Vol. 14, No. 02, pp. 1280-1304, 2024 DOI: 10.23960/jpp.v14.i2.202492

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpp/

STEAM Approach in Renewable Energy Education: Global Trends and Future Research Direction

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Received: 06 September 2024 *Accepted: 08 October 2024* *Published: 14 October 2024*

Abstract: STEAM Approach in Renewable Energy Education: Global Trends and Future Research Direction. Renewable energy education is an alternative to reducing fossil energy consumption at the school level in which students are hoped to save the energy in their living environment by playing a role in behavior in dealing with energy crises. Many studies regarding the use of STEAM approach to educate students on renewable energy have sharply grown. **Objectives;** This recent research aims to find the novelty of those previous studies regarding renewable energy education using STEAM approach for future researches. **Method;** a systematic review using bibliometric analysis was performed to carry out this research whereby 16 literatures indexed by Scopus and published in 2015 – 2021 were involved as the data. Several analyses, such as co-word, performance, citation, and co-authorship were used to analyze the data promoted by VOSviewer software. **Fundings;** the Results of this recent study showed that publication trend of renewable energy education studies involving the STEAM approach slightly increased in the period of 2015 – 2021 while citation trend sharply decreased. Several documents and lots of authors coming from some countries in each continent contributed most to the studies of STEAM approach in renewable energy education. **Conclusion;** some main themes such as country's participant, environment, renewable energy, awareness, sustainability, education, learning approach, and competence also emerged to synthesize the prospectively new direction of future researches in renewable energy education using the STEAM approach.

Keywords: bibliometric, renewable energy education, STEAM approach.

To cite this article:

Kesuma, A. P., Sunyono, Lengkana, D., Haenilah, E. Y., Firdaus, R., Fuad, M., & Muhammad, U. Z. (2024). STEAM Approach in Renewable Energy Education: Global Trends and Future Research Direction. *Jurnal Pendidikan Progresif*, *14*(2), 1280-1304. doi: 10.23960/jpp.v14.i2.202492.

INTRODUCTION

The preparation of jobs for students in the renewable energy field is a challenge for educators. Ideological debates, rapid technological advances, changing economic policies, emerging research results, regulatory guidelines, and even global environment and climate agreement are actively shaping and influencing the demands and expectations of the workforce in the sector, all of which have the effect on renewable energy development and implementation in the educational program. Moreover, schools are an area that can change student behaviour patterns, the energy crisis is a problem not only for one country but for the whole country. By teaching how to use and utilize

renewable energy in educational institutions, students are expected to be able to apply it in the surrounding environment.

Global CO2 emissions fell 5.8% in 2020 or nearly 2 Gt CO2, the largest ever decline and almost five times greater than the 2009 decline after the global financial crisis. CO2 emissions fell further than energy demand in 2020 as the COVID-19 outbreak hit demand for coal and oil harder than other energy sources while renewables increased. The massive increase in ecological damage, energy demand, and climate change over the decades has created and formed new businesses primarily in the use of biomass feedstocks derived from biological systems and organic materials for renewable energy implementations (Steinbrück et al., 2019). Of the 17 Sustainable Development Goals (SDGs), tackling climate change has become one of the main challenges from policy directions in both developing and developed countries (Baumeister, 2018).

The latest report published by Baumeister (2018), showing the position of OECD countries in achieving the SDGs, can be said that one of the main reasons behind this shortfall is the lack of research-based initiatives and innovation. The distance between achieving SDGs 13 (climate action) and SDGs 13 (clean and affordable energy) indicates the low penetration of renewable energy solutions across countries (Baumeister, 2018). A World Bank report shows that global waste production accounted for about 5% of global emissions in 2016, with an output of 1.6 billion metric tons of carbon dioxide equivalent. Food waste accounts for 47% of these emissions, representing both an opportunity and a monumental problem for the gases released by food waste to be utilized for renewable energy. Environmental literacy has been studied at various ages (Ozsoy et al., 2012; Saltan, 2017).

Environmental awareness that arises from educational policymakers to frame friendly policies on the environment. Therefore, it means that the education has an essential role in decreasing the deterioration of ecological quality. Furthermore, the educational role in getting the goals of the SDGs has proven to be very important (Zafar et al., 2020). Baumeister (2018) stated that several competencies for the sustainability in education and development are critical thinking, inter-transdisciplinary, values, ethics, and systematic thinking. The pedagogical approach used in Education for Sustainable Development (ESD) must be following these competencies. The Science, Technology, Engineering, Art, and Mathematics (STEAM) should be noticed as an approach to ESD in enhancing the environmental literacy.

The STEAM combines between the arts and STEM subjects in enhancing students' abilities such as problem-solving, innovation, engagement, and creativity. The combination also increases job skills such as adaptability, communication, and teamwork required for economic advancement and also career. Additionally, STEAM has been reported to enhance academic learning outcomes and processes, integrity, problem solving, collaboration, and critical thinking (Perignat & Katz-Buonincontro, 2019). Meanwhile, Mungmachon (2012) also added that cultural values are associated with art in STEAM. Therefore, the STEAM approach accommodates various artistic aspects that can act as facilitators for science learning. Moreover, the STEAM is able to generate meaningful education for students through the regular integration of attitudes, skills, concepts, and knowledge enabling students in solving problems, containing in the environmental literacy.

To date, the publication trend related to the use of STEAM approach in educating renewable energy on students has grown moderately. Nevertheless, studies offering comprehensive bibliometric review and mapping related to the implementation of STEAM approach to educate

students about renewable energy in SDGs have not been carried out nor also found in the journal or conference proceeding. For a deeper exploration and understanding of the topic, a systematic review utilizing bibliometric approach was applied. So far, a lot of bibliometric analysis reports have studied the STEM approach in educational field (Assefa & Rorissa, 2013; Aytac & Slutsky, 2017; Aytac & Tran, 2021; Du et al., 2022; Ha et al., 2020; Hinojo-Lucena et al., 2020; Novia et al., 2021; Nugraha et al., 2023; Phuong et al., 2023; Shamim et al., 2022; Shidiq et al., 2021). Moreover, few bibliometric analysis studies regarding the implementation of STEAM approach in mathematics and science education have been carried out (Marín-Marín et al., 2021; Santi et al., 2021). On the other hand, this current bibliometric approach study focuses on the use of STEAM approach in enhancing environmental literacy in renewable energy. Therefore, the aim of this recent research is to find state of the art of numerous previous studies regarding the use STEAM approach to improve environmental literacy in renewable energy, and then use it for future researches on STEAM approach in educating renewable energy.

