability competence" AND instrument OR measurement) AND (LIMIT TO (DOCTYPE, "ar")) AND (LIMIT TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")). The inclusion and exclusion process flow are as shown in Figure 1, which ultimately resulted in 11 selected articles. To analyze the article data found in this SLR, we used a systematic approach that focused on answering five main research questions. The data obtained from the Scopus database were processed using software such as VOSviewer and Scopus online system.

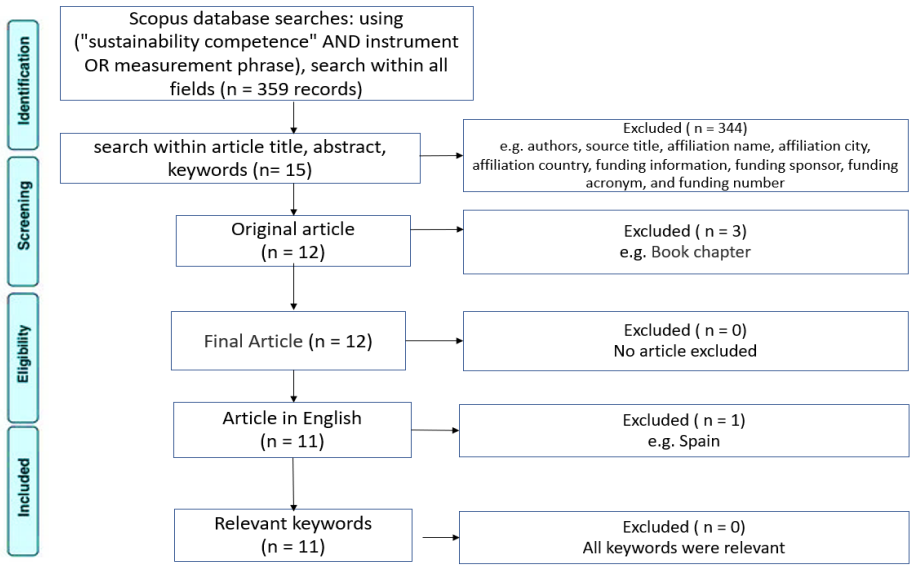

Figure 1. PRISMA Flow Diagram

FINDING AND DISCUSSION

The number of articles in the Scopus database after the exclusion and inclusion process, from 2020-2024 (the last five years) can be seen in Figure 2. Data shows that the number of publications on the issue of instruments and sustainability competences tends to fluctuate in the last five years, the lowest being one article and the highest being three articles. In 2023 and 2024 the number of publications is stable, at three articles.

Figure 2 provides insights into the trend of publications in the Scopus database related to instruments and sustainability competences from 2020 to 2024. After applying the inclusion and exclusion criteria, the data reveals a fluctuating pattern in the number of publications over the past five years. The number of articles published each year ranges from a minimum of one to a maximum of three. This indicates a relatively low but varying level of scholarly interest in this specific topic. The fluctuations may

reflect shifting priorities in sustainability research or the niche nature of this particular subject area (Sahle et al., 2024; Sala et al., 2019).

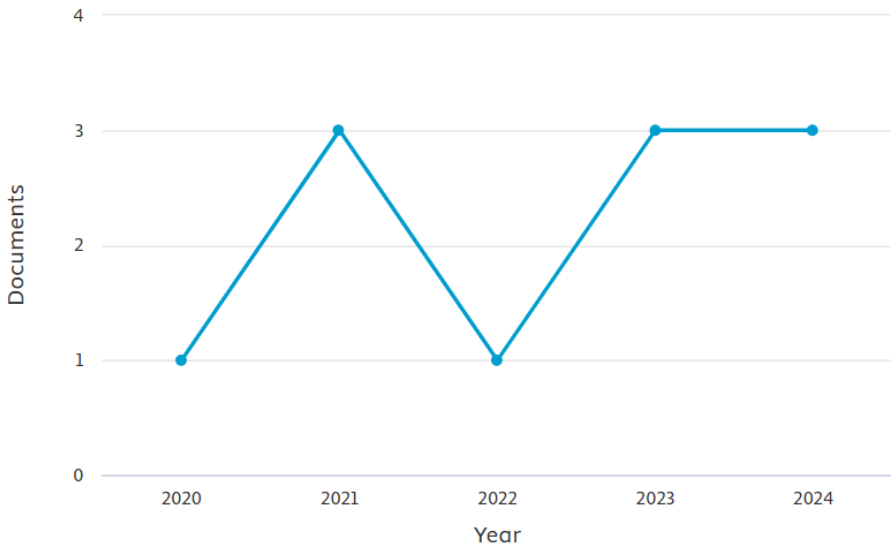

Figure 2. Documents by Year

Interestingly, the data shows stability in 2023 and 2024, with three articles published in each of these years. This consistent number suggests a growing or sustained interest in recent years, potentially influenced by the global emphasis on sustainability and the need for reliable tools to assess sustainability competences. While the overall number of publications remains modest, the stability observed in the last two years could signify an emerging recognition of the importance of research in this field. This trend offers a valuable opportunity for further exploration and calls for increased attention from researchers and institutions to expand the body of knowledge on this critical topic (Redman et al., 2021; Valdes-Ramirez et al., 2024).

