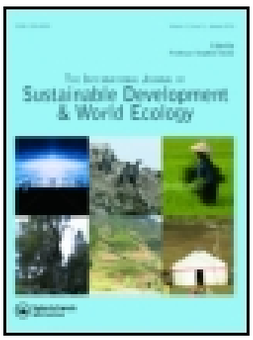

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Towards a common future: revising the evolution of university-based sustainability research literature

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ABSTRACT

The field of sustainability has evolved considerably since the report "Our Common Future" was published in 1987. Whereas matters related to sustainable development used to be of marginal interest in the 1980s, it has substantially evolved since, and have become mainstream. As a result, there is a plethora of research on different aspects, whose focus has also been influenced by societal developments. This line of thinking also applies to sustainability research in higher education, a special and central field. Unfortunately, the variety of research on matters of sustainable development in universities makes it difficult to obtain an insight into its current status, and to ascertain how it has evolved since 1987. Based on the perceived need to fill this gap, a study focusing on the evolution of university-based sustainability research literature has been undertaken. The study entailed approximately 1700 papers published between 1987 and 2019, being one of the most comprehensive studies on this field ever undertaken. Apart from performing a bibliometric analysis using science mapping software tools, the research clustered the research into some key areas. The results suggest that, whereas impressive, the evolution of university-based sustainability research has been uneven, and calls for a more balanced emphasis to as to cover some research areas which have so far been neglected. The implications of this work are twofold: it will support the further development of the university-based sustainability research literature, and will help to address some thematic gaps, which are seen today, and to which greater attention is needed.

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Sustainable development research; academic research; higher education sustainability

1. Introduction: the evolution of sustainability research

Sustainability research is a term often used interchangeably with sustainability science, and it refers to the collection, assessment and application of knowledge regarding the Earth obtained through relevant studies, along with knowledge surrounding society and human relationships, in order to produce effective solutions to properly mitigate, adapt and reduce the effects of worldwide crises that are either natural or man-made (Kieffer et al. 2003; Reitan 2005).

This research may take place within a single discipline or it may be transdisciplinary. Sustainability research is able to focus on problems that threaten the livelihood and integrity of global civilization (Miller et al. 2014). Sustainability research and science has mainly encompassed the study of human-natural systems, providing much-needed insight and drawing attention to problems that require sustainable solutions (Miller et al. 2014).

Sustainability research can be classified into two categories: descriptive analytical and transformational

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sustainability research (Wiek and Lang 2016). Descriptive-analytical research focuses on solving sustainability issues by describing the problem and analyzing the situation. This breaks down the problem into its complexity, dynamics and causes (Collins et al. 2011; De Vries 2012). Past, present and future sustainability problems are taken into consideration using this approach (Wiek and Lang 2016).

Transformational sustainability research refers to the development of solutions that are evidence-based (Sarewitz et al. 2012; Wiek et al. 2015). Solutions produced from this research are changes that are dependent on the action and execution of people, researchers and stakeholders. These solutions are based on evidence and can produce real changes in the world. The solutions are often complex and require adequate action plans and long-term applications (Sarewitz et al. 2012).

Research on sustainable development began on a small scale. However, it has been over the past decades evolved to become an academic field of its own. As sustainability research evolved, it led to the creation of several different subfields. These included different vocabularies, methods, research questions, epistemologies, and research groupings (De Vries 2012; Haider et al., 2018).

At present, a significant portion of sustainability research is undertaken to achieve the sustainable development goals set by the United Nations Development Programme. Aside from this, day-to-day research is also undertaken. For instance, research was conducted to deal with the after effects of the 2011 triple-disaster in Japan, as well as toxic waste dispersion in certain countries. Furthermore, a large portion of research is dedicated to the energy crisis globally, many with a specific focus on developing countries (Wiek et al. 2015).

The constant need for sustainability research has led it to change and adapt over the years. Furthermore, this field has evolved to encompass the understanding of the complexity, structures and features of various problems and issues surrounding modern society. In this context, sustainability research is constantly being developed to ensure that feasible and effective solutions are designed for specific problems (Chapin et al. 2011; Wiek et al. 2015). This rapid development has led to the creation of academic departments, courses at both undergraduate and postgraduate level, the establishment of peer-reviewed journals and multiple publications in scientific journals on matters related to sustainability (Bettencourt and Kaur 2011).

Past lessons have shown that the future of sustainability research is characterized by a continuous transformation and evolution. In order to successfully adapt to future problems four pathways have been suggested. These includes (1) mapping and deliberating on sustainability values, (2) creating scenarios for future developments, (3) exploring and fostering socio-technical change, and (4) enabling social and institutional learning for sustainable development. These are intended to assist in enhancing the feasibility and effectiveness of future research (Miller et al. 2014).

In Higher Education Institutions (HEI), the signature of Declarations, Charters, or Initiatives (DCI) by top management was recognized as an assertion of Sustainable Development (SD) (Farinha et al. 2019). These academic front-runners on sustainable development vowed to also transform them into SD catalysts and, even before the United Nations 2005 strategy (Karatzoglou 2013) known as Education for Sustainable Development (ESD) Decade, provided a clear signal later enhanced by multiple DCI in Higher Education (HE). Nevertheless, this is not enough. In fact, to implement the whole-school approach (UNESCO, 2012) is crucial to engage students, so that they become themselves drivers for a sustainable future (Leal Filho, 2018).

As HEIs have a fundamental role as shapers of mindsets, training the policy-makers and leaders of tomorrow (Cortese 2003; Lozano 2006; Tilbury and Mulà 2009), they also have a critical responsibility in heightening the general public awareness for SD (Mora et al. 2018).

In a constantly changing society based on rapid and complex information, to be able to meet new challenges, it is of utmost importance that education is always in step with evolution. As changes require a well-thought leadership system that generates a sustainable education system, i.e., a system capable of integrating social, economic, political, technological changes, adaptation to these changes are needed, so as to ensure that everyone's needs, and human rights are met (Filip et al. 2019).

Concerning the UN Decade (2005–2014) (UNESCO 2005), the incorporation of ESD in Universities was mainly made across components such as education, research, campus processes, and community outreach actions all together or even a subset thereof (Wals, A., 2014). After the Decade, the Nagoya Declaration restated that the stakeholders' commitment vis-à-vis ESD should continue (UNESCO 2014).