METHOD

To present a bibliometric review and mapping of studies regarding STEAM approach with renewable energy education, a systematic review using bibliometric analysis was performed. Moreover, Donthu et al. (2021) argued that bibliometric approach is a well-known and harsh method to explore and analyse the large volumes of scientific data in which it can get a one-step overview, acquire novel ideas for next researches, and recognise knowledge gaps. According to some literatures, there were five stages to conduct bibliometric analysis that were: (1) specifying the search keyword, (2) exploring initial search results, (3) refining the documents, (4) compiling the initially statistical data, and (5) analysing the data (Fuad et al., 2022, 2023; Helsa et al., 2023b; Juandi, Suparman, et al., 2022; Juandi, Tamur, et al., 2022; Juandi et al., 2023; Putra et al., 2024; Suparman et al., 2022; Suparman & Juandi, 2022a, 2022b; Susiyanti et al., 2022; Suyanto et al., 2023; Tawaldi et al., 2023; Yunita et al., 2022). Particularly, every stage to conduct bibliometric analysis in this study was elucidated in the following subsections.

Specifying the Search Keyword

To discover the documents regarding STEAM approach with renewable energy education, Scopus database was utilized in that it had many electronically well-qualified documents from numerous scientific field (Zhu & Liu, 2020). The specific keyword ("renewable energy education") was established to seek the prospective documents which was suitable to the studies related to STEAM approach with renewable energy education. The search process of documents in Scopus database was performed in December 31st, 2021, specifically at 11.59 PM in Western Indonesian Time.

Exploring Initial Search Results

The results at the beginning search discovered 3,249 documents published in the period of 1978 – 2022 and sourced from journal, book, conference proceeding, and book series. The publication stage of documents was in final and press whereby those consisted of conference paper, article, review, book chapter, editorial, conference review, book, short survey, letter, note, erratum, and data paper. The documents were written in a lot of languages such as Spanish, Portuguese, Chinese, Turkish, Italian, Russian, Korean, English, Persian, Slovenian, Dutch, Croatian, Hungarian, Serbian, African, Polish, Slovak, Estonian, Czech, Bosnian, French, Malay, Norwegian, Lithuanian, Catalan, Arabic, German, Finnish, Danish, Greek, Indonesian, Japanese, Romanian, and Swedish.

Refining the Documents

To gain the documents related to renewable energy education studies, some inclusion criteria were established. Firstly, the document was published in the period of 2015 – 202. Secondly, the document only sourced from the journal and the type of document was only in article. Thirdly, the title of document had to contain the keyword "renewable energy". Fourthly, there was the use of STEAM approach in educating renewable energy in every document. Fifthly, the document was only written in English and the publication stage of document had been in final. The document which did not meet the inclusion criteria were removed from the selection process. Some literatures stated that there were four stages to select the document systematically that were: (1) identification, (2) screening, (3) eligibility, and (4) inclusion (Fuadi et al., 2021; Helsa et al., 2023a; Jaya & Suparman, 2021; Juandi, Suparman, et al., 2022; Sulistiawati et al., 2023; Suparman et al., 2022; Suparman & Juandi, 2022a, 2022b). The process of document selection is systematically presented in Figure 1.

Moreover, comparison metric between initial search and refinement search related to documents involved in this study can be seen in Table 1.

Table 1. Comparison metrics

Metrics Data	Initial Search	Refinement Search
Source	"Renewable energy education"	"Renewable energy"
Publication year	1978 - 2022	2015 – 2021
Papers	3.249	16
Citations	91.237	205
Cites/year	35.17	41.00
Cites/paper	6.81	12.81
Author/paper	2.55	2.88
h_Index	67	6
g_Index	31	14
hI_Norm	7	4
hI_Annual	0.67	0.80

Compiling the Initially Statistical Data

The eligible literatures were downloaded from Scopus database in two formats that were Research Information System (RIS) and Comma Separated Values (CSV) whereby the formats contained some information such as bibliometric information, abstract and keyword, and bibliographic information (Muhammad et al., 2022). Additionally, the RIS format presented in the software of Perish or Publish (PoP) provided the data such as author names, number of document citations, document titles, publication years, document sources, publishers, and document types (Fuad et al., 2022).

Moreover, the appearance of PoP software presented the descriptive analysis summary such as the total of publication (TP), the number of citations per publication (NCP), the number of citations per year (NCY), the period of publication and citation years, the number of authors per publication (NAP), h-index, the total of citation (TC), and g-index (Muhammad et al., 2022). On the other hand, the CSV format presented in the software of VOSviewer displayed the most numerous publication and citation viewed from the unit of document, author, country, source, and institution, and also keyword occurrence, total of strength link, some

