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A BIBLIOMETRIC ANALYSIS OF DEEP LEARNING FOR EDUCATION RESEARCH

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Abstract

The purpose of this study was to determine the role, trend, and development of deep learning (DL) in education. The research method used is a bibliometric analysis method using the VOSviewer tool. VOSviewer is used to analyse the distribution of documents each year in various countries, institutions, journals, authors, and the relationship between keywords that appear. The results of this study show that the growth of publications on DL articles in the world of education increased by 31.69%, while the growth of DL articles as learning media increased by 11%. The most productive country in publishing articles related to DL in education is the United States with a total of 460 related documents and 13,162 citations. The most productive institution that researches DL in education is Stanford University with a total of 21 articles published. Furthermore, the most productive journal in IEEE Access with a total publication of 58,219 articles and a citation score of 4.8. The relationship between authors shows that the co-authoring network with Zhang Y. is the largest network with a total of 24 co-authored articles. The keyword that appears the most is the keyword "deep learning" which is directly related to "Data Analytics" and "AI". It is also seen that the topics that may arise for future research are topics related to the keyword "deep learning" which is related to "Virtual Reality" or "Educational Psychology". This research can be useful to find research gaps regarding the development or implementation of *deep learning* in the field of education to improve the quality of education and solving problems related to the world of education.

Keywords: Bibliometric analysis, Deep learning in education, Learning media, Technology 4.0, VOSviewer.

1. Introduction

Bibliometric analysis is a method used to analyse large amounts of scientific data that can produce high research impact using a quantitative approach and statistical description [1, 2]. The bibliometric analysis method reads a pattern of articles that have been published to produce an analysis and classification of bibliographic records [3]. Bibliometric analysis has a broad scope, including analysis of research trends on a topic, analysis related to co-authorship, the most productive countries, and journals, or keywords that are widely used as research topics [4, 5]. This fairly broad scope makes the early stages of research on a topic more accurate and comprehensive [6, 7]. Bibliometric analysis is important to do so that we can know the development of research related to certain topics [8-10]. One of the important topics to analyse is the topic related to deep learning (DL).

DL is important to analyse because it is one of the renewable technologies in the 21st century that can solve various complex problems due to advances in digital technology today. DL is one form or implementation of Artificial Intelligent (AI) intelligence [11]. Layers owned by DL can process and represent complex data in the form of images, text, and sound [12]. The ability of DL to process various kinds of complex data is a distinct advantage compared to other technologies. This makes DL a spotlight for global researchers to continue to develop and also implement DL in their respective fields. Thus, it is important to perform an in-depth bibliometric analysis of DL. Mainly DL is implemented and developed in the field of education.

The field of education should be the main aspect of the development and implementation of DL. This is because education is the basis for the emergence of various scientific sources. In addition, related to existing technological advances, educational problems are increasingly complex and require fast handling. For example, problems regarding the development of an effective distance learning system or distance learning [13], problems in how to improve student performance in learning [14], curriculum system development and educational collaboration system between universities [15], governance and data management issues [16], the problem of finding factors that affect the quality of a school's system and graduates [17], etc. These problems need to be handled with the help of appropriate and highly capable technology to process thousands or more of data. Therefore, it makes bibliometric analysis related to DL in the world of education increasingly important so that we know the extent of the role of DL in the world of education.

Research related to DL bibliometric analysis has been carried out, such as studies on the status of DL research from 1968-2018 [18], a bibliometric analysis of DL from 2007-2019 [19], DL to process medical images and COVID-19 [20], the study of emotions based on brain-computer technology [21], natural language processing application (NLP) analysis [22], scientific and thematic production breakthroughs in smart learning [23], as well as the incorporation of deep neural networks and bibliometric indicators to predict research topics [24]. In addition to these topics, there is a recent study related to DL by Chicaiza et al. who conducted bibliometric analysis research on the contribution of DL in the fight against COVID-19 [25]. Khairi et al. [26] display DL bibliometric analysis in reading Histopathology images to classify breast cancer. Brika et al. [27] conduct bibliometric analysis research related to e-learning trends in higher education during the COVID-19 pandemic. However, unfortunately to our knowledge by looking at the various DL bibliometric analysis studies that have been carried out, there has been no DL bibliometric analysis in the field of education in general.