The data presented in Figure 3 highlights the distribution of publications by subject area, revealing distinct trends in research focus on instruments and sustainability competences. Social Sciences dominate the field, accounting for 52.4% of the total publications, indicating that this area serves as the primary lens for addressing these topics. This prevalence suggests a significant emphasis on understanding the human, societal, and behavioral dimensions of sustainability competences. The next largest contribution comes from Energy, which constitutes 23.8% of the publications, reflecting a substantial interest in exploring how sustainability competences are applied or assessed within energy-related contexts. Environmental Science, contributing 19.0%, provides critical support by addressing ecological and environmental perspectives, while Computer Sciences, with 4.8%, suggests a smaller but growing role, possibly in developing digital tools or models for assessing sustainability competences.

From the overall distribution, it is evident that the primary focus of research lies within social sciences and energy, supported by environmental science and, to a lesser extent, computer sciences. The dominance of these fields underscores their relevance in understanding and advancing sustainability competences, whether through societal applications, energy systems, or environmental considerations (Gomes, 2019; Michel et al., 2022; Redman et al., 2021). Notably, other subject areas have not yet contributed to this discourse, which could be attributed to the exclusion and inclusion process applied during data collection. This gap presents an opportunity for interdisciplinary exploration, as integrating

insights from additional domains could provide a more holistic understanding of the instruments and competences required to address sustainability challenges effectively (Liu et al., 2022; Schoolman et al., 2012).

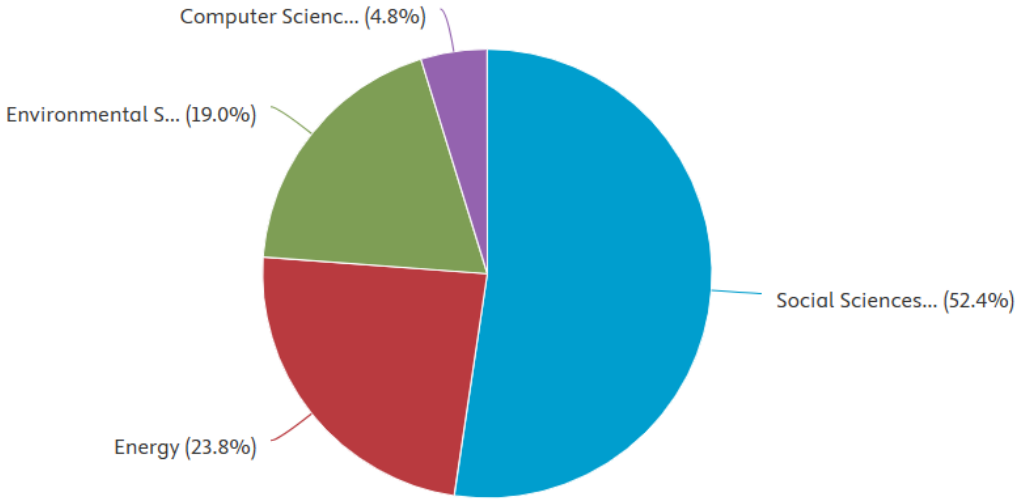

Figure 3. Documents by subject area

The data in Figure 4 illustrates the geographical distribution of authors publishing on the topic of instruments and sustainability competences. Spain emerges as the most dominant contributor, with authors from the country producing seven articles. This significant output underscores Spain's active role in advancing research in this field, possibly driven by the nation's academic focus on sustainability education and the development of assessment tools for sustainability competences (López-Serentill et al., 2024). Ecuador and Germany follow as notable contributors, each producing two articles, highlighting their emerging involvement in this research area. These contributions suggest growing interest in integrating sustainability competences within diverse contexts, particularly in regions where sustainability is increasingly prioritized in educational and professional settings (Dornhoff et al., 2019).