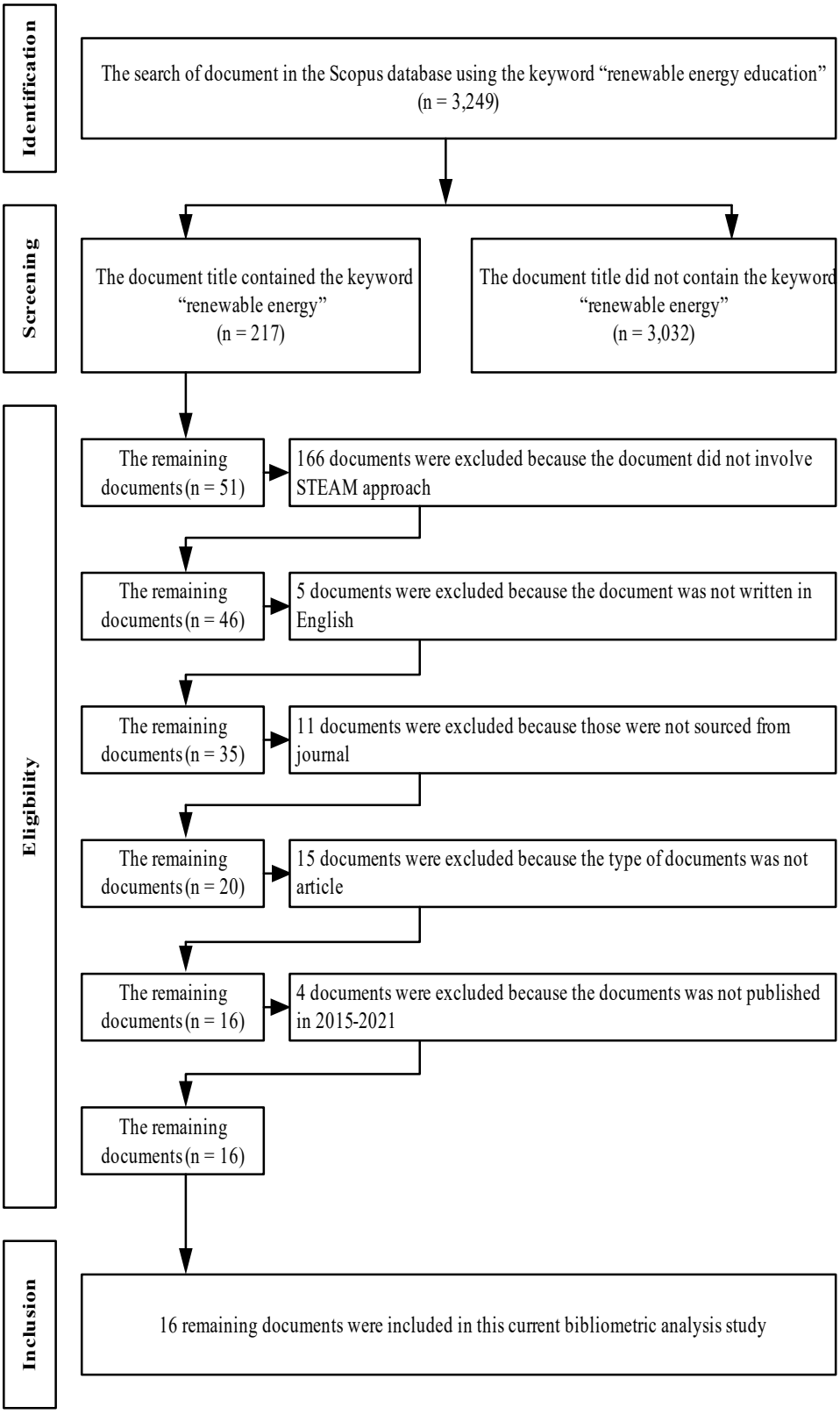

Figure 1. The process of document selection

visualizations, and clustering (Fuad et al., 2022).

Analysing the Data

Some analyses such as performance, co-word, citation, and co-authorship were performed to analyse the data. In particular, performance analysis was applied to present the development of publication and citation of studies regarding STEAM approach with renewable energy education. In addition, citation analysis was used to provide the information regarding the influential documents contributing most to renewable energy education studies. Moreover, co-authorship analysis was performed to present the social interactions among authors related to renewable energy education studies. Then, co-word analysis was employed to present the most frequently emerging keywords and the distribution of appearing keywords regarding renewable energy education studies in the current period in which at least it could provide state of the art of studies related to STEAM approach with renewable energy education. Co-authorship and co-word analysis were enriched by some additional analyses such as visualisation analysis and clustering analysis. According to Fuad et al. (2022), performance analysis could be supported by the software of PoP. In contrast, the software of VOSviewer supported other analyses such as citation analysis, co-authorship analysis, and co-word analysis.

■ RESULT AND DISCUSSION

The Development of Publication and Citation of Studies Regarding STEAM Approach with Renewable Energy

Performance analysis was carried out to show the development of the publication and citation of renewable energy education studies between 2015 and 2021. The report related to the development of publication and citation of renewable energy education studies is presented in Figure 2.

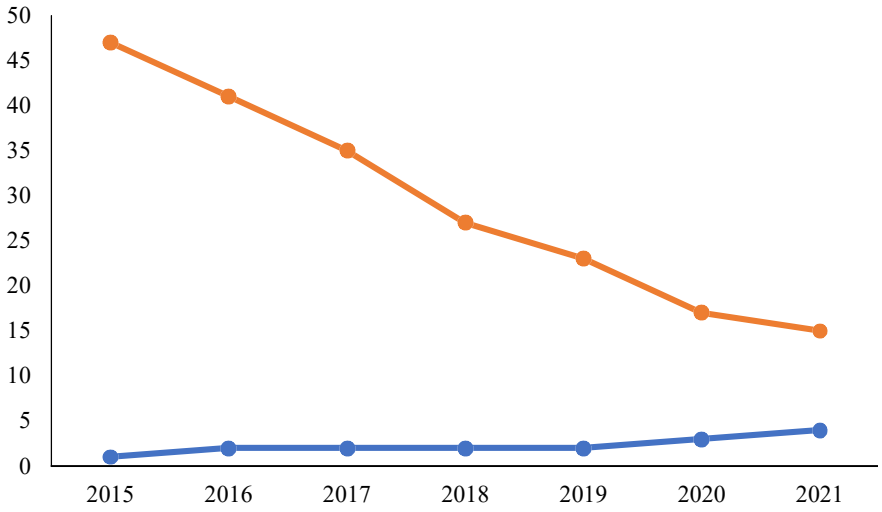

Figure 2. Publication and citation trend of renewable energy education

Figure 2 shows that the publication trend of studies of renewable energy education involving the STEAM approach slightly soared in the period of 2015 - 2021. In detail, of 16 documents, there were four documents published in 2021, followed by three documents in 2020, two documents in 2016, 2017, 2018, and 2019, and one document in 2015. This indicates that

studies focusing on renewable energy education that its implementation in the learning process uses the STEAM approach are interested by many researchers. This is line to Marín-Marín et al. (2021) that the development of publication of studies related to STEAM approach in education sharply increased from 2006 to 2020. Moreover, Santi et al. (2021) also revealed that the publication trend of studies focusing on STEAM approach in environment and science education slightly increased between 2013 and 2020. These reports provide sufficient evidences that researches regarding the use of STEAM approach in educational field are increasingly interested by lots of researchers in the recent period.

In contrast, the citation trend on studies related to STEAM approach in renewable energy education sharply fell from 2015 until 2021. Particularly, of the total of 205 citations, the documents were cited as many as 47 times in 2015, followed by 41 times in 2016, 35 times in 2017, 27 times in 2018, 23 times in 2019, 17 times in 2020, and 15 times in 2021. This shows that the longer the document is published, the more the document is cited. Santi et al. (2021) also revealed that of 113 documents cited as many as 746 times, the citation trend of studies related to STEAM approach in science education slightly decreased in the period of 2013 – 2020. Those are a little different to Marín-Marín et al. (2021) that of 67 documents cited as many as 541 times, the development of citation on studies regarding the use of STEAM approach in educational field relatively fluctuated between 2006 and 2020. These indicate that the citation trend on studies focusing on the use of STEAM approach in education field, especially in renewable energy education tends to decrease gradually to the current period.

The Documents Contributing Most to Studies of STEAM Approach in Renewable Energy Education

The documents involved in this current study can be informed in some categories viewed on approach/method, journal quartile, publisher, document source, and subject area. A few of approaches or methods used in those documents are presented in Figure 3.

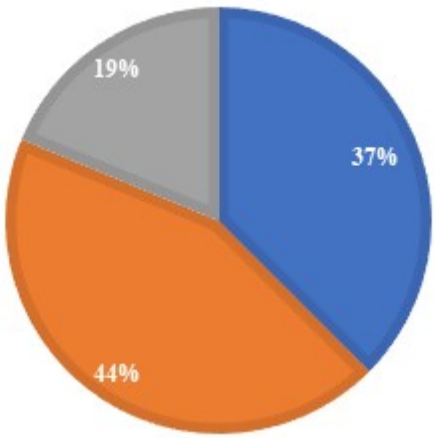

Figure 3. The approach/method used in the documents

From Figure 3, it shows that the documents using qualitative and quantitative method were more dominant than the documents using mix-method. Subsequently, some publishers which published the documents are presented in Figure 4.