In 2015, 'quality education' became one out of 17 Sustainable Development Goals (SDG) (United Nations 2016), which is an additional opportunity to holistically integrate sustainability in universities (Beynaghi et al. 2016; Brudermann et al. 2019; Caeiro et al. 2020). Moreover, the worldwide community is engaged in addressing the SDGs, and so are HEIs, especially regarding their 'third mission' (Leal Filho et al. 2019), involving external community within academic activities (Brudermann et al. 2019). As stated by Berzosa and

Fernandez-Sanchez (2017), adjustments and structuring in some universities are needed – and some have been made.

2. Sustainability research in higher education: some trends

Social developments and policy agreements calling for universities to engage and demonstrate responsibility for sustainable development have increasingly inspired the interest of academics and influenced the growth of research that explores how the concept might be operationalized in a higher education setting. Following the early focus on harmonizing development with environmental needs and issues, the research orientation initially reflected ideas presented by the above-mentioned higher education declarations, with academics 'trying to understand the environmental needs and implications of their operations' (Leal Filho et al. 2015, p. 1).

Some of the early literature, sought not only to exhort universities to engage with sustainable development but debated the meaning of sustainability, provided persuasive rationales for change, and highlighted the benefits of engagement (Sterling 2001, 2004; Cortese 2003). Over time, the body of research has grown exponentially, with a number of separate themes being explored at different times, as policy contexts shift. Considering the globally recognized value of education in all processes to achieve sustainability, the early thrust of the literature provides intensive discussion on the content and concept of environmental education (EE), and its relationship to sustainable development. Debates about its aims led a number of authors to propose distinctions between education for and about the environment (Huckle 1983 and Robbottom 1987, in Kopnina 2013). The last decade of the 20th century brought new insights into the goal of EE, and previously widely used, 'behavioral change', was replaced with concepts of 'action qualification' or 'action competence'. The latter was strongly promoted by the researchers from the 'Nordic school', who were approaching education as 'a search for meaning and for knowledge' (Breiting 1990, in Breiting and Nielsen 1996, p. 51), where participation of all people interested in solutions and the ethics of their behavior are emphasized (Breiting 1993, in Smyth 2006).

After the adoption of the Millennium Development Goals (MDGs) in 2000, the tendency to broaden the concept (and the content) of EE can be recognized within academic research, affecting the approach and the scope of subjects within HE curricula. As noted, 'different fields of education, such as environmental education, global education, economics education, development education, multicultural education, conservation education, outdoor education, global change education, among others, are complemented by education in sustainability' (Leal Filho 2009, in Shulla et al. 2020, p. 460).

The first decade of the millennium was marked by the call for 'greening' or 'integrating environmental discourse' into education, and the development of the 'green campus' movement in HE (Lange 2010) – a movement that has more recently been aligned with education, under the theme of 'Living Labs' (Filho et al. 2019), where the university campus serves as a 'platform for sustainability science' and the 'co-production of learning' (Evans et al. 2015). At times, campus greening has dominated the literature, as concluded in a thematic review of articles in the International Journal of Sustainability in Higher Education between 2001 and 2010, with the results showing that 'most articles focus on things like: environmental management, university greening and reducing a university's ecological footprint' (Wals 2014, p. 2); many of the studies also tended towards descriptive single-site case-studies. Furthermore, numerous authors at that time also recognized a large ambivalence and misunderstanding of the term 'sustainability', as well as remnants of 'mono-disciplinarity' in research and curricula design; the challenges of integrating SD in universities were noted (Schirberg Thomas, in Sibbel 2009).

In parallel, research has explored governance and leadership for sustainability, albeit to a lesser extent than environmental management (Shiel 2012; Lozano et al. 2013), as well as ways to build capacity in the community (Shiel et al. 2016), where community is seen as an important element of a holistic approach to sustainability that embraces campus, curriculum, culture and community (Selby 2009). However, these topics have not been as extensive as reducing the environmental impact of campus operations, or the much larger educational endeavor.

The research in the field of education and learning for sustainability has had a strong focus since the outset and has been influenced by processes and recommendations brought within the UN DESD (2005–2014). Researchers have continued to seek best practice and develop approaches with the potential to influence larger numbers of students. Moving from 'attention to the meaning and the content of the SD in ESD', to consider the 'E', i.e the education process required (Wals and Kieft 2010), this process has been on-going and aligns more closely with pedagogical principles (Araneo 2019). Research has shown that 'inclusive and integrative approaches to learning and teaching, using applied, futures-oriented, critical and participatory pedagogies' (Tillbury and Ryan 2012, p. 1) that nurture and support participation in both higher education and community development, also require carefully designed teachers' professional development (UE4SD 2015; UNESCO 2017). Authors interested in

the integration of SD into curricula continue to debate these issues but also 'the old question of the cross-curricular approach versus the development of stand-alone courses' (Orlovic Lovren et al. 2020, p. 316), or a combination of the two (Ceulemans and de Prins 2009). The concept of sustainability competences – viewed as 'capacities for participation and critical thinking' (Madsen 2013, p. 3774) or as 'the capacity or disposition to act to address complex challenges' (Rieckmann 2018, p. 45), has also extended the research focus and attracted increased attention of the research community in later years.(Rieckmann 2018; Orlovic Lovren 2019).

This interest has spread further in the context of the global recognition of the importance of education – not only as a specific and separate goal within the Sustainable Development Goals (SDGs) – but also as a process and mechanism contributing to the implementation of all the other SDGs. Starting from the premise that meeting global requirements to cope with the complexity of life and an uncertain future is not possible without developing multidimensional qualities of all goals, a number of researchers are looking at the interrelations between sustainability competences, learning objectives, and integrating SD and ESD into curricula of HE studies (Rieckmann 2018; Kitzmann and Mota 2019; Concina 2019; Orlovic Lovren et al. 2020).

Recent studies also provide data on increased research interest in issues related to incorporating SDGs, reflecting specificities of the regions in terms of focusing on particular goals, but also suggesting that there is globally increased attention to climate change issues, dominantly comprised by the SDG 13 (Lange Salvia et al. 2019).

