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Low Carbon Education: A Review and Bibliometric Analysis

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Abstract: The concept of low carbon education is one solution to provide knowledge to students related to low carbon behavior. The purpose of this paper is providing an extensive bibliometric literature review on 'low carbon education'. Articles found by Publishing or Perish (PoP) software with the Google Scholar database. There were 55 out of 97 articles found from Google Scholar data base ranging from 2014 to 2019 analyzed in this study. The chosen references were then managed using a referencing manager software namely Zotero. After managing the database, this study classified and visualized it using VOSviewer software. Overall, this review provides an appropriate reference point for further research on 'low carbon education'.

Keywords: *Bibliometric analysis, low carbon, low carbon education, low carbon society.*

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Introduction

The low carbon behavior of the community is still of concern (Bai & Liu, 2013) and needs to be improved. This behavior has a significant role in reducing carbon emissions and improving the environment's quality around us (Chen & Li, 2019). To this relation, there are several factors influencing this behavior namely low-carbon awareness, low-carbon knowledge, personal norms, social norms, private low-carbon behavior, public low-carbon behavior, situational factors, and psychological factors. Psychological factors can also determine the low-carbon behavior of people in urban areas or in rural ones (Neo, Choong, & Ahamad, 2017). The responsibility for reducing low carbon does not only lie with the people and the government. In this context, factories causing air pollution must also have awareness to reduce carbon emissions (Zhang, 2017).

Public awareness about the concept of low carbon must be increased immediately. This will have an impact on economic life (Lyu, Ngai, & Wu, 2019) and threatens the stability of the natural ecosystem and the human environment (Zhou, Ang, & Han, 2010). Developing countries such as Indonesia is in need of paying serious attention to various types of development; one of which is that in low carbon economy (Hohne, Wartmann, Herold, & Freibauer, 2007). This is done to effectively reduce CO_2 emissions while maintaining economic growth.

The use of low carbon can also be applied using technology (Lv & Qin, 2016). The application of this technology not only contributes to a significant percentage of the reduction of carbon dioxide emissions, but also helps reduce energy consumption (Anbumozhi & Kalirajan, 2017). To cope with this, education needs to play its role by teaching the concept of low carbon since early childhood. Low carbon has been a major concern in recent years gradually become a focus in the academic/educational field.

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The education world is most responsible for ensuring awareness of low carbon behavior. The development of low carbon education is very important and must be done. Awareness of low carbon behavior must be introduced since 6 or 7 years old, in which in Indonesia is the ideal age of starting elementary school (Phang, Wong, Ho, Musa, Fujino, & Suda, 2016) and higher education (Dai, Cheng, Liu, Tang, Zheng, & Wang, 2019; Horan, Shawe, & O'Regan, 2019) so that their environment is free of carbon emissions. Actually, most students learn about the environment at school since the school (Amin, Permanasari, & Setiabudi, 2019) is responsible to provide good learning environment (leading to promoting good behavior and good characters) as well as good environmental literacy (Agboola, & Tsai, 2012). It is believed that students with good environmental literacy are able to create the most effective environment for themselves (Saltan, & Divarci, 2017).

In this digital era, technology is important in education, including in low-carbon education (Li, 2012; T. Zhang, 2017). For elementary school children, the introduction of low carbon education can be in the form of materials that are appropriate in the curriculum in each country, such as 3R (Reduce, Reuse and Recycle), reduce CO2, and low carbon education programs (Wong, Phang, Ho, & Musa, 2017). It also can use materials about saving water and saving electricity (Fatin Aliah Phang et al., 2016). Growing the concept of environmental education in schools can introduce the low carbon concept and foster social awareness related to the low carbon concept (Horan et al., 2019). Low carbon education is a concept that has been carried out by several developing countries. This concept is needed by all students to be able to obtain the required knowledge and skills to promote sustainable development. In addition, low carbon education is also well-known as a trend aiming to reduce energy consumption and pollutant emissions, increase the level of green energy, and create awareness of low carbon society behavior.