Figure 4 presents that the documents published by Elsevier were more numerous than the documents published by Taylor & Francis, SAGE, Emerald, and Wiley. the distribution of journal quartile of the documents is presented in Figure 5.

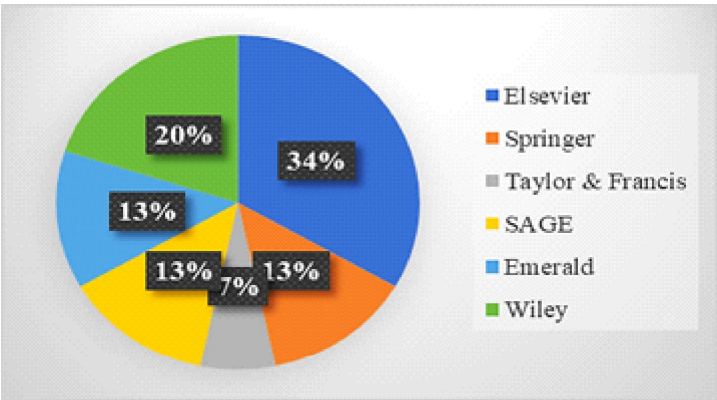

Figure 4. The publisher of the documents

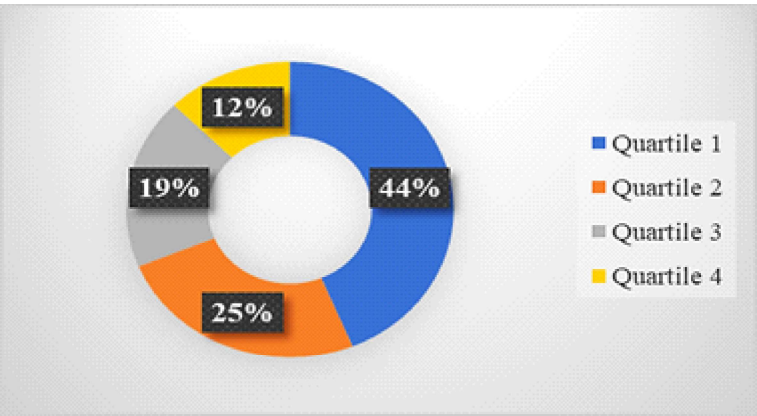

Figure 5. The journal quartile of the documents

From Figure 5, It can be seen that the documents indexed by Scopus in Q1 were more numerous than the documents indexed by Scopus in Q2, Q3, or Q4. Additionally, specific subject area of studies those documents is presented i Figure 6.

Figure 6 shows that subject area in environmental science was more involved in the studies related to the use of STEAM approach in renewable energy education than other subject areas such as social science, multidisciplinary, and energy.

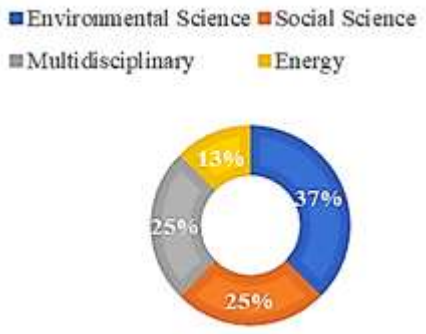

Figure 6. Subject area of studies in the documents

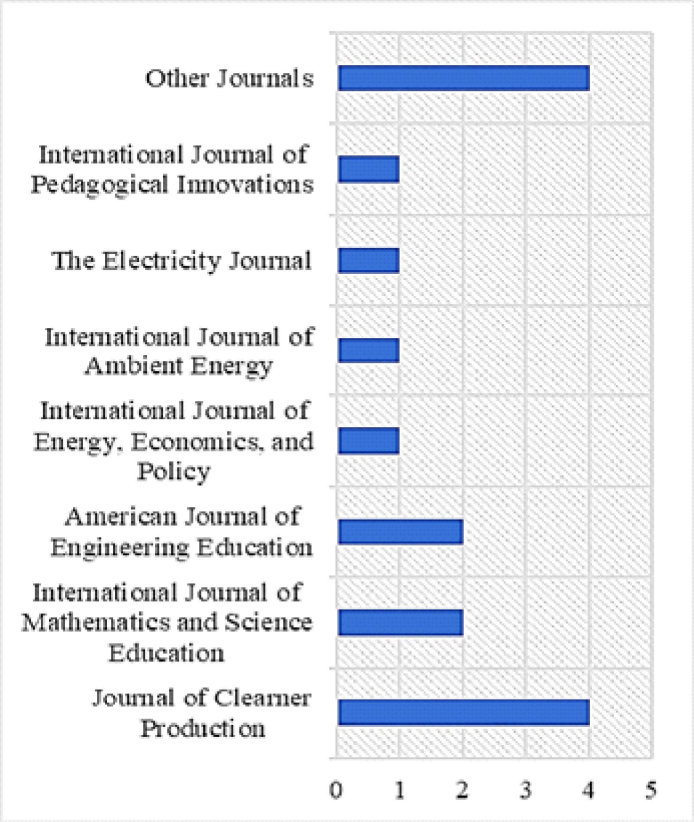

Figure 7. The document sources

In addition, the source of documents is presented in Figure 7.

From Figure 7, it presents that Journal of Clearner Production was more desirable to the authors in publishing their studies related to STEAM approach in renewable energy education than other sources such as International Journal of Mathematics and Science Education, American Journal of Engineering Education, and International Journal of Ambient Energy.

Citation analysis was carried out to show the influential documents contributing most to studies of the STEAM approach in renewable energy education. According to Muhammad et al. (2022), the most influential documents were measured by using the number of citations. The most influential documents regarding renewable energy education studies involving the STEAM approach are shown in top ten documents in Table 2.

Table 2. The top 10 most influential documents

Year	Author	Title	Journal	Cite
2020	Zafar, M.W., Shahbaz, M., Sinha, A., Sengupta, T., & Qin, Q.	How renewable energy consumption contribute to environmental quality? The role of education in OECD countries (Zafar et al., 2020).	Journal of Cleaner Production	10