In summary, researchers have focused on why HE should engage with SD, what that might look like, and how it might be achieved, providing a more detailed focus on specific niche areas of activity. Topics considered reflect ongoing themes such as campus greening and environmental sustainability in campus operations; ESD including sustainability within the curriculum, through student engagement and throughout the student learning experience; leadership and governance, and to a lesser extent; the university's role in working with external stakeholders to build capacity through community engagement. Sometimes these topics have been considered as distinct niche areas of research, at other times, they are researched as part of a 'whole-university' (McMillan and Dyball 2009) or 'integrative approach' to sustainability (Leal Filho et al. 2015).

3. Methodology

In respect of the evolution of university-based sustainability research, there is a gap in the literature. In order to address this need, this work aims at describing the evolution of university-based sustainability literature since the concept of SD was introduced in 1987 in the report 'Our Common Future' (WCED 1987). To accomplish this objective, a literature review was performed considering articles published on the Web of Science through a bibliometric and science mapping approach.

Fink (2019, p. 6) defines research literature reviews as a systematic, explicit and reproducible method, frequently adopted to identify, evaluate and synthetize the existing body of completed and recorded work produced by researchers, scholars, and practitioners. According to Linnenluecke et al. (2019) among the numerous ways to present the results of a systematic literature review, bibliographic mapping approaches are suggested for visualising the intellectual origins of that topic and the structure of the literature over time. Those approaches support a temporal analysis, to identify the nature of phenomena represented by a sequence of observations such as patterns, trends, seasonality, and outliers, which is the basic 'to analyze the evolution of the research field across different periods of time' (Cobo et al. 2011, p. 1385).

The process model proposed by Cobo et al. (2011) has been chosen for this work, as it provides a clear structure for conducting a research literature review through a science mapping approach on a detailed basis. The process model followed comprises three steps: (a) data retrieval and preprocessing; (b) network extraction, normalization, and mapping; and, (c) analysis and visualization, as shown in Figure 1.

Step 1: data retrieval and preprocessing,

Retrieving data from a bibliometric source (Web of Science); applying preprocessing methods to delete duplicated or unrelated references as well as misspelled elements.

Step 2: network extraction, normalization, and mapping,

Defining and applying the network extraction approach (unit of analysis; co-word analysis; co-author analysis, etc.); to normalize the text to set a weight to each term according to its importance in the corpus; applying a mapping algorithm to the whole network formed using the relationship among the selected units of analysis.

Step 3: analysis and visualization,

Applying a set of analysis to extract useful knowledge (network analysis; temporal analysis to analyze the evolution of the research field across different period of time; and geospatial analysis); define the proper visualization technique to a good understanding and good interpretation of the output.

While contributing to the knowledge on the evolution of university-based sustainability research over time, the study presented in this article nonetheless is

Step 1 data retrieval and preprocessing	**Retrieving data from bibliometric source (Web of Science); Applying preprocessing methods to delete duplicated or unrelated references as well as misspelled elements.**
Step 2: network extraction, normalization, and mapping	Defining and applying the network extraction approach (unit of analysis; co-word analysis; co-author analysis, etc.); to normalize the text to set a weight to each term according to its importance in the corpus; applying a mapping algorithm to the whole network formed using the relationship among the selected units of analysis
Step 3: analysis and visualization	Applying a set of analysis to extract useful knowledge (network analysis; temporal analysis to analyze the evolution of the research field across different period of time; and geospatial analysis); define the proper visualization technique to a good understanding and good interpretation of the output.

Figure 1. Methodological procedure followed to collect, analyze and mapping data. Operationally, a set of keywords was deployed (see Figure 3), which guided the web search.

subject to the following limitations: firstly, although the adoption of a set of strategies in the pre-processing phase can guarantee the quality of the selection procedure, it may not be enough to rule out all selection bias. This is explained by the fact that the sustainability literature is so wide that the sampled terms may not be representative of the population intended to be analyzed. This risk has been reduced by making sure that a focus was given to some key terms.

Secondly, the Web of Science, chosen as a boundary of the analysis, even considering its wide scope, cannot prevent possible omissions in identifying relevant nodes for the analysis of the evolution of university-based sustainability research literature. Despite these limitations, the study was comprehensive enough to allow the identification of important trends, and to cater for the identification of the key issues surrounding the evolution of the literature on sustainability research.

4. Results and discussion

In this section, the analysis performed by the VOSViewer software will be described and discussed. In order to systematise the presentation of the results, the following six items have been used for the analysis:

(1) terms/thematic areas;
(2) source;
(3) authors' references;
(4) authors;
(5) organizations and
(6) countries.

VOSViewer is a text mining tool that is applied in the field of science mapping and in particular to visualize large networks for a bibliometric analysis (van Eck and Waltman 2010, 2020). VOSViewer includes text mining features such as co-occurrence, co-citation analysis, as well as bibliometric coupling. The visualization of the results is considered as a strength of the software, as the figures representing the linkages and relatedness by distance-based nodes are rather intuitive (van Eck and Waltman 2014).

4.1. Developments in the field of sustainability publications

First, we analyse the development in the field of evolution over time in terms of publication volumes and the frequency of the occurrence of topics and themes.

Figure 2 shows the number of publications over time from 1995 to 2020 and reveals rapidly increasing publication trends from 2005 onwards. Three periods

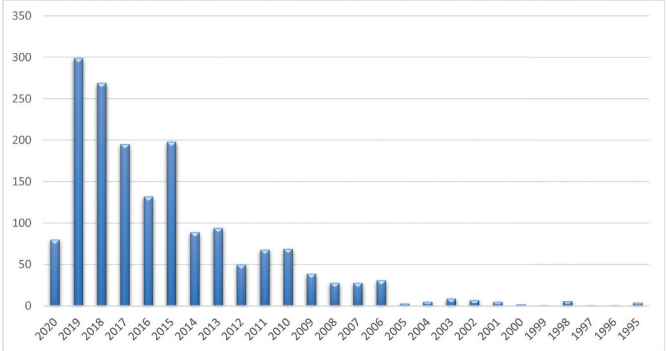

Figure 2. Number of publications per year from 1995 to 2020.

in publication trends can be distinguished based on the sample: (1) The first phase from 1995 to 2004, i.e. the pre-ESD decade phase, where the volume of publication was below nine articles. (2) The second phase from 2005 to 2015 covers the UN decade of ESD, when research grew moderately with a peak in 2013 (94 publications) and 2014 (89 publications). (3) In the third phase, finally, a considerable increase in publication trends can be seen from the data. Publication efforts peaked in 2019 with 299 publications. If the trend is assumed to continue, 2020 should be the year with the most publications on the topic. As the results show an increasing number of publications over the years, it is noticeable that there was a growing awareness about the importance of sustainability at universities among the scientific community.