The low carbon concept itself has already been discussed (Li et al., 2012; Du et al., 2020). Even articles on low carbon with bibliometric analysis already exist, one of which is on low-carbon electricity (Wang, Wei, & Brown, 2017). In the existing literature, a number of relevant concepts to low carbon education are low carbon economics (Wei, 2014; Liu, 2019), low carbon energy (H. qiang Li, Wang, Shen, & Chen, 2012; (Hishammuddin et al., 2013), low carbon technology (Anbumozhi & Kalirajan, 2017), low carbon transportation (Harto, Meyers, & Williams, 2010), low carbon society (Shukla, Dhar, & Mahapatra, 2008; Phang et al., 2017), low carbon city (Phdungsilp, 2010), low carbon community (Jiang, Chen, Xu, Dong, & Kennedy, 2013) and low carbon tourism (Scott, Peeters, & Gossling, 2010; J. Zhang, 2017), have been widely discussed. However, a review that discusses low carbon in the world of education is still very minimal. So far, no bibliometric analysis of the term 'low carbon education' has been conducted.

Considering the aforementioned rationale, this paper aims to fill in the research gap by providing an extensive bibliometric analysis of the literature in relation to low carbon education. Articles published and indexed by Google Scholar (GS) were analyzed and categorized based on their author distribution and affiliation. This analysis can see what research topics are being the subject of many more publications, and the future 'low carbon education' topics that provide opportunities for further research. The methodology applied to conduct the analysis is to use bibliometric analysis, including the steps of the method related to the implementation of GS data-based software and publish or perish (PoP). Then present the results using VOSviewer followed by a discussion session and conclusions from the literature study using bibliometric analysis that has been done.

Methodology

This review of the bibliometric literature is based on a systematic and explicit method (Garza-Reyes, 2015) or a mind mapping method emphasizing the limits of knowledge (Tranfield, Denyer, & Smart, 2003). This research method adopts the five-stage method (Tranfield et al., 2003); Setyaningsih, Indarti, & Jie, 2018) as in Figure 1.

Figure 1. Five-step method bibliometric analysis

3.1 Determine search keywords

Literature search was conducted in October 2019 with the keyword 'low carbon education'. Google Scholar was selected since it is currently the biggest data base and Publish or Perish was chosen since it has been proven to be the most effective way of searching articles on the GS (Baneyx, 2008). The first search included query language to the PoP software with the keyword 'low carbon education'.

3.2 Initial search results

This search is specific to 'journals', 'title words' only, and the year '2015-2019'. 97 articles were found at the initial search. The results are compiled in Research Information Systems (RIS) format to include all important article information such as paper titles, author and affiliation names, abstracts, keywords and references.

3.3 Refinement of search results

Appropriate and indexed articles in the GS database are filtered. Proceedings, newspapers, books, book reviews, and book chapters are not included in this data. Only journal articles were selected. Then to make the appropriate improvements, the file is saved in the form of an RIS file. RIS data is imported into Zotero's bibliographic software. The resulting RIS file is used for further data analysis.

3.4 Compile preliminary data statistics

The data collected were stored in the form of RIS. At the initial stage, the complete components of the journal articles (publication year, volume, number, page, etc.) were checked and we added required information if there were some incomplete data found. Data analysis was carried out so that articles could be classified by year and source of publication and publisher.

3.5 Data analysis

The bibliometic analysis in this study employed PoP software (Baneyx, 2008; Parmar, Ganesh, & Mishra, 2019). However, to analyze and visualize bibliometric networks, Vosviewer software is used (Martinez-López, Merigó, Vázquez-Abad, & Ruiz-Real, 2019; Shukla, Merigó, Lammers, & Miranda, 2020). VOSviewer is used because of its ability to work efficiently with large data sets and provide a variety of interesting visuals, analyzes, and investigations (van Eck & Waltman, 2010). Vosviewer can also create publication maps, author maps, or journal maps based on co-citation networks or to build keyword maps based on shared networks.