2019	Leal Filho, W., Salvia, A.L., & Paço, A.A..	A comparative study of approaches towards energy efficiency and renewable energy use at Higher Education Institutions (Leal Filho et al., 2019).	Journal of Cleaner Production	8
2020	Edsand, H.E., & Broich, T.	The Impact of Environmental Education on Environmental and Renewable Energy Technology Awareness: Empirical Evidence from Colombia (Edsand & Broich, 2020).	International Journal of Science and Mathematics Education	5
2020	Jeong, J.S., & González-Gómez, D.	A web-based tool framing a collective method for optimizing the location of a renewable energy facility and its possible application to sustainable STEM education (Jeong & González-Gómez, 2020).	Journal of Cleaner Production	2
2016	Walz, K.A., Slowinski, M., & Alfano, K.	International Approaches To Renewable Energy Education – A Faculty Professional Development Case Study With Recommended Practices For STEM Educators (Walz et al., 2016).	American Journal of Engineering Education	2
2021	Tsaurai, k., & Ngcoba, L.	Renewable Energy Consumption, Education and Economic Growth in Brazil, Russia, India, China, South Africa (Tsaurai & Ngcobo, 2020)	International Journal of Energy Economics and Policy	1
2021	uz Zaman, Q., Wang, Z., Zaman, S., & Rasool, S.F.	Investigating the nexus between education expenditure, female employers, renewable energy consumption and CO2 emission: Evidence from China (Zaman et al., 2021).	Journal of Cleaner Production	1
2018	Hammad, B., Al-Zoubi, A., & Castro, M.	Harnessing technology in collaborative renewable energy education (Hammad et al., 2018)	International Journal of Ambient Energy	1
2021	Rodgers, M.D.	Pathways to eliminate carbon emissions via renewable energy investments at higher education institutions (Rodgers, 2021).	The Electricity Journal	1

2017	Bosman, L.B., & Chelberg, K.	Integrating Context and Authenticity to Increase Pre-College Engagement through the STEM Academy for Renewable Energy Education (Bosman & Chelberg, 2021)	International Journal of Pedagogical Innovations	1

Table 2 shows that the document entitled "How renewable energy consumption contribute to environmental quality? The role of education in OECD countries" authorized by Zafar et al. was the most influential document regarding the use of STEAM approach in renewable energy education. The document published in Journal of Cleaner Production by Elsevier has been cited as many as ten times by other relevant studies from 2020 to date. Moreover, particularly the document studied the contribution of renewable energy education on environmental quality in OECD countries. This shows that the role of environmental literacy developed in renewable energy education using the STEAM approach is extremely needed to ensure that the environmental quality is always awake. According to Perignat and Katz-Buonincontro (2019), the environmental literacy skills is extremely required by each individual, especially students in the educational field in cultivating the attitude to save the best quality of an environment. Additionally, Baumeister (2018) stated that the role of STEAM approach in renewable energy education contributes in enhancing students' environmental literacy skills. These indicate that the involvement of STEAM approach in renewable energy education is extremely essen for the development of students' environmental literacy skills.

Social Interaction Among Authors Regarding Studies of STEAM Approach in Renewable Energy Education

All documents involved in this study were authorized by 48 authors distributed in five continents (See Figure 8), twelve countries (See Figure 9), and 28 educational institutions (See Figure 10).

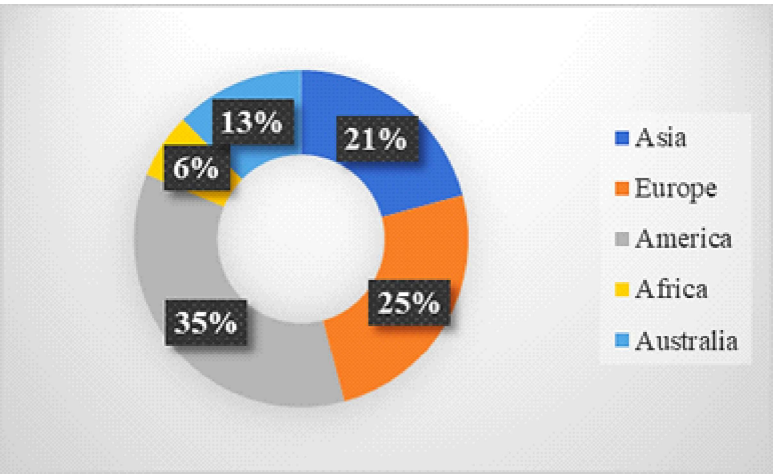

Figure 8. The distribution of authors in some countries

Figure 8 presents that the authors in the documents were more dominated by American authors than Asian, European, African, and Australian Authors. This shows that American authors more contribute in carrying out the studies of STEAM approach in renewable energy education than other authors in other continents.

From Figure 9, it can be seen that there were four countries in America contributing most to studies of the use of STEAM approach in renewable energy education, followed by one country in Australia, three countries in Europe, three countries in Asia, and one country in Africa. Additionally, authors who come from the USA more dominated in working the studies regarding

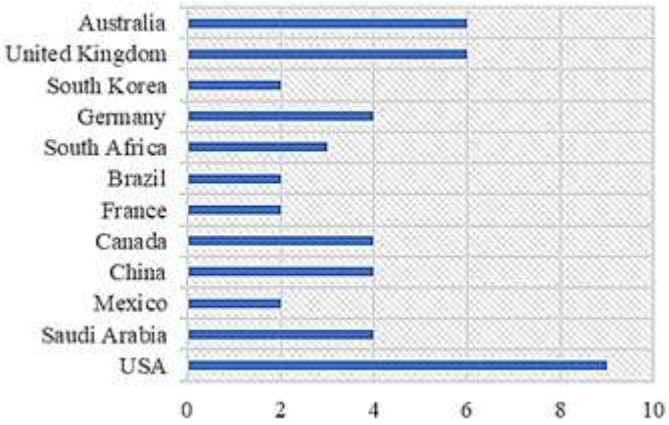

Figure 9. The distribution of authors in several countries

the use of STEAM approach in renewable energy education than authors who come from other countries such as United Kingdom, Australia, South Korea, South Africa, and Canada.

Figure 10 shows that the studies regarding the use of STEAM approach in renewable energy education were worked by four institutions in USA, followed by two institutions in Canada, one institution in Brazil, one institution in Mexico, four institutions in United Kingdom, three institutions in Germany, two institutions in France, two institutions in China, two institutions in Saudi Arabia, one institution in South Korea, two institutions in South Africa, and four institutions in Australia.

Furthermore, co-authorship analysis was conducted to present the social interactions among authors who conducted the studies regarding the use of STEAM approach in renewable energy education. Network visualisation and clustering analysis was also

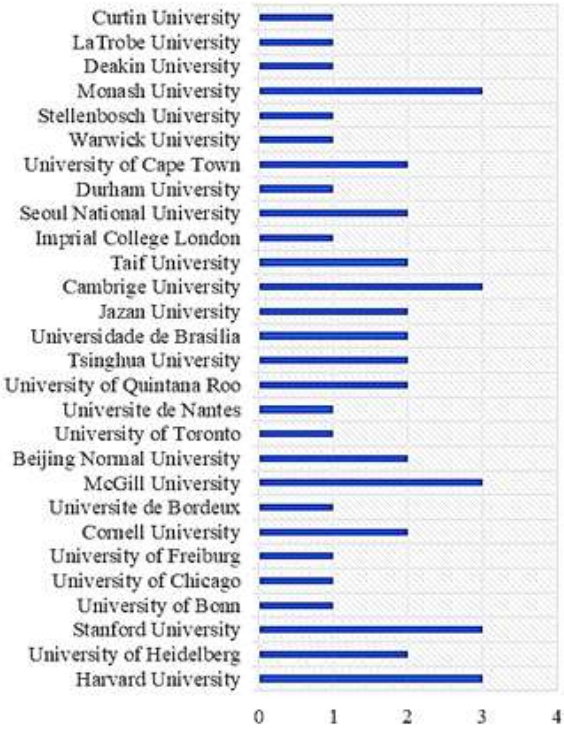

Figure 10. The distribution of authors in many educational institutions

involved to enrich this analysis (Fuad et al., 2022; Muhammad et al., 2022). The visualisation analysis among authors was conducted by selecting the minimum number of documents of an author as many as one document and the minimum number of citations of an author as many as no citation. As a result, 48 connected authors distributed into fifteen clusters such as blue, red, yellow, green, and others emerged (See Figure 11).