Two instruments have been applied with the VOSViewer software (Eck & Waltmann 2020) in order to analyse the thematic development in the field: the co-occurrence of terms and keywords and the co-citation analysis. Assuming that keywords are properly assigned to the articles, it is possible to analyse which subjects appear often and how they are connected (i.e. co-occurrence of keywords). The link strength, which is a positive numerical value, indicates the number of publications in which (the two) terms/keywords occur together. The higher the value of the link strength, the stronger the relationship between the keywords (van Eck and Waltman 2020). Figures 2 and 3 represent the main topics as described by keywords of the article in the sample. In the figure, the size and distance of the nodes as well as the interconnecting lines are used to show the most frequently used keywords. Based on a text mining process in VOSViewer, the keywords are categorized into different clusters that represent keywords that mostly co-occur.

Terms close to each other (in one cluster) have co-occurred more frequently and form a thematic cluster. For instance, the green cluster seems to be more focused on theoretical underpinnings of sustainable development and ESD. The red cluster is probably focused on campus-based activities, living labs. The green cluster focuses on curriculum and education components. Consistent with this thinking, three different clusters are identified:

- *Cluster 1 (red)* with 26 topics, e.g. university, management, campus sustainability, environmental management, implementation, organizational change;
- *Cluster 2 (green)* with 20 topics, e.g. sustainability, higher education, sustainable development, education, students, ESD;
- *Cluster 3 (blue)* with 17 topics, e.g. curriculum, sustainability education, competences, interdisciplinary, transdisciplinary, engineering education.

The terms Higher Education, Sustainability, University, Sustainable Development, Education and ESD are the major topics with the highest values in terms of total link strength and occurrence (see Figure 4 for co-occurrence). These terms are the most interrelated keywords with the highest frequency with the analysed sample, e.g. higher education, sustainability, university. However, co-occurrence does not show future trends, but indicates past trends (i.e. the frequently used terms).

4.2. Influential journals, authors, and institutions

Co-citation analysis is used to identify which journals and which authors can be considered as most influential in the research area (Trujillo and Long

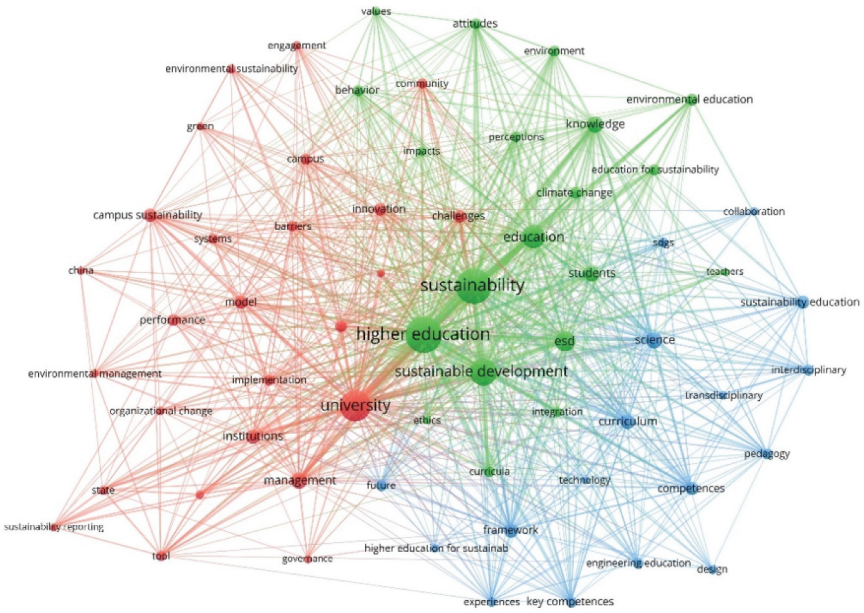

Figure 3. Thematic areas of publications (key terms) .

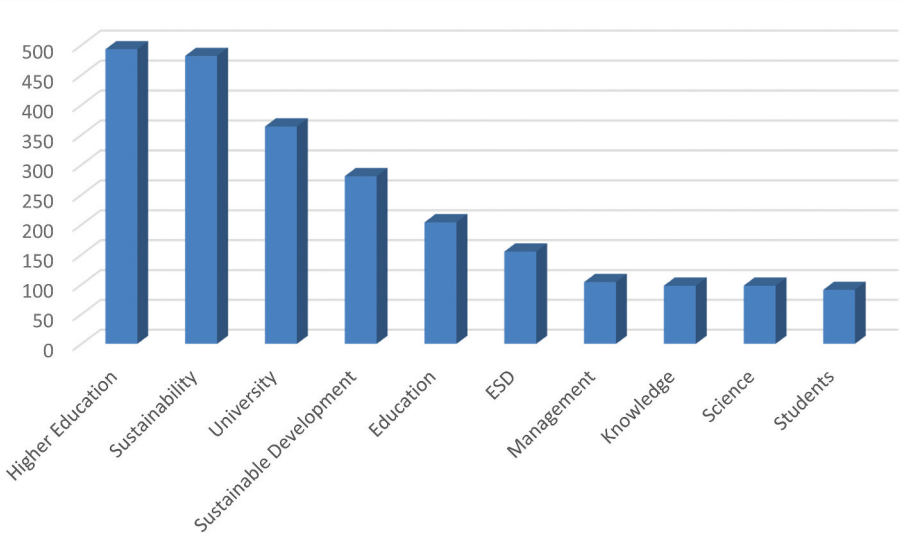

Figure 4. Ten main thematic areas of publication (occurrence of terms) .