Results

4.1 Publications and citation structures

The output is analyzed based on the PoP software through the VOSviewer software to determine the most frequently appeared keywords. However, the number of the most frequently-appearing keywords is adjusted to the needs of the data collection and analysis. VOSviewer is used to visualize bibliometric maps. This software shows bibliometric mapping on three different visualizations namely, tissue visualization, overlay visualization, and density visualization.

Before refining the search results 97 articles were obtained through the GS database. After refinement, 55 articles were grouped from the GS database. This data has been verified well on the GS database from 2014-2019 with the keyword 'low carbon education'. About 97 articles are obtained in initial results with 358 citations (71.60 citations / year). Refinement of results obtained 55 articles; data on citations also changed, with 317 citations and 63.4 citations/year. The complete results of metric data comparison from initial search and enhanced search can be seen in Table 1.

Table 1. Comparison metrics

Metrics data	***Initial search***	***Refinement search***
Source	'low carbon education'	'low carbon education'
Publication year	2014-2019	2014-2019
Papers	97	55
Citations	358	317
Cites/year	71,60	63,4
Cites/paper	3,69	5,76
Author/paper	2,67	3,15
h_index	10	9
g_index	17	16
hI_norm	4	4
hI_annual	1,80	0,80

The researcher tries to present the most relevant contributions in this study. The step taken is to take 55 articles with the keyword "low carbon education" which has the highest citation score (top 10 articles cited). Obtained results as in Table 2.

Tabel 2. Top 10 cited articles

No	Publication Year	Author	Title	Journal	Cites	Publisher
1	2017	Shuai, C; Shen, L; Jiao, L; Wu, Y; Tan, Y	Identifying key impact factors on carbon emission: Evidences from panel and time-series data of 125 countries from 1990 to 2011	Applied Energy	119	Elsevier
2	2017	Zhang, J	Evaluating regional low-carbon tourism strategies using the fuzzy Delphi-analytic network process approach	Journal of cleaner production	22	Elsevier
3	2016	Hu, MC; Wadin, JL; Lo, HC; Huang, JY	Transformation toward an eco-city: lessons from three Asian cities	Journal of cleaner production	21	Elsevier
4	2017	Liu, H; Wang, X; Yang, J; Zhou, X; Liu, Y	The ecological footprint evaluation of low carbon campuses based on life cycle assessment: A case study of Tianjin, China	Journal of cleaner production	18	Elsevier
5	2017	Neo, SM; Choong, WW; Ahamad, RB	Differential environmental psychological factors in determining low carbon behaviour among urban and suburban residents through responsible environmental behaviour model	Sustainable cities and society	12	Elsevier
6	2017	Zhou, X; Guan, X; Zhang, M; Zhou, Y; Zhou, M	Allocation and simulation study of carbon emission quotas among China's provinces in 2020	Environmental Science and Pollution Research	12	Springer
7	2014	Sahni, S; Aulakh, RS	Planning for low carbon cities in India	Environment and Urbanization Asia	11	Sage
8	2018	Wang, X; Xue, M; Xing, L	Analysis of carbon emission reduction in a dual-channel supply chain with cap-and-trade regulation and low-carbon preference	Sustainability	11	MDPI
9	2016	Wei, J; Chen, H; Cui, X; Long, R	Carbon capability of urban residents and its structure: Evidence from a survey of Jiangsu Province in China	Applied energy	10	Elsevier
10	2014	Chuanmin, S; Xiaomin, Y; Yukun, Z; ...	Consumer behavior on low-carbon agri-food purchase: a carbon labeling experimental study in China	Agricultural Economics (Czech Republic)	9	Czech Academy of Agricultural Sciences

The top 6 publishers who publish articles on this topic are presented in Table 3.