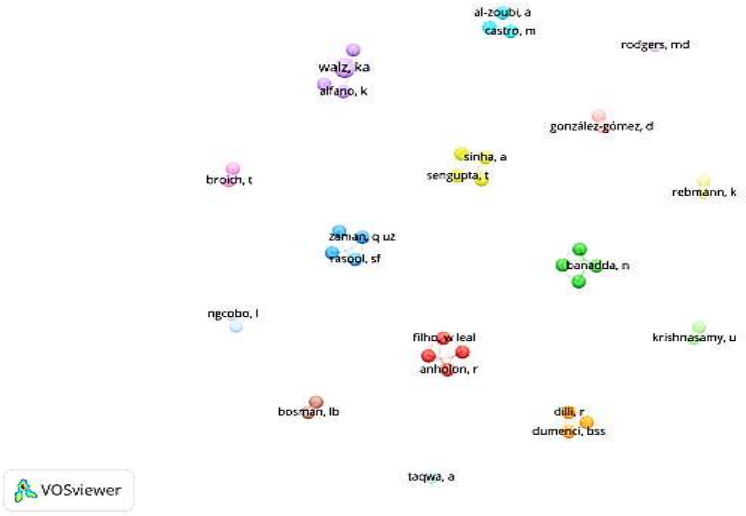

Figure 11. The social interactions among authors regarding renewable energy education studies

From Figure 11, it can be seen that the set of authors in each document containing 16 studies was distributed in fifteen clusters. It means that there are two studies in one cluster whereby it is purple cluster which contained four authors such as Shoemaker, J.B., Walz, K.A., Alfano, K., and Slowinski, M (See Figure 12).

Figure 12 presents that Walz, K.A. who was an author in red cluster jointly worked the study related to international approaches in renewable energy education with few authors in green cluster such as Alfano, K. and Slowinski, M. They concurently studied a faculty professional development case study with

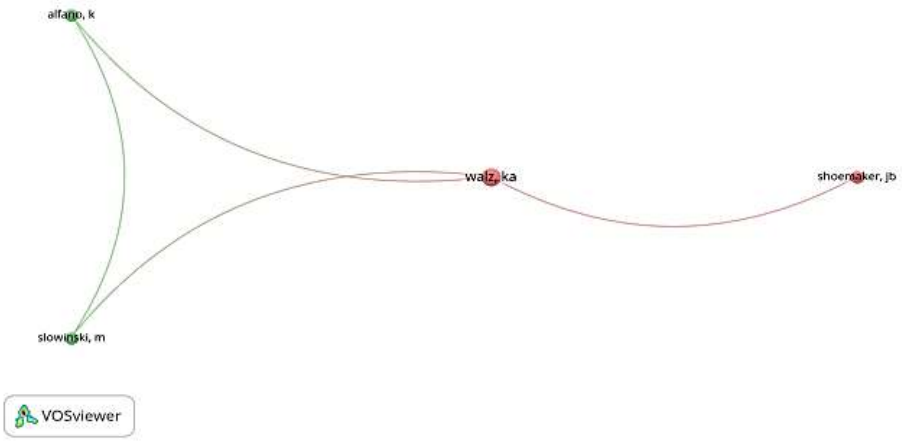

Figure 12. The social relationships among authors in purple cluster

recommeded practices for STEAM educator in renewable energy education (Walz et al., 2016). Their study has been publisged in American Journal of Engineering Education, from 2016 to date, this document has been cited as many as ten times by other relevant studies. Moreover, in common, Walz, K.A. and Shoemaker, J.B in red cluster carried out the study related to renewable energy advanced technology education in which they simultanesously worked the study regarding the preparation of future sustainable energy using renewable energy advanced technology education (Walz & Shoemaker, 2017). The results of this study have been reported and published in the Journal of Sustainability Education whereby the document has been cited as many as five times by other relevant studies from 2017 to date. Thus, even though there are not many social interactions among authors who carry out the studies related to the use of STEAM approach in renewable energy education, but at least there is a social relationship among authors in purple cluster whereby this shows that the studies the use of STEAM approach in renewable energy education are not worked independently.

The Emerging Theme of Renewable Energy Education Studies and Its Distribution in the Most Current Period

Co-word analysis was performed to present the frequently emerging keywords and the distribution of appearing keywords regarding renewable energy education studies involving the STEAM approach in the current period. Moreover, at least it was expected to provide statement of the art of renewable energy education studies carried out between 2015 and 2021. The network visualisation analysis was conducted to show the frequently emerging keywords regarding the STEAM approach in renewable energy education. The minimum number of occurrences of a keyword as many as one occurrence were selected, so 97 interconnected keywords appeared (See Figure 13).

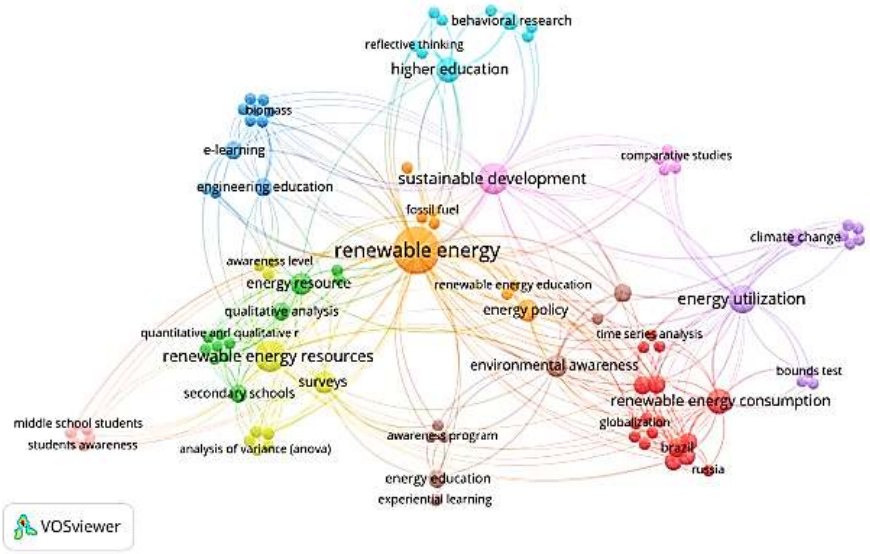

Figure 13. The social relationships among authors in purple cluster

Moreover, hierarchical clustering analysis was performed to group some similarly emerging keywords into some themes (See Table 3).