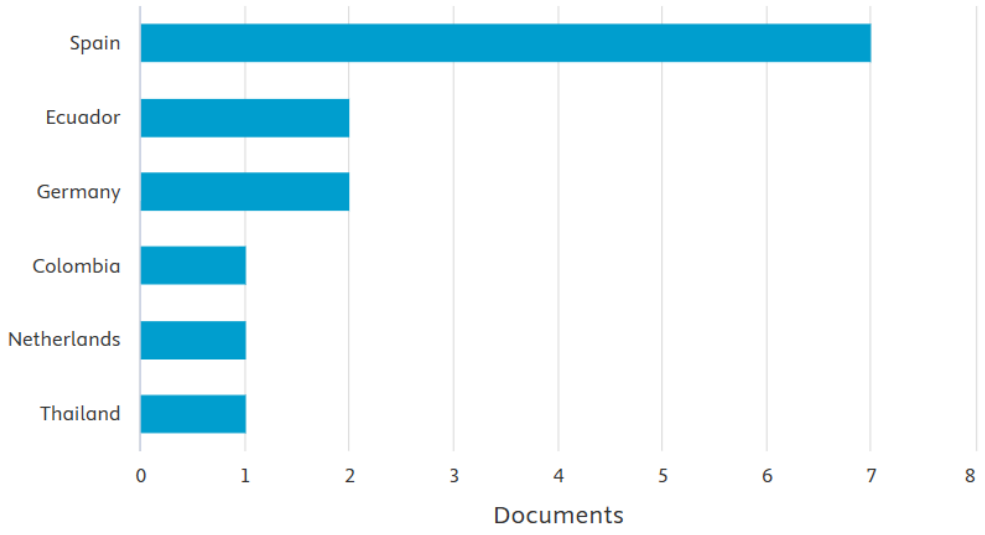

Figure 4. Documents by Country

Meanwhile, Colombia, the Netherlands, and Thailand each contributed one article, reflecting a more modest engagement in this field. This limited participation could indicate either the niche nature of the topic or varying levels of research funding and institutional emphasis on sustainability-related studies across these regions. The low number of contributing countries highlights a significant gap in global representation, suggesting the need for broader international collaboration (Smith, 2024). Expanding contributions from a wider range of countries could provide diverse perspectives and enhance the development of robust, globally relevant tools for assessing sustainability competences. This trend calls for greater investment in sustainability research and international cooperation to ensure comprehensive and inclusive progress in this critical area (Leal Filho et al., 2022; Schneider et al., 2023).

The data presented in Figure 5 highlights the distribution and relevance of keywords within publications focusing on instruments for assessing sustainability competences. There are keywords related to this theme, namely sustainability competence, higher education, education, and sustainable development as dominant keywords, while others - which are also related to the three main keywords - are SDGs, SDGs learning, environmental education, community development, collective action, entrepreneur, firm performance, education for sustainability, education for sustainable development, competence-based education, primary education, critical mathematics education, research, work, curriculum, and competences.

The analysis reveals a clear dominance of keywords such as sustainability competence, higher education, education, and sustainable development. These primary keywords underline the strong emphasis on education as a central avenue for promoting sustainability competences and the pivotal role of higher education institutions in embedding sustainability principles into curricula and practices. The consistent presence of these dominant keywords reflects the critical connection between education systems and the cultivation of competences necessary to address global sustainability challenges (Prior et al., 2024; Young, 2024).

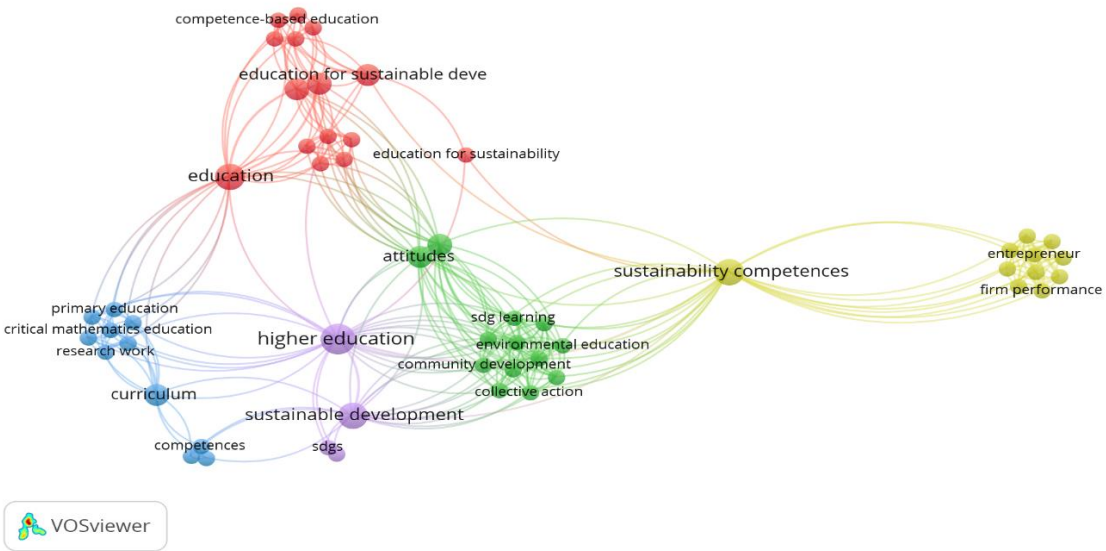

Figure 5. Relevant Keywords (VOSviewer Results)

In addition to the primary keywords, a variety of related terms contribute to the thematic richness of the publications. Keywords such as SDGs, SDGs learning, environmental education, and education for sustainable development indicate a strong alignment with global frameworks and goals for sustainability.

Similarly, terms like community development, collective action, and entrepreneur reflect a broader focus on applying sustainability competences in real-world contexts, fostering societal and economic impacts (Demssie et al., 2023; Quaye et al., 2024). Other keywords such as curriculum, research, and competences suggest ongoing efforts to refine educational approaches and methodologies. Meanwhile, niche terms such as critical mathematics education and competence-based education indicate that the discourse is diversifying, exploring specific pedagogical approaches to advancing sustainability competences (Andersson & Barwell, 2021; Lambrechts et al., 2010).

The diversity of keywords reveals a multi-dimensional approach to addressing sustainability competences, encompassing global frameworks, educational strategies, and real-world applications (Lambrechts et al., 2017; Sá et al., 2022). However, the dominance of certain keywords suggests that the field still centers heavily around established educational contexts, particularly higher education (Lozano et al., 2022). This concentration underscores the need for broader exploration into less-represented areas, such as primary education and professional development, to create a more comprehensive understanding of how sustainability competences can be developed and applied across different sectors and levels of education (Cebrián et al., 2020).