Table 3. Top 6 publishers who publish Low carbon education topic

No	Publisher	Articles
1	Elsevier	13
2	China Academic Journals	10
3	Trans Tech Publications	8
4	Italian Association of Chemical Engineering - AIDIC	4
5	MDPI	4
6	Springer	3

Journals that have relevant articles are presented in Table 4.

Table 4. Top 7 journals that have relevant articles on Low carbon education topic

No	Journal	Total Articles	Cites
1	Advanced Materials Research	7	5
2	Journal of Cleaner Production	6	75
3	Chemical Engineering Transactions	4	3
4	Guangzhou Environmental Science	4	0
5	Sustainability	3	13
6	Clean Technologies and Environmental Policy	2	10
7	Applied energy	2	129

The data network visualization display on GS data related to the keyword 'low carbon education' that has been refined in search can be seen in Figure 2, overlay visualization can be seen in Figure 3, and visualization of density in Figure 4.

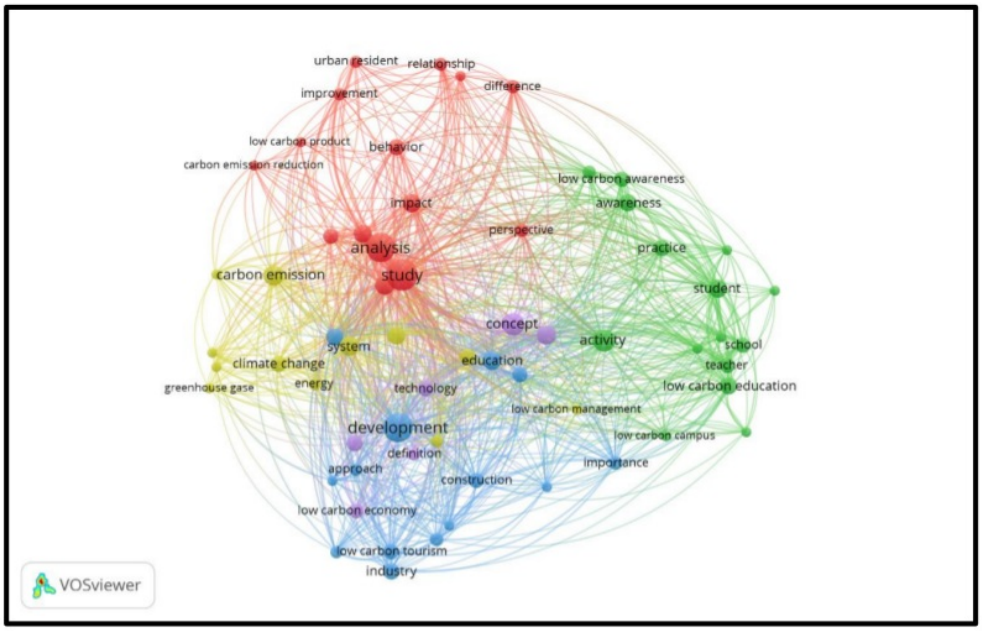

Figure 2. Network visualization on the GS database

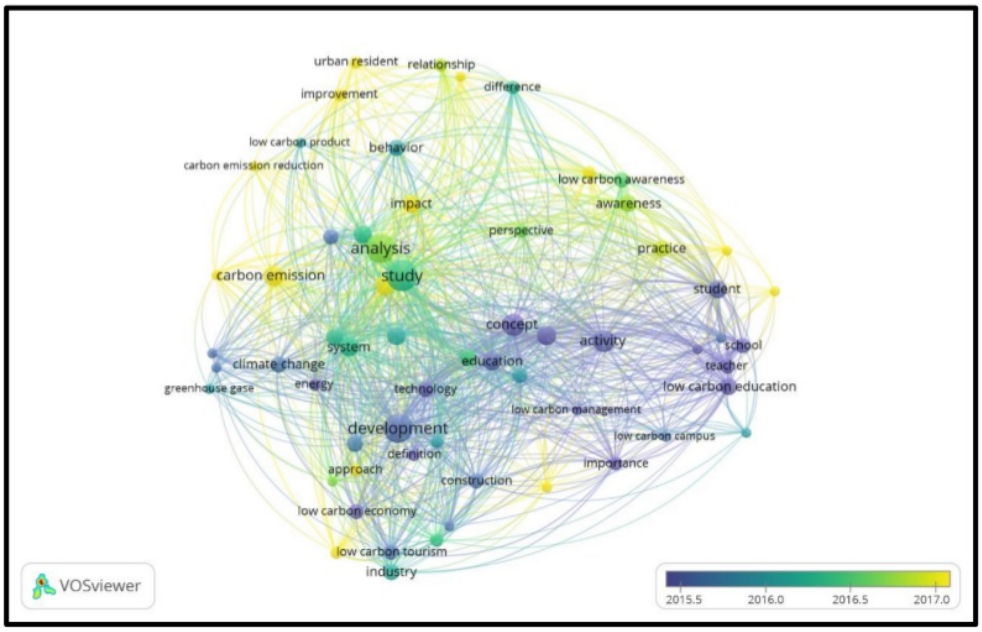

Figure 3. Visualization of overlays in the GS data base

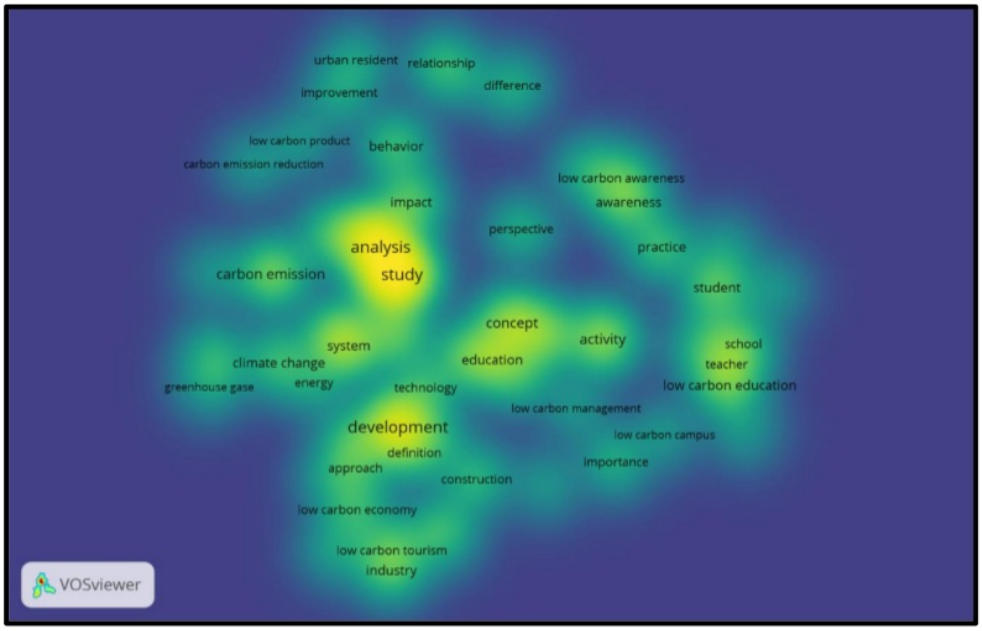

Figure 4. Visualization of density in GS data base

This result was extracted from the title, keywords, and abstract with full calculation of the minimum number of events set to 3. About 62 items were found that met the criteria of 106 items. Common words are excluded in this item. Each item representing the keyword is added, which is indicated by the size of the node. In other words, the node size indicates the co-occurrence frequency of the keyword. Five groups are identified here. The keywords appear in each cluster represent the flow of study in low carbon education can be seen in Table 5.

Table 5. Keywords representing each cluster.