2018), based on the cited references of documents retrieved from the search in the Web of Science. These are the journals that most frequently have been cited together in the retrieved articles. The following Figure 5 visualizes a co-citation network of 46 journals, based on citations and link strength. The size of the nodes, the closeness in terms of the frequencies of the journals, cite each other (Martinez et al. 2019). Four different main clusters have been identified based on the frequency of co-citation:

- Cluster 1 (red) 19 journals (e.g. 'Journal of Cleaner Production', 'Sustainability-MDPI', 'International Journal Sustainability in Higher Education', 'Environmental Education Research', 'Journal of Business Ethics');
- Cluster 2 (green) 11 journals (e.g. 'Sustainability Science', 'Futures', 'Ecological Economics', Research Policy);
- Cluster 3 (blue), 11 journals (e.g. 'Journal of Environmental Psychology', 'Energy Policy', 'Journal of Environmental Education');

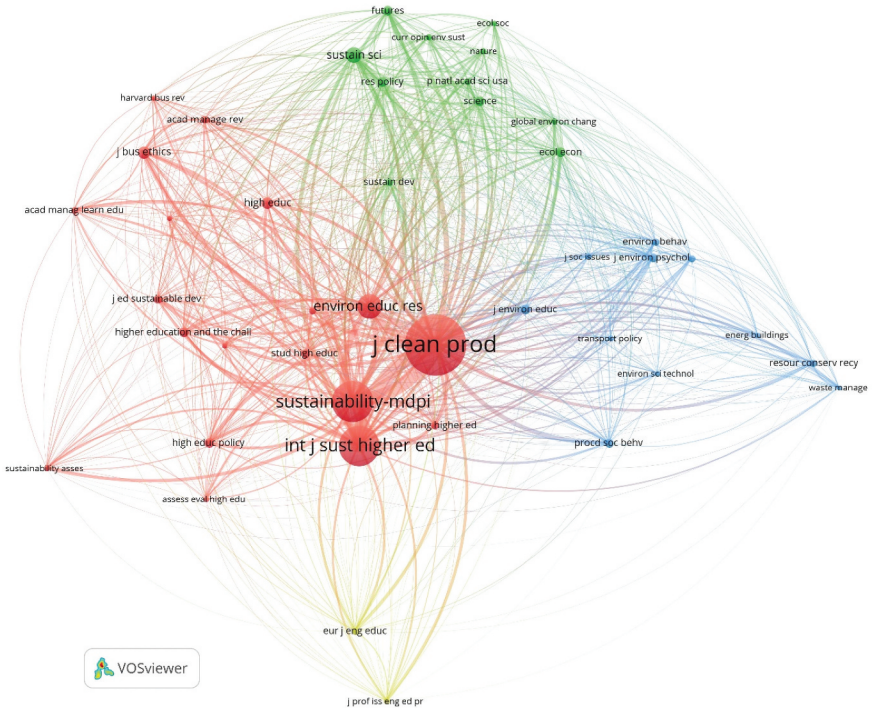

Figure 5. Main publication sources and journals.

- Cluster 4 (yellow), 2 journals (Journal of Professional Issues in Engineering Education, European Journal of Education).

The clusters show the degree of interrelatedness (Martinez et al. 2019; Jin et al. 2019), i.e. all the journals in a cluster have a high degree of mutual citation. The Journal of Cleaner Production is characterised by a high value for the total link strength of about 94.800 and is closely linked to the International Journal of Sustainability in Higher Education with a total link strength of 62.075. The parameters 'total link strength' and 'total citations' allow some conclusions to be drawn about productivity. Ten journals were considered as important in that way that these journals have had more pivotal roles in the development of the field (see Figure 6).

However, highly productive journals do not necessarily have a high significance in the scientific community and research area (Martinez et al. 2019)

Co-citation analysis was also used to identify the most influential publications and authors in the field. Figure 7 illustrates an analysis of cited references, which indicates the number of references (two) journals have in common. Co-citation of references, i.e., papers, is based on a minimum number of 45 citations

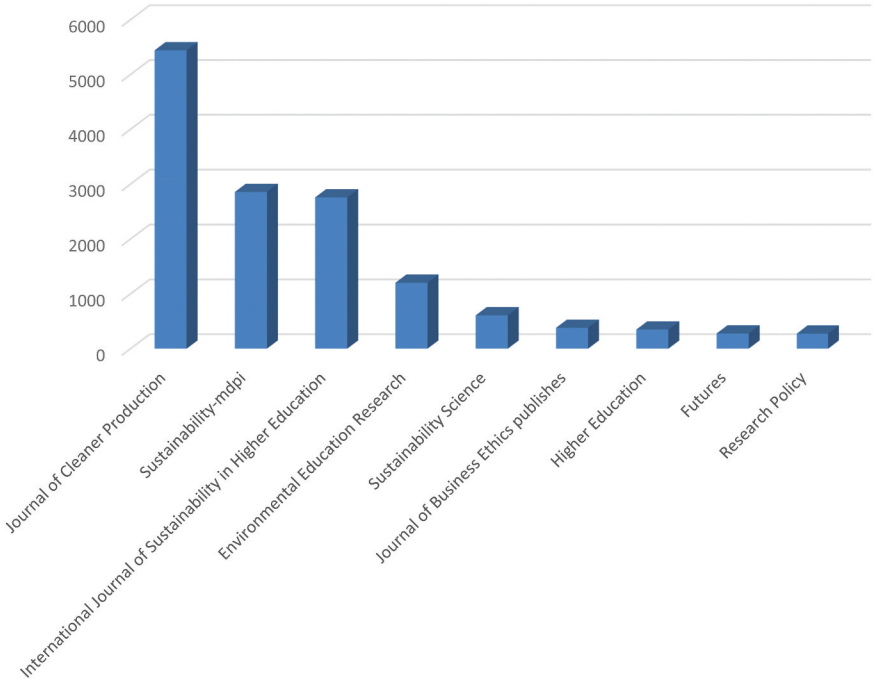

Figure 6. Ten main titles of publication sources.