Table 1 summarizes information about the instruments contained in 11 articles found in the Scopus database. The description is done on the aspects of the instrument name, the purpose of the instrument and important information about the instrument. Table 1 illustrates that these instruments demonstrate diverse applications and significant contributions to advancing sustainability competencies across various educational contexts.

Table 1. Information Regarding the Instruments Used in Each Article

No	Author(s)	Instruments	Purpose	Important information about the instrument
1	(Napal et al., 2020)	Sustainability Teaching Tools	Serve to characterize the four dimensions of scientific competence: contents of science, contents about science, the value of science, and the utility of science in educational materials.	The proposed instrument offers a significant advantage by providing a detailed framework that integrates specific contents, actions, understandings, and values within the dimensions of scientific competence, guided by an explicit higher-order conceptual framework. This feature facilitates the integration of competences into educational planning at both the class and curriculum levels, making it particularly useful for ESD, where transformative learning is a key focus. However, the instrument faces limitations, particularly the lack of theoretical references to precisely define the elements constituting the proposed competences. This vagueness, commonly noted by scholars, can hinder the seamless integration of competences into curricula. To address these challenges, a three-step validation process is suggested: expert validation to ensure alignment with foundational scientific concepts and skills, pilot testing for accuracy and differentiation, and user validation with teachers to assess comprehensibility and specificity

No	Author(s)	Instruments	Purpose	Important information about the instrument
2	(Lucas Mangas et al., 2021)	A scale developed by Steg et al (2005), and taken from Hernández et al (2019).	This instrument was designed to effectively assess personal responsibility norms within the framework of the VBN model. It was adapted to a traditional Likert scale format, featuring seven response options ranging from "strongly disagree" to "strongly agree," and included a total of nine items.	This instrument facilitates the analysis of tendencies to foster personal responsibility, as outlined by the VBN model, through environmental education and the implementation of service-based learning projects. Notably, significant differences were identified in only one group of participants in this study.
3	(Moreno-Pino et al., 2021)	An adaptation of the model of the Green Curriculum in Higher Education (ACES model) and the map of generic competencies in sustainability of the EDINSOST project.	• The ACES Network has established a set of criteria for each of the previously mentioned characteristics, enabling the diagnosis of the greening process in a study. Furthermore, these criteria for creating a more sustainable curriculum can be applied across various scales and areas of focus, including curricula, study programs, institutional policies (such as strategic plans), research, and university outreach activities. • The EDINSOST project, focused on education and social innovation for sustainability, trains professionals as change agents in Spanish universities to address societal challenges. Funded by Spain's Ministry of Economy, Industry, and Competitiveness under the state R&D program (EDU2015-65574-R), it uses the four sustainability competencies defined by the CRUE-Sustainability Sectoral Commission as the foundation for mapping sustainability competencies in education.	This study highlights the effectiveness of targeted instruments in diagnosing the integration of sustainability competencies within mathematics education curricula. At the Universidad de Cádiz, sustainability competencies are incorporated at an average rate of 25%, with ethical aspects (SUS4) showing the lowest presence (10%) and critical contextualisation and creative thinking (SUS1) the highest (52%). Most competencies are established at the lowest mastery level (L1: "know"), indicating the need for further curricular development. The Master's degree in Teacher Training showed the highest contribution to sustainability competencies (32%), followed by Early Childhood Education (25%) and Primary Education (18%). These results provide valuable insights for enhancing sustainability education, aligning with SDG 4.7 by promoting reflective and critical mathematical education that equips students with the skills and ethical awareness necessary for sustainable societal transformation.
4	(Scharenberg et al., 2021)	Measurement Instruments at the Student Level and Measurement Instruments at Teachers' Level	• A questionnaire was designed to evaluate various aspects of basic sustainability competencies at the lower secondary level. The full details of the questionnaire are provided in the final report of the research project, including a paper-pencil questionnaire for students (p. 50 onward) and an online questionnaire for teachers (p. 81 onward). • For teachers, the questionnaire included items assessing their professional knowledge about	The study demonstrates the effectiveness of the framework and instruments in assessing sustainability competencies among students and identifying key influencing factors. While students' knowledge improved after integrating ESD into the curriculum, their attitudes and motivation toward sustainability declined. Teachers' self-efficacy, professional knowledge, and institutional emphasis on ESD were critical for fostering students' development, highlighting the instrument's value in improving ESD implementation and addressing gaps in competency development.