No	Cluster	Element
1	The first cluster (red)	analysis (50), behavior (27), carbon emission reduction (16), characteristic (25), difference (24), impact (32), improvement (20), low carbon product (16), perspective (33), process (43), questionnaire survey (20), relationship (19), strategy (51), study (57) and urban resident (16).
2	The second cluster (green)	activity (51), awareness (35), environmental education (24), low carbon awareness (22), low carbon campus (20), low carbon concept (14), low carbon education (31), low carbon life (19), low carbon practice (24), low carbon society (13), practice (31), school (29), student (36), survey (28), and teacher (33)
3	The third cluster (blue)	approach (24), CO2 emission (31), construction (38), development (51), economic development (28), education (47), environment (44), importantce (31), important role (29), indicator (24), industry (26), low carbon tourism (28), low carbon transparency (28), and reduction (43).
4	Fourth cluster (yellow)	carbon emission (41), climate change (31), community (38), energy (24), government (46), greenhouse gase (19), low carbon management (22), policy maker (23), pollution (18), resource (29), system (46), and transportation (21).
5	the fifth cluster (purple)	concept (50), definition (21), global warming (28), low carbon (38), low carbon economy (19), and technology (27).

4.2 Authors and co-authorship relations

Analysis of joint authors and networks related to patterns of collaboration between individuals can be seen in Figs. 5. In this network, each node represents the author in his writing connection. Many different dimensions can be integrated in this analysis to visualize groups and associations between dimensions or time changes. Figure 5 shows an analysis of the author's network seen from the year the authors were together. In this case, the relationship of the authors can be classified as their annual relationship. It is proven that Zhou is the author with the most relationships with the others. In the meantime, the latest studies are marked yellow, such as one by Zhao.

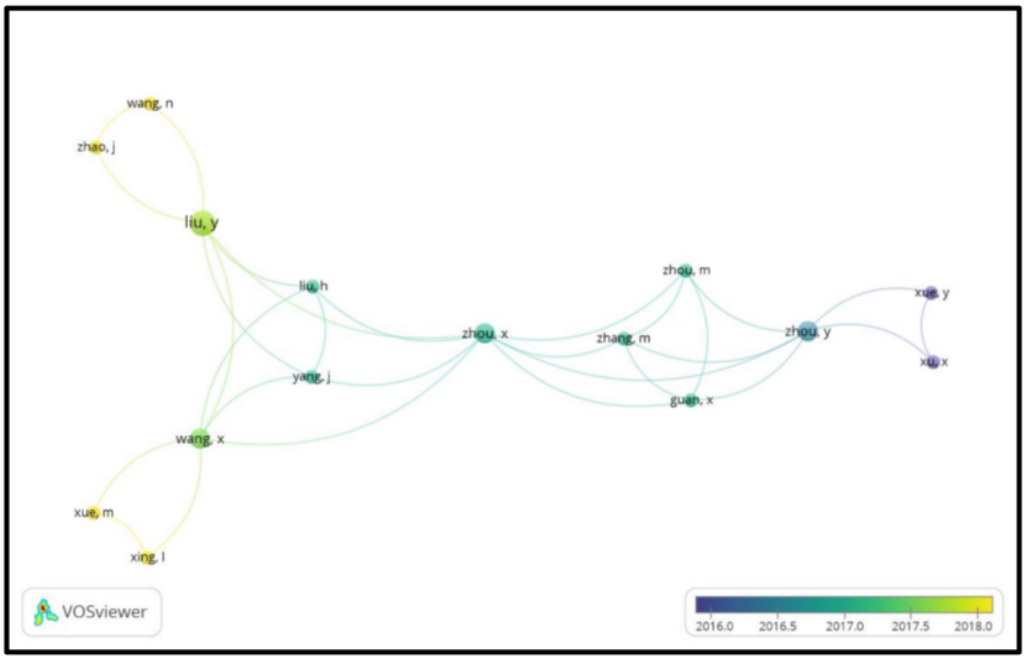

Figure 5. Visualization of overlay Authors and co-authorship relations on the GS database

4.3 Affiliation statistic

The author's affiliation was extracted from the RIS file at BibExcel. The city was extracted from each affiliate to analyze this. This analysis was extracted using the coordination of cities with the open source of online platform gpsvisualizer.com (Zhang, Zhao, Deng, Hu, Wang, & Ouyang, 2017; Garvetto, Badis, Perrineau, Rad-Menendez, Bresnan, & Gachon, 2019). Figure 6 presents the location of the authors who contributed to the low carbon education article.