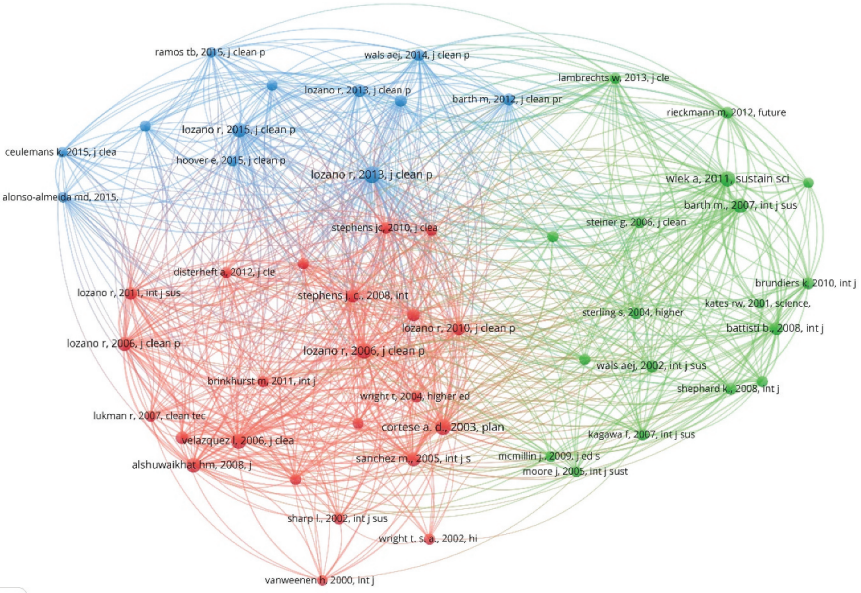

Figure 7. Co-citation by cited references.

for a cited reference. Three clusters have been identified for influential papers based on number of citations and link-strength:

- Cluster 1 (red) 23 papers;
- Cluster 2 (green) 18 papers;
- Cluster 3 (blue), 12 papers

In the following Tables 1 and 2, the top 10 most influential papers based on co-citations and link strengths are compiled.

Regarding the influence of single authors, a co-citation analysis was performed based on a minimum number of 70 citations per author. The following clusters are derived from the data analysis with VOSViewer (see Figure 8):

- Cluster 1 (red), 20 authors and institutions
- Cluster 2 (green) 19 authors and institutions
- Cluster 3 12 authors and institutions

In the following Figure 9, the top 10 influential authors based on co-citations and link strength are compiled.

Another approach of science mapping is bibliographic coupling analysis, which refers to linking publications that cite the same documents in the reference list (Boy-ack and Klavans 2010; Rehn et al. 2014). Hence, a bibliographic coupling link is a link between two items that both cite the same document (van Eck and Waltman 2020). The idea behind bibliographic coupling is that publications within a particular area may share the same core materials. It is also possible to identify conceptual connections between the articles, in case that they have been published just recently, with not enough time to get many citations. For this study, a bibliometric coupling analysis was carried out for organizations and countries in order to identify the most productive institutions in the field and the most prominent countries. Figure 10 summarizes bibliographic coupling by organization for a minimum number of 10 documents per organization. The following three clusters occur, showing the engagement of certain universities and the relations between them:

- Cluster 1 (red), 18 organizations, such as Arizona State University, Delft University of Technology, University of British Columbia.
- Cluster 2 (green), six items, such as University Alberta, University of Coimbra, and University Nova Lisboa.
- Cluster 3 (blue), four items, for instance, Manchester Metropolitan University, Hamburg University of Applied Sciences and University Passo Fundo among others.

The next, figure 11, highlights the most productive universities based on the number of documents in the sample.

Table 2. Overall impacts of some authors as recorded at Research Gate.

Author	Research Gate Ranking (June 2020)
Alshuwaikhat, H. M. .	21.22
Barth, M.	25.83
Leal Filho, W.	43.80
Lozano, R.	37.48
Velazquez, L.	24.58
Wals, A.	32.28
Wiek, A.	37.10
Wright, T.	22.95

Table 1. Ten main co-citation by cited references.

Number	Author	Title	Journal	Year	Number of citations	Total link strength
1st	Lozano, R	Declarations for sustainability in higher education: becoming better leaders, through addressing the university system	Journal of Cleaner Production	2013	177	1185
2nd	Cortese A. D	The Critical Role of Higher Education in Creating a Sustainable Future.	Planning higher Education	2003	169	934
3rd	Lozano, R.	Incorporation and institutionalization of SD into universities: breaking through barriers to change	Journal of Cleaner Production	2006	155	1014
4th	Wiek, A.	Key competencies in sustainability: a reference framework for academic program development	Sustainability Science	2011	146	744
5th	Velazquez, L.	Sustainable university: what can be the matter?	Journal of Cleaner Production	2006	134	826
6th	Barth, M.	Developing key competencies for sustainable development in higher education	International Journal Higher Education	2007	125	704
7th	Alshuwaikhat, H. M.	An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices	Journal of Cleaner Production	2008	121	616
8th	Lozano, R.	A review of commitment and implementation of sustainable development in higher education: results from a worldwide survey	Journal of Cleaner Production	2015	112	731
9th	Sanchez, M.	An appraisal of the factors which influence sustainability in higher education institutions	International Journal of Sustainability in Higher Education	2005	103	665
10th	Lozano, R.	A tool for a Graphical Assessment of Sustainability in Universities (GASU)	Journal of Cleaner Production	2006	98	677