Additionally, the overlay visualisation analysis was conducted to present the distribution of appearing keywords regarding STEAM

Table 3. The theme of emerging keyword

Theme	Keyword	Frequency
Country's Participation	Brazil	5
	China	4
	Germany	2
	France	2
	South Korea	1
	Russia	1
	South Africa	1
Environment	Environmental Economics	4
	Environmental Impact	3
	Environmental Protection	3
	Environmental Quality	2
	Environmental Sustainability	2
	Environmental Technology	2
Renewable Energy	Renewable Enegry Consumption	8
	Renewable Energy Resource	5
	Renewable Energy Technology	4
Sustainability	Sustainable Living	5
	Sustainable Campus	3
	Sustainable Development	2
	Sustainable University	2
Energy	Energy Resource	3
	Energy Targets	2
	Energy Utilization	2
	Energy Planning	2
	Energy Policy	1
	Energy Efficiency	1
	Energy Sustainability	1
Awareness	Affective Awareness	2
	Cognitive Awareness	2
	Public Awareness	2
	Awareness Program	1
	Environmental Awareness	1
	Students Awareness	1
Research Design	Research and Development	3
	Mixed Method Research	3
	Qualitative Research	2
	Quantitative Research	2
Data Analysis	Time Series Analysis	3
	Qualitative Analysis	2
	Quantitative Analysis	2
	Sensitive Analysis	1
	Analysis of Variance	1
	Multi-Criteria Decision Analysis	1
Participant/Educational Level	Primary Education	4
	Secondary Education	3

	Vocational Education	3
	Undergraduate Education	2
	Higher Education	2
	University Students	1
	Middle School Students	1
Data Collection	Semi Structured Interview	3
	Survey	2
	Test	2
Education	Environmental Education	5
	Renewable Energy Education	4
	Sustainable Education	4
	Energy Education	3
	Engineering Education	3
	STEM Education	2
	Nature Education	2
	Outdoor Education	2
Learning Approach	Blended Learning	4
	E-learning	2
	Interactive Learning	2
	Students-centered Learning	2
	Experiental Learning	1
	Online Training	1
Competence	21st Century Skills	4
	Learning Outcome	3
	Reflective Thinking	2
	Public Attitude	2
Negative Factor on Environment	Carbon Emission	4
	Biomass	4
	Carbon Dioxide	3
	Climate Change	3
	Crude Oil	3
	Fossil Fuel	2
	Nuclear Power	2
	Pollutan	2
	Urbanization	2
	Globalization	2

approach in renewable energy education in the curent period. The minimum number of occurrences of a keyword as many as one occurrence were selected, so 97 interconnected keywords appeared (See Figure 14).

At least there were eight keywords emerged in the most current period such as "carbon dioxide", "bound test", "CO2 emission", "urbanization", "environmental economics", "carbon emission", "globalization", and "primary and secondary education".

Hierarchical clustering analysis promoted by thematic analysis shows that at least there were 14 mainly emerging themes related to the studies of STEAM approach in renewable energy education. The emerging themes were such as

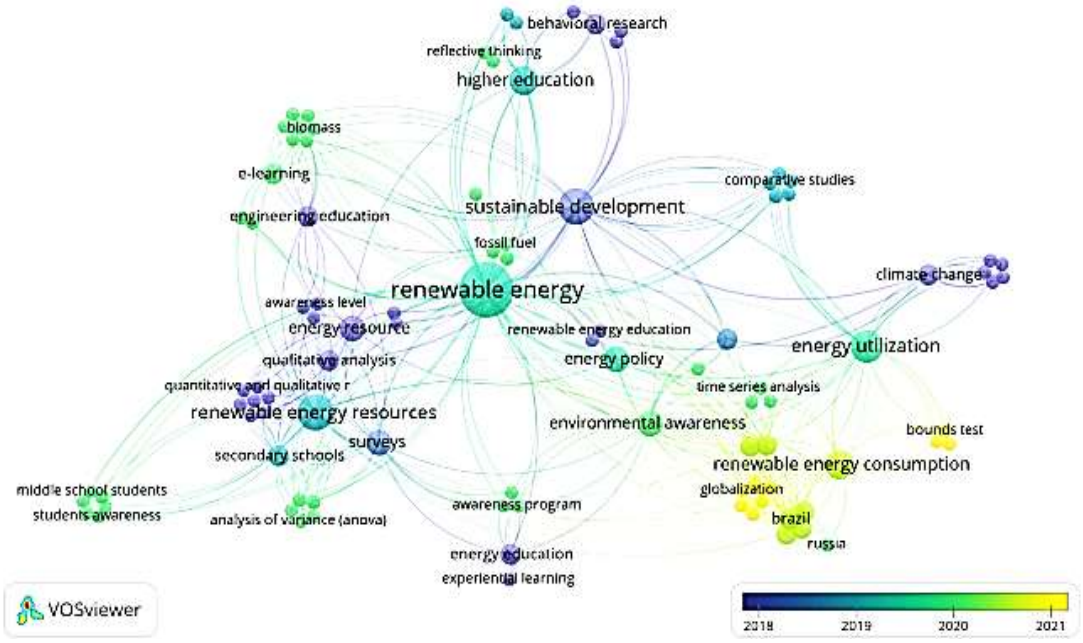

Figure 14. The social relationships among authors in purple cluster

country's participant, environment, renewable energy, sustainability, energy, awareness, research design, data analysis, participant/educational level, data collection, education, learning approach, competence, and negative factor on environment. Some of these themes would be comprehensively explained and discussed in the following paragraph.

The first theme was related to the involvement of some countries in carrying out the studies of STEAM approach in renewable energy education. There were some countries such as Brazil, China, Germany, France, South Korea, Russia, and South Africa. This shows that the studies regarding the use of STEAM approach in renewable energy education have been conducted in few countries in Asia, America, Europe, and Africa. Marín-Marín et al. (2021) also revealed that several countries in each continent have studied the use of STEAM approach in renewable energy education. This indicates that the researches focusing on STEAM approach in renewable energy education have been well-known in some countries in every continent. However, Indonesia located in Southeast Asia has not popularized the use of STEAM approach in renewable energy education. It means that it can be newly future research direction by Indonesia researchers, especially in the field of science education, and make it well-known in Indonesia.