Figure 6. Geographical location of contributing authors

Discussion and Conclusion

The most relevant contribution in this study is the number of citations. Based on table 2, the highest citations indexed by GS are articles from Shuai, C et al in 2017. This article discusses effective policies and strategies in stimulating a reduction in global carbon emissions (Shuai, Shen, Jiao, Wu, & Tan, 2017). This article is cited in more than 100 research articles. Meanwhile, there is one publisher with the highest frequency of citation based on the data, namely Elsevier.

In addition, the publisher who contributed the most articles to this study was also analyzed. In 55 articles published, 13 articles were published from major publishers namely Elsevier, followed by China Academic Journals 10 articles, Trans Tech Publications 8 articles, Italian Association of Chemical Engineering-AIDIC and MDPI each 4 articles and Springer 3 articles. For other publishers, an average of 1 article is published on this topic

In addition to the number of articles per publisher, it is also analyzed based on the relevance of the journal. The results obtained in the top 7 journals that contain this topic. There are journals that have the most citations, namely applied energy. This shows that articles with subjects related to low carbon education are scattered in certain journals, although there are also other journals.

Analysis overlay visualization and visualization of density is used to identify key themes in each study or scope of knowledge. This result is done by measuring the co-occurrence of keyword pairs (Liu, Yin, Liu, & Dunford, 2015; Nagy, 2018). The analysis was made with the help of Vosviewer software. It can be identified that each cluster connects to other keywords. This can be indicated that the development of research on this subject is related.

Network analysis also allows identification of the author's authority (Bilik, Damar, Ozdagoglu, Ozdagoglu, & Damar, 2019). Joint author analysis is a widely used bibliometric research technique that investigates authors in conducting joint research from a particular field.

The density of contributing authors to articles about low carbon education can be found in Eastern Asia. Geographical distribution of this writer shows that research on low carbon education is still dominated by the Asian region, especially China and Malaysia. Overall this data allows this paper to answer the question of what research trends in the field of low carbon education in the past 10 years. Some words that are not used can be linked and examined in further research. Therefore, many more topics can be developed based on these keywords such as affiliations, cities, and countries. Those aforementioned elements could provide a more comprehensive analysis.

The current study reviews journal articles whose themes related to the keyword 'low carbon education'. Articles are collected from the GS database by PoP software. Then 55 of these articles were selected from a larger original set of 97 articles published in the period 2014 to 2019. To meet the objectives of this study, all articles found were classified by author, year of publication, name of the publisher's journal, cites, authors and co-authorship relations and affiliation statistics. In the context of this study, it was concluded that the distribution of writers who examined related to low carbon education was still dominated by China and Malaysia. The gap in this research shows the direction for the future agenda that low carbon education is very important to be studied. Overall, from year to year, studying the concept of low carbon education tends to increase. This is also required for more inter-regional research collaboration involving researchers from Asia and other developing countries in certain areas.

Suggestions/Limitations

This study has two limitations. First, this study is generally based on a limited set of keywords and also potentially limited by the narrow database (GS) used for article collection. Second, although this study uses formal software as tools (PoP software, VOSviewer, Zotero, Microsoft Excel and gpsvisualizer.com), the subjective assessments of the author occur and still possibly lead to errors. The future studies are recommended to use a larger sample by expanding the keywords used and the more accessible databases. It also can use a comparison of different and recommended bibliometric analysis results (such as BibExcel and HistCite). It is recommended that further related studies provide more elaborate explanations for that there is limited number of studies discussing low carbon education.

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