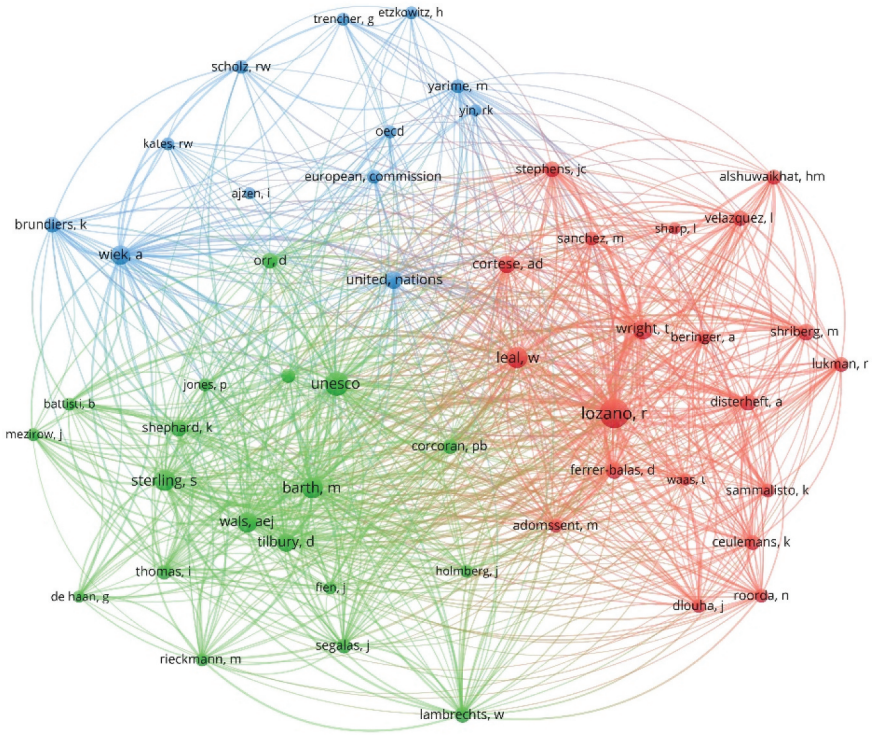

Figure 8. Co-citation by cited authors and institutions.

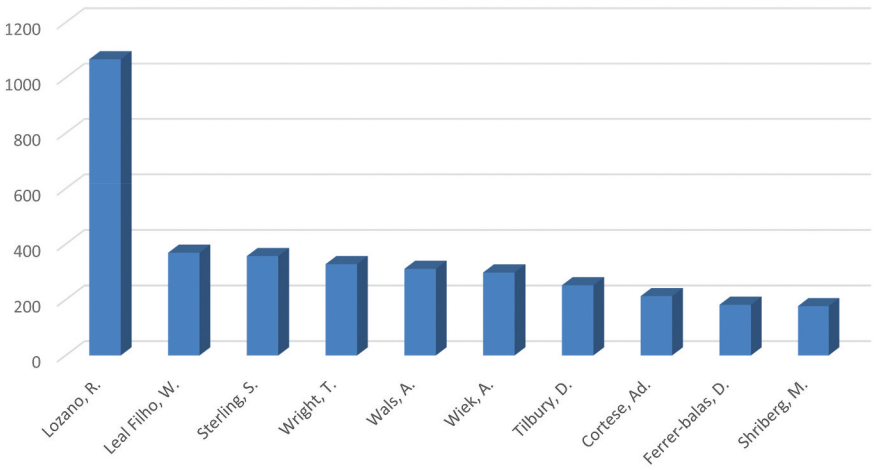

Figure 9. Ten main co-citation by cited authors.

In Figure 12, the bibliographic coupling by country is visualized, starting with a minimum of 20 documents per country. Again, three clusters can be derived from the analysis:

- Cluster 1 (red), 18 countries, e.g. USA, England, Australia, Spain, Brazil, and others
- Cluster 2 (green), 8 countries, e.g. Germany, Sweden, the Netherlands, and others
- Cluster 3 (blue), 3 items Belgium, Mexico, and Wales

In Figure 12 the most prominent countries are depicted. It can be seen, in figure 13, that most publication activities in terms of documents in the sample comes from the USA, England, and Australia.

Finally, a cross-reference with the impacts of some authors and their rankings at Research Gate was assessed and is summarized in Table 2.

Overall, whereas some geographical regions seem to be more predominantly seen in the literature, the spread of authors across countries is rather wide, especially in Europe

5. Conclusions

This paper has presented an analysis of the evolution of the international literature on sustainable

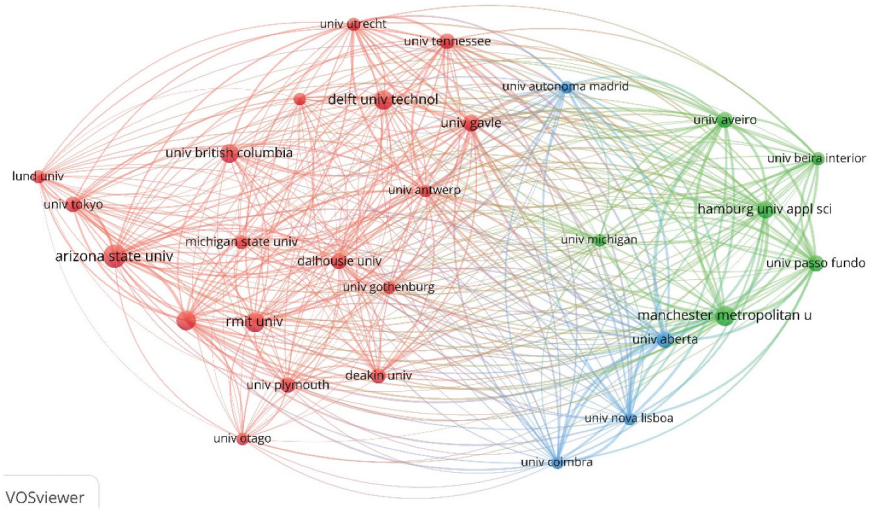

Figure 10. Bibliographic coupling by organization.

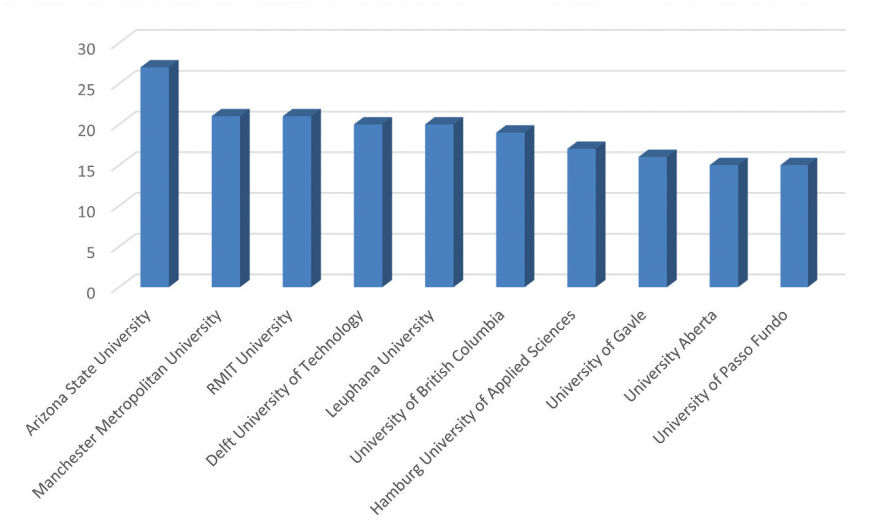

Figure 11. Ten main bibliographic coupling by organization by number of documents.