No	Author(s)	Instruments	Purpose	Important information about the instrument
			ESD, their teaching practices related to ESD, and their attitudes toward ESD. Many of these items were adapted from a prior study conducted in 2007 in Baden-Wuerttemberg, which was based on a representative sample of teachers.	
5	(Álvarez-García et al., 2022)	A structured questionnaire designed to measure the latent variables of the proposed model and to profile the respondents.	• The scale of competences on sustainable entrepreneurship has a total of 23 items adapted from the scale of Lans et al; • The scale of SEO includes 12 items —5 for social innovativeness and 7 for social proactiveness and risk-taking—, adapted from Kraus et al. • The five items presented in Hormiga et al. were used to measure economic performance, • Four items from the scale of Hosseininia and Ramezani (2016) were consid- ered and adapted to measure social performance, plus 8 items to mea- sure green innovation performance.	The issue of common method bias (CMB) from single-source data collection was addressed using Harman's single-factor test and post-control measures through SPSS. The results showed no single factor explaining more than 50% of the variance, confirming that CMB was not a concern in this study.
6	(Baena-Morales et al., 2023)	Physical Education for Sustainable Development – Future Teacher PESD-FT questionnaire	This instrument assesses sustainable competences in its three dimensions (social, economic and environmental).	To evaluate the impact of the curriculum on sustainability competencies, the academic year under study was included as a variable. Additionally, factors such as gender, age, and experience in institutionalized sports were incorporated into the statistical analysis.
7	(Álvarez-Vanegas et al., 2023)	An instrument used by Leal Filho et al. was found helpful to enquire about sustainability knowledge. The instrument covers 52 questions divided into five parts.	This instrument enables authors to examine (i) the depth of knowledge on sustainability, including approaches to teaching for sustainability, (ii) attitudes toward the Sustainable Development Goals, and (iii) the competencies that Latin American university educators believe they possess.	Aauthors utilized the first two sections, focusing on sustainability knowledge and teaching practices, while also comparing the performance of Latin American educators to the global average reported by the original authors. To ensure consistency, adjustments were made to our results since Leal Filho et al. employed a five-point Likert scale, whereas we used a four-point scale to eliminate a neutral option. This modification aimed to capture clearer tendencies, distinguishing between rejection (values 1 and 2) and support (values 3 and 4) for various statements.
8	(van Harskamp et al., 2023)	The Environmental Citizenship Opinions (ECO) questionnaire	The instrument focusses on general citizenship components, key sustainability competences, and Socio-Scientific Reasoning aspects. By	The ECO questionnaire was validated through a pilot study and a large-scale survey involving 781 lower secondary students. After multiple rounds of Confirmatory Factor Analysis, the final model consisted of 38 items across 7 first-order and 5 second-order constructs. The

No	Author(s)	Instruments	Purpose	Important information about the instrument
				results demonstrate that the ECO questionnaire is a reliable and valid tool for assessing students' environmental citizenship, with practical applications for tracking student progress and assisting teachers in effectively teaching EC both inside and outside the classroom.
9	(Toma et al., 2024)	A multiple-choice test for sustainability competence in primary school using the GreenComp framework	The instrument is designed as a reference tool for educators and researchers to assess primary school students' sustainability competence, allowing for targeted interventions to address identified gaps.	The instrument, comprising eleven multiple-choice items, was validated through expert review and factor analysis, demonstrating strong construct validity and reliability. When applied to students aged 8 to 12, it highlighted a dominance of basic and anthropocentric views on sustainability. This tool shows promise for assessing sustainability competence in primary education and has potential for broader application across Europe.
10	(Gil-Molina et al., 2024)	Ocean is supported by the two participating universities and Euskampus Fundazioa (an inter-institutional instrument which manages the UPV/EHU's International Campus of Excellence)	The instrument analyses students' perceptions of the competences developed by taking part in the cross-border interdisciplinary Ocean i3 project.	At the regional level, local stakeholders propose challenges related to the cross-border environment of the universities, such as reducing ocean plastic pollution. On the employability front, students develop cross-disciplinary sustainability competences to better align with future professional demands.
11	(Rukspollmuang & Chansema, 2024)	A 5-point rating scale survey questionnaire	Questionnaire was used to collect data from students.	The analyzed data was presented to a focus group discussion, conducted with 19 internal and external stakeholders, as a basis to propose guidelines for promoting sustainability literacy.

The reviewed instruments showcase diverse approaches to assessing sustainability competencies across various educational contexts. Tools such as the sustainability teaching tools (Napal et al., 2020) and the green curriculum in higher education model (Moreno-Pino et al., 2021) emphasize integrating sustainability competencies into curricula and educational planning. These tools offer frameworks for diagnosing curriculum greening and fostering critical competencies like reflective thinking and ethical awareness, essential for addressing societal challenges. However, challenges such as vague theoretical foundations and limited implementation in curricula highlight the need for clearer definitions and robust validation processes to improve their applicability.

Another category of instruments focuses on personal responsibility and behavioral aspects, such as the VBN model-based scale (Lucas Mangas et al., 2021) and the ECO questionnaire (van Harskamp et al., 2023). These tools assess knowledge, attitudes, and environmental citizenship among students and educators, offering insights into how sustainability principles translate into actions. For example, the

ECO questionnaire's validation and application revealed its effectiveness in tracking students' environmental citizenship development and supporting teachers in teaching sustainability both in and outside the classroom.

Instruments targeting specific educational levels or sustainability dimensions also present significant findings. The PESD-FT questionnaire (Baena-Morales et al., 2023) evaluates social, economic, and environmental sustainability competencies, highlighting demographic and contextual factors affecting competency development. Similarly, tools like the GreenComp-based multiple-choice test (Toma et al., 2024) focus on primary education, revealing basic anthropocentric sustainability perspectives while offering broader applicability across Europe. These instruments collectively highlight the evolving landscape of sustainability competency assessment, emphasizing the importance of interdisciplinary approaches, teacher efficacy, and reflective learning practices.

The analysis reveals that researchers employ a wide range of instruments to assess sustainability competencies, from curriculum-based frameworks to behavioral and knowledge-focused tools. These instruments uncover valuable findings, such as the significant role of teacher self-efficacy, institutional commitment, and tailored educational approaches in fostering sustainability competencies. However, challenges like vague theoretical foundations and limited integration into curricula remain. These findings underscore the need for more comprehensive, validated, and context-sensitive instruments to advance education for sustainable development, providing researchers and educators with actionable insights to shape a more sustainable future.