The second theme was related to environment whereby there were some emerging keywords of this theme such as "environmental economics", "environmental impact", "environmental protection", "environmental quality", "environmental sustainability", and "environmental technology". Moreover, the third theme was related to competence in which there were few emerging keywords of this theme such as "21st century skills", "learning outcome", "reflective thinking", and "public attitude". Nevertheless, it has not been seen the keyword related to "environmental literacy". Meanwhile, environmental literacy is one of the essential skills that have to be cultivated on each individual, especially every students. Some literatures stated that environmental literacy refers to the ability in

understanding the character and phenomenon of an environment (Buldur et al., 2020; Mahalik et al., 2021; Zafar et al., 2020; Zaman et al., 2021). It is expected to promote energy sustainability by saving the energy in the living environment. The educational system has an important role in cultivating the environmental literacy. Therefore, the use of STEAM approach, especially in renewable energy education is one of the alternative approaches in enhancing students' environmental literacy.

The fourth theme was related to sustainability whereby there were some emerging keywords of this theme such as "sustainable living", "sustainable campus", "sustainable development", and "sustainable university". Additionally, the fifth theme was related to education in which there were some emerging keywords of this theme such as "environmental education", "renewable energy education", "sustainable education", "energy education", "engineering education", "STEM education", "nature education", and "outdoor education". This shows that the sustainable education in environment, energy, or renewable energy can be new direction of future studies. Sustainable education has to be performed to ensure that the educational process on each individual will be exist either formal or informal. Several reports also revealed that sustainable education has an important role in continuing the cultivement of individual's skill and ability in lots of life field such as health, economics, science, social and politic, law, and others (Edsand & Broich, 2020; Hammad et al., 2018; Jeong & González-Gómez, 2020; Leal et al., 2019; Tsaurai & Ngcobo, 2021). Consequently, to save the energy in the living environment from the enegy crisis, sustainable education in environment, energy, and also renewable enegry has to be continued.

The sixth theme was related to learning approach whereby there were some emerging keywords of this theme such as "blended learning", "e-learning", "interactive learning", "students-centered learning", "experiental learning", and "online learning". In addition, the seventh theme was related to awareness in which there were some emerging keywords of this theme such as "affective awareness", "cognitive awareness", "public awareness", "awareness program", "environmental awareness", and "students awareness". From the STEAM approach implemented, it has not been seen a few of learning models applied in the renewable energy education. Few learning models such as problem-based learning and project-based learning can be embedded in the STEAM approach in renewable energy education to cultivate students' environmental literacy skills. According to Ulazia and Ibarra-Berastegi (2020), problem-based learning implemented in renewable energy education is able to enhance students' environmental literacy skills. Moreover, Buldur et al. (Buldur et al., 2020) revealed that project-based learning applied in renewable energy education affects on the enhancement of middle school students' environmental literacy skills. Additionally, few literatures revealed that problem and project-based learning combined with the STEAM approach in renewable energy education can cultivate environmental awareness (Edsand & Broich, 2020; Hammad et al., 2018). These reports show that proposing project-based learning and problem-based learning embedded in the STEAM approach can be new directions of future studies in renewable energy education, especially both in enhancing students' environmental literacy skills and students' environmental awareness.

The other arguments focus on teaching art as a way to enhance students' critical and creative thinking (Marín-Marín et al., 2021). According to Jeong and González-Gómez (2020), even though STEM skills are in demand in that they are noticed as a necessity for careers in the 21st century, creativity will eventually be seen as even

more important. Therefore, Shukshina et al. (2021) proposed the integration from the arts into STEM to create a STEAM focus as a central goal for the 21st century education. In accord with this argument, STEAM provides the benefits for students and to economic growth (Edsand & Broich, 2020; Hammad et al., 2018). Unfortunately, STEAM is still a new approach when teachers teach about the concept of renewable energy. Root-Bernstein (2015) revealed that STEAM can enhance students' abilities such as problem-solving, innovation, engagement, and creativity. STEAM also has room for non-STEM disciplines as an essential aspect of the approach. Some areas such as humanities, arts, and other areas of interest include the environmental study and social interaction (Herro & Quigley, 2016). Implementing the educational environment for students can be improved to create a society that cares about the environment (Hammad et al., 2018). Through STEAM, students can enhance their knowledge of environmental-related topics, which in this case, specifically about renewable energy, and recognize the social dimensions supporting and defining the topic. Currently, STEAM researchers are generally discussing the usefulness and effectiveness of various empirical STEAM approaches to improve learning quality, student retention, and achievement (Brown & Crippen, 2016). Nevertheless, some studies are still limited to certain topics.

■ CONCLUSION

STEAM has showed in helping students to achieve competencies following the ESD, formerly known as Environmental Education; to realize environmental literacy, research on the use of STEAM, especially using renewable energy, is still rare. This study found that in 6 years of research, there were only 16 documents related to STEAM approach in renewable energy education. Publication trend of renewable energy education studies involving the STEAM approach slightly increases in the period of 2015 – 2021 while citation trend sharply decreases. Several documents and lots of authors coming from some countries in each continent contribute most to the studies of the use of STEAM approach in renewable energy education. Some main themes such as country's participant, environment, renewable energy, awareness, sustainability, education, learning approach, and competence also emerge to synthesize the prospectively new direction of future researches in renewable energy education using the STEAM approach.

This current study encourages more researchers to contribute in this area, noticing the previous success of STEAM and what citizens need to be prepared to protect the environment, especially in renewable energy. STEAM must be an important alternative to improve environmental literacy in teaching materials in schools regarding the use of renewable energy, especially in the context of using renewable energy in everyday life. This material should be integrated into related contexts such as art, sociology, science subjects to achieve the SDGs through education. Meanwhile, research in the field of renewable energy education is still scarce. Introducing and implementing STEAM projects into environmental management systems in schools, inside or outside the classroom as an innovative, hands-on and unconventional form of environmental education has to be carried out massively by future researchers, especially Indonesian researchers. They may need to consider the enhancement of environmental literacy skills in renewable energy education using the STEAM approach. Moreover, few learning models such as problem-based learning and project-based learning can be embedded in the STEAM approach in renewable energy education to cultivate students' environmental literacy skills. To save the energy in the living

environment from the enegy crisis, sustainable education in environment, energy, and also renewable enegry has to be continued. Consequently, sustainable education has to be performed to ensure that the educational process on each individual will be exist either formal or informal.

This study only involves the Scopus as the scientific database to search the documents related to STEAM approach in renewable energy education. Even though the Scopus is one of the scientific databases which have the large well-qualified documents, but these documents have not represented the certain field regarding renewable energy education studies using STEAM approach. Therefore, this study suggests to involve other scientific databases which also have numerous well-qualified documents such as Web of Science and MDPI. In addition, this study only uses co-word analysis to synthesize the mainly emerging themes of STEAM approach in renewable energy education. Meanwhile, there are other analyses such as co-citation analysis and bibliographic coupling that can enrich findings of the mainly emerging themes. As a consequence, the involvement of some analyses such as co-citation analysis and bibliographic coupling is needed to enrich co-word analysis.

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