development in a higher education context, and has documented the evolution

of the topic since 1987. Among the main findings, it can be stated that the evolution of the theme over time is reflected in quantitative terms, i.e. in the increases in the number of scientific papers produced over the years, as well as in qualitative terms, in terms of the diversity of themes being tackled. In addition, the paper has revealed a set of journals that have been dominating the conversation, in particular the International Journal of Sustainability

in Higher Education (IJSHE) and the Journal of Cleaner Productions (JCP), but other eight journals are also engaged on the topics. Other journals also tackle the topic, but on an ad hoc basis.

Moreover, the paper has identified the fact that apart from individual articles, some organisations such as UNESCO, UN Environment Programme and OECD are very active and present in the literature. Finally, the work performed has revealed the existence of geographical gaps. Whereas some countries and regions are well represented in the literature, such as the United States and some European countries, many are not. It is noticeable that papers from Latin America, Asia and Africa are not frequently cited in the international literature on sustainability in higher education, a trend which needs to be addressed.

The work performed has some limitations. Firstly, the study entailed approximately 200 papers published between 1987 and 2019 and focused on those directly emphasising sustainable development in a higher education context. It did not, for instance, consider papers handling sustainability issues in other contexts. Secondly, the use of VOSViewer, deployed to visualize large networks with text mining features such as co-occurrence, co-citation analysis, as well as bibliometric

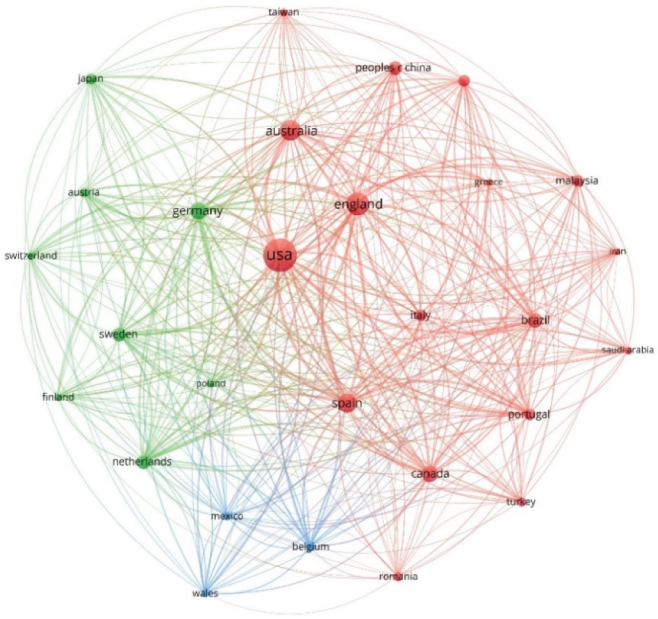

Figure 12. Bibliographic coupling by country.

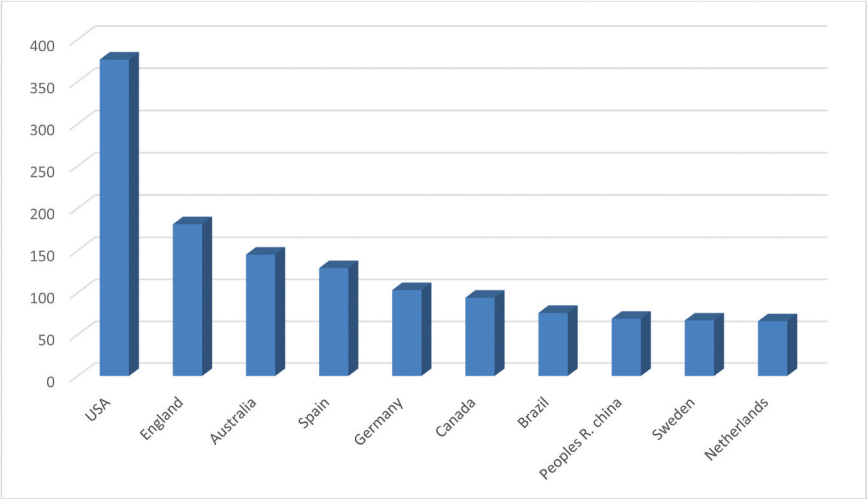

Figure 13. Ten main bibliographic coupling by country.

coupling, focuses on papers predominantly published in journals, and does not fully correlate with other published works such as books and book chapters. If this would

be the case, the frequencies of citations of many authors would be much higher.

Despite these limitations, the research is one of the most comprehensive studies of the sustainability in higher education literature ever undertaken. Apart from performing a bibliometric analysis using science mapping software tools, the visualization of the results means that linkages and relatedness are clearly understood. Also, the study clustered the research into some key areas, which increases the understanding of its dynamics.

The results also show that the evolution of sustainability research has been uneven and calls for a more balanced emphasis to cover some research areas which have been so far neglected. This applies, for instance, to themes such as CO2 emission reductions on campuses, or matters related to sustainability reporting, or transport, among others.

There are some measures which may be deployed, in order to address the current thematic gaps. One of them is the increased networking among sustainability researchers,

who may perform joint research efforts and address some of the neglected topics. This can be implemented, for instance, by making use of the network opportunities offered by the

European School of Sustainability Sciences and Research (ESSSR) https://esssr.eu/and the Inter-University Sustainable Development Research Programme (IUSDRP)

https://haw02.haw-hamburg.de/en/ftz-nk/programmes/iusdrp which congregates hundreds of sustainability researchers from around the world. Also, the data show that a stronger emphasis to research on the development of competencies is needed, since this highly relevant aspect has not been duly captured.

As the world recovers from the COVID-19 pandemic and higher education institutions are now busy in adjusting their teaching and research programmes, there is a window of opportunity which should be used, in order to adjust future trends on university-based sustainability research, and by doing so, work towards a common future.

Disclosure statement

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