CONCLUSION

This systematic literature review has addressed the research questions by providing a comprehensive overview of the current state of instruments used to assess sustainability competences. First, the temporal analysis revealed a stable yet sustained interest in this field, indicating ongoing recognition of the importance of assessing sustainability competences. Second, the subject area distribution showed a dominance of Social Sciences, reflecting a strong focus on societal and behavioral aspects, while multidisciplinary contributions from Energy and Environmental Sciences indicate broader engagement. Third, geographic analysis identified Spain as a leading country in publication output, highlighting disparities in global research participation. Regarding keyword relevance and thematic content, the instruments studied emphasize key factors such as teacher self-efficacy, institutional commitment, and the customization of educational approaches to foster sustainability competences effectively. However, the review also identified critical challenges, including unclear theoretical foundations and insufficient integration of these instruments into formal curricula and educational frameworks.

In line with the research objectives, these findings suggest the urgent need for the development of culturally and contextually relevant assessment tools with stronger theoretical underpinnings and practical applicability. Future research should focus on addressing these gaps to support educators, policymakers, and researchers in enhancing sustainability competence assessment, particularly in biology and applied biology contexts. culturally sensitive, locally relevant, and adaptable to various educational contexts, particularly for prospective teachers. Such instruments should incorporate local cultural and environmental contexts to address region-specific sustainability challenges effectively. Additionally, there is a need to expand research efforts into underrepresented areas, including primary education and teacher training, to foster sustainability competences from an early stage. Researchers should also focus on refining theoretical frameworks to ensure clarity and consistency, enabling seamless integration into

curricula. These advancements will not only enhance the quality of sustainability education but also support broader global efforts to achieve sustainable development goals.

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REFERENCES

Albuquerque, F., & dos Santos, P. G. (2024). A systematic literature review on the role played by sustainability matters in the educational environment. *Cogent Education*, *11*(1), 1-16. https://doi.org/10.1080/2331186X.2024.2436295

Álvarez-García, J., Hormiga-Pérez, E., Sarango-Lalangui, P. O., & del Río-Rama, M. de la C. (2022). Leaders' sustainability competences and small and medium-sized enterprises outcomes: The role of social entrepreneurial orientation. *Sustainable Development*, *30*(5), 927–943. https://doi.org/10.1002/sd.2291

Álvarez-Vanegas, A., Rieckmann, M., Lopera Pérez, M., & Aguirre, P. M. (2023). Teaching with a rounder sense of purpose: A survey study on education for sustainable development competences in Latin America. *Frontiers in Education*, *8*(1), 1–14. https://doi.org/10.3389/feduc.2023.1205478

Andersson, A., & Barwell, R. (2021). Applying critical mathematics education. *Applying Critical Mathematics Education, 6*(3), 1-22. https://doi.org/10.1163/9789004465800

Baena-Morales, S., García-Taibo, O., Merma-Molina, G., & Ferriz-Valero, A. (2023). Analysing the sustainability competencies of preservice teachers in Spain. *Journal of Applied Research in Higher Education*, 15(3), 731–744. https://doi.org/10.1108/JARHE-02-2022-0040

Bianchi, G. (2020). *Sustainability competences: A systematic literature review*. Publications Office. https://data.europa.eu/doi/10.2760/200956

Caeiro, S., Leal Filho, W., Jabbour, C., & Azeiteiro, U. M. (2013). Sustainability assessment tools in higher education institutions: Mapping trends and good practices around the world. Springer. https://doi.org/10.1007/978-3-319-02375-5

Cebrián, G., Junyent, M., & Mulà, I. (2020). Competencies in education for sustainable development: Emerging teaching and research developments. *Sustainability*, *12*(2), 1-9. https://doi.org/10.3390/su12020579

Demssie, Y. N., Biemans, H. J. A., Wesselink, R., & Mulder, M. (2023). Fostering students' systems thinking competence for sustainability by using multiple real-world learning approaches. *Environmental Education Research*, *29*(2), 261–286. https://doi.org/10.1080/13504622.2022.2141692

Dornhoff, M., Sothmann, J. N., Fiebelkorn, F., & Menzel, S. (2019). Nature relatedness and environmental concern of young people in Ecuador and Germany. *Frontiers in Psychology*, *10*(3), 1–13. https://doi.org/10.3389/fpsyg.2019.00453

Duda, E. (2022). Building the learning environment for sustainable development: A co-creation approach. *Proceedings of the ETHICOMP 2022: Effectiveness of ICT ethics – How do we help solve ethical problems in the field of ICT?*, 63-77. University of Turku, Turku, Finland. https://doi.org/10.48550/arXiv.2208.14151

Dzhengiz, T., & Niesten, E. (2020). Competences for environmental sustainability: A systematic review on the Impact of Absorptive Capacity and Capabilities. *Journal of Business Ethics*, *162*(4), 881–906. https://doi.org/10.1007/s10551-019-04360-z

Gil-Molina, P., Cruz-Iglesias, E., & Rekalde-Rodriguez, I. (2024). Developing competences in a cross-border interdisciplinary project: student and teacher perceptions of the Ocean i3 project. *Journal of University Teaching and Learning Practice*, *21*(1), 1-26. https://doi.org/10.53761/677rfm42

Gomes, C. (2019). Computational sustainability: Computing for a better world and a sustainable future. *Communications of the ACM*, *62*(9), 56–65. https://doi.org/10.1145/3339399

Heldal, R., Nguyen, N.-T., Moreira, A., Lago, P., Duboc, L., Betz, S., Coroamă, V. C., Penzenstadler, B., Porras, J., Capilla, R., Brooks, I., Oyedeji, S., & Venters, C. C. (2023). Sustainability competencies and skills in software engineering: An industry perspective. *Software Engineering*, 1-19. https://doi.org/10.48550/arXiv.2305.00436

Hernández, B., Ruiz, C., & Suárez, E. (2019). Comunidad, causas y sostenibilidad: El reto de los territorios. *Proceedings of the XV Congreso Internacional de Psicología Ambiental, PSICAMB, Santa Cruz de Tenerife, Spain*. https://www.psicamb.org/images/libro_abstracts_psicamb_isbn-comprimido.pdf

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022a). Action competencies for sustainability and its implications to environmental education for prospective science teachers : A systematic literature review. *Eurasia Journal of Mathematics, Science & Technology Eduaction*, *18*(8), em2138. https://doi.org/10.29333/ejmste/12235

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022b). Environmental education research in Indonesian scopus indexed journal: A systematic literature review. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *8*(2), 105–120. https://doi.org/10.22219/jpbi.v8i2.21041

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022c). Sustainable development research in Eurasia Journal of Mathematics, Science and Technology Education: A systematic literature review. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(5), em2103. https://doi.org/10.29333/ejmste/11965

Kusumaningrum, M. E., Kuswanto, H., Jumadi, Suyanto, S., Suhartini, Purwasih, D., & Prabawati, R. (2023). A bibliometric review of research on education for sustainable development, 2019-2023. *International Electronic Journal of Elementary Education*, *16*(1), 75–88. https://doi.org/10.26822/iejee.2023.315

Lambrechts, W., Mulà, I., & Van den Haute, H. (2010). The integration of sustainability in competence based higher education: using competences as a starting point to achieve sustainable higher education. *Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU conference*, 1–22. https://www.researchgate.net/publication/312084795

Lambrechts, W., Verhulst, E., & Rymenams, S. (2017). Professional development of sustainability competences in higher education: The role of empowerment. *International Journal of Sustainability in Higher Education*, *18*(5), 697–714. https://doi.org/10.1108/IJSHE-02-2016-0028

Leal Filho, W., Wall, T., Barbir, J., Alverio, G. N., Dinis, M. A. P., & Ramirez, J. (2022). Relevance of international partnerships in the implementation of the UN Sustainable Development Goals. *Nature Communications*, *13*(1), 613. https://doi.org/10.1038/s41467-022-28230-x

Liu, J., Watabe, Y., & Goto, T. (2022). Integrating sustainability themes for enhancing interdisciplinarity: a case study of a comprehensive research university in Japan. *Asia Pacific Education Review*, *23*(4), 695–710. https://doi.org/10.1007/s12564-022-09788-z

López-Serentill, P., Alsina, Á., Gual, M., & Pincheira, N. (2024). Integrating sustainability in mathematics education: An approach to the Spanish primary curriculum. *Journal of Sustainability Research*, *6*(3), 1-22. https://doi.org/10.20900/jsr20240058

Lozano, R., Barreiro-Gen, M., Pietikäinen, J., Gago-Cortes, C., Favi, C., Jimenez Munguia, M. T., Monus, F., Simão, J., Benayas, J., Desha, C., Bostanci, S., Djekic, I., Moneva, J. M., Sáenz, O., Awuzie, B., & Gladysz, B. (2022). Adopting sustainability competence-based education in academic disciplines:

Insights from 13 higher education institutions. *Sustainable Development*, *30*(4), 620–635. https://doi.org/10.1002/sd.2253

Lucas Mangas, S., Marbán Prieto, J. M., Unanue Cuesta, M. C., Manso Argüelles, M. Á., & Romay Martínez, J. (2021). The role personal responsibility norms play in sustainable development for university students: The impact of service-learning projects. *Sustainability (Switzerland)*, *13*(13), 1-13. https://doi.org/10.3390/su13137330

Michel, J. O., Brundiers, K., Barth, M., Fischer, D., Mochizuki, Y., Redman, A., & Zint, M. (2022). Sustainability competencies in higher education. In R. C. Brears (Ed.), *The Palgrave Encyclopedia of Urban and Regional Futures*, 1710–1715. Springer. https://doi.org/10.1007/978-3-030-87745-3_342

Moreno-Pino, F. M., Jiménez-Fontana, R., Domingo, J. M. C., & Goded, P. A. (2021). Study of the presence of sustainability competencies in teacher training in mathematics education. *Sustainability (Switzerland)*, *13*(10), 1-19. https://doi.org/10.3390/su13105629

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(143), 1–7. https://doi.org/10.1186/s12874-018-0611-x

Napal, M., Mendióroz-Lacambra, A. M., & Peñalva, A. (2020). Sustainability teaching tools in the digital age. *Sustainability (Switzerland)*, *12*(3366), 1–14. https://doi.org/10.3390/SU12083366

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ*, *372*(71), 1–9. https://doi.org/10.1136/bmj.n71

Prior, D. D., Mysore Seshadrinath, S., Zhang, M. (Yu), & McCormack, M. (2024). Measuring sustainable development goals (SDGs) in higher education through semantic matching. *Studies in Higher Education*, 1–14. https://doi.org/10.1080/03075079.2024.2386625

Quaye, J. N. A., Halsall, J. P., Winful, E. C., Snowden, M., Opuni, F. F., Hyams-Ssekasi, D., Afriyie, E. O., Opoku-Asante, K., Ocloo, E. C., & Fairhurst, B. (2024). Social enterprises and the sustainable development goals (SDGs): A means to an end. *Environment, Development and Sustainability*. Springer, 1-30. https://doi.org/10.1007/s10668-024-05359-x

Redman, A., Wiek, A., & Barth, M. (2021). Current practice of assessing students' sustainability competencies: a review of tools. *Sustainability Science*, *16*(1), 117–135. https://doi.org/10.1007/s11625-020-00855-1

Rukspollmuang, C., & Chansema, T. (2024). Promoting sustainability literacy for students in Thai higher education institution: a case of Siam University. In *International Journal of Comparative Education and Development*. https://doi.org/10.1108/IJCED-07-2023-0065

Sá, P., Lourenço, M., & Carlos, V. (2022). Sustainability competencies in higher education research: An analysis of doctoral theses in Portugal. *European Journal of Investigation in Health, Psychology and Education*, *12*(4), 387–399. https://doi.org/10.3390/ejihpe12040028

Sahle, M., Lahoti, S. A., Lee, S. Y., Kamiyama, C., Tan, X., Kozar, R., Saito, O., & Takeuchi, K. (2024). Mapping the evolving research landscape of sustainability science from 2006 to 2023: unveiling its transformation. *Sustainability Science*, *19*(5), 1735–1750. https://doi.org/10.1007/s11625-024-01529-y

Sala, O. E., Boone, C. G., Turner, B. L., & Currier, C. M. (2019). The sustainability publication gap and its implications. *Current Opinion in Environmental Sustainability*, *39*(2019), 39–43. https://doi.org/10.1016/j.cosust.2019.06.006

Scharenberg, K., Waltner, E. M., Mischo, C., & Rieß, W. (2021). Development of students' sustainability competencies: Do teachers make a difference? *Sustainability (Switzerland)*, *13*(22), 1–22. https://doi.org/10.3390/su132212594

Schneider, F., Patel, Z., Paulavets, K., Buser, T., Kado, J., & Burkhart, S. (2023). Fostering transdisciplinary research for sustainability in the Global South: Pathways to impact for funding programmes. *Humanities and Social Sciences Communications*, *10*(620), 1-11. https://doi.org/10.1057/s41599-023-02138-3

Schoolman, E. D., Guest, J. S., Bush, K. F., & Bell, A. R. (2012). How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. *Sustainability Science*, *7*(1), 67–80. https://doi.org/10.1007/s11625-011-0139-z

Singh, A. B., Meena, H. K., Khandelwal, C., & Dangayach, G. S. (2023). Sustainability assessment of higher education institutions: A systematic literature review. In *Engineering Proceedings*, *37*(1), 1-7. https://doi.org/10.3390/ECP2023-14728

Smith, J. S. (2024). International collaboration for sustainable development in the Third Space: A conceptual framework and relevant approaches based on China-US sponge city exchange. *International Journal of Chinese Education*, *13*(3), 1–15. https://doi.org/10.1177/2212585X241278376

Steg, L., Dreijerink, L., & Abrahamse, W. (2005). Factors influencing the acceptability of energy policies: A test of VBN theory. *Journal of Environmental Psychology*, *25*(4), 415–425. https://doi.org/10.1016/j.jenvp.2005.08.003

Toma, R. B., Ortiz-Revilla, J., & Greca, I. M. (2024). Development and validation of a multiple-choice test for sustainability competence in primary school using the GreenComp framework. *International Journal of Educational Research Open*, *7*(9), 1-7. https://doi.org/10.1016/j.ijedro.2024.100388

Umar, S. B., Ahmad, J., Bukhori, M. A. B. M., Mohd Ali, K. A., & Wan Hussain, W. M. H. (2024). A decade in review: bibliometric analysis of sustainable performance trends in higher education institutes. *Frontiers in Education*, *9*, 1-14. https://doi.org/10.3389/feduc.2024.1433525

Valdes-Ramirez, D., de Armas Jacomino, L., Monroy, R., & Zavala, G. (2024). Assessing sustainability competencies in contemporary STEM higher education: a data-driven analysis at Tecnologico de Monterrey. *Frontiers in Education*, *9*(2024), 1-14. https://doi.org/10.3389/feduc.2024.1415755

van Harskamp, M., Knippels, M. C. P. J., Boeve-de Pauw, J. N. A., & van Joolingen, W. R. (2023). The environmental citizenship opinions questionnaire: a self-assessment tool for secondary students. *Frontiers in Education*, *8*(7), 1–12. https://doi.org/10.3389/feduc.2023.1182824

Young, H. (2024). Beyond tick boxes: Re-imagining education for sustainable development in higher education. *Professional Development in Education*, 1–14. https://doi.org/10.1080/19415257.2024.2394879