Based on this update and seeing the problems that exist in the world of education in the digital era, it is necessary to do a bibliometric analysis of DL in the world of education. This research aims to see the role, trends, and developments of DL research in education. Bibliometric analysis related to this topic is useful for finding research gaps [28]. It is good for finding studies regarding the development or implementation of DL in the field of education to improve the quality of education and solve problems related to the world of education. This bibliometric analysis was carried out with the help of the OpenRefine, Ms. Excel, and VOSviewer. The research questions in this study are as follows.

RQ1 : What is the trend of DLE research by year?
RQ2 : Which institution is the most productive?
RQ3 : Which is the most productive country?
RQ4 : Which is the most prolific writer?
RQ5 : Which are the most productive journals?
RQ6 : Which is the most cited paper?
RQ7: Which keywords appear the most?

2. Deep Learning

The DL algorithm is inspired by the network that resides in the human brain. Networks in DL have their respective tasks to study different parameters, each network is grouped in layers contained in DL [29]. When the input data goes into DL, the layers will start the feedforward process. The feedforward process is a process where the order of layers will continue to change to map input data into the desired output [29]. Feedforward can be represented in Eq. (1).

$$Y = f\left(\sum_{i=1}^{n} w_i x_i + w_0\right) \quad (1)$$

Where the activation function in the feedforward is symbolized by f, the weight that goes into each input is symbolized by , while the bias that occurs is symbolized or represented by , and the value of the input process is indicated by $w_i w_0 x_i$ [30]. The feedforward network can be seen in Fig. 1.

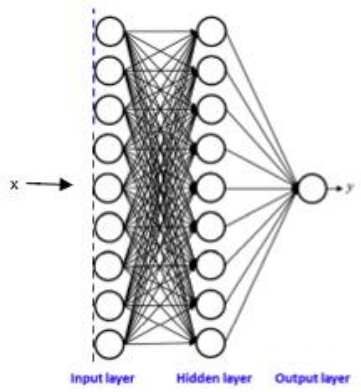

Fig. 1. Feedforward network [31].

The concept of DL is based on concepts relevant to algebra, probability theory and information theory of numerical computing, and machine learning [32]. This concept further explains that the techniques used by DL in the process include deep

feedforward networks, regularization, optimization algorithms, convolutional networks, sequence modeling, and practical methodologies [32]. These techniques are applied in natural language processing (NLP), speech recognition, computer vision, online recommendation systems, bioinformatics, and video games [32]. The application of DL in various fields:

(i) Education, as an effective method to change the process of a smart learning environment to be fully automated based on image detection [12].

(ii) Geophysics, to predict natural disasters that may come in the future [33].

(iii) Medical field, to classify ECG images [34].

(iv) Food processing, as a food quality control system [35].

3. Method

3.1. Data source

The emergence of DL has had a great influence on helping human work to be easier and more accurate. Of course, with powerful DL capabilities in analysing data, many researchers have conducted research on DL. This means that there is still the possibility of research on DL that is not covered in this analysis.

This bibliometric analysis of DL in the field of education utilizes data from the Scopus database. Data collection was carried out on Wednesday, 16 March 2022, at 11.11 a.m. and was retrieved automatically by entering keywords from the topic you wanted to search for based on the article title, abstract, and keywords. Our research went through two stages of data collection with two different keyword groups. The first group of keywords is "deep learning" AND education OR "vocational school". The OR operator is used to enter the equivalent or synonym of the keyword we want to search for. While the AND operator functions to find keywords for a topic that you want to associate with the first keyword.

Based on the results of the first keyword group, there were 4,851 documents related to DL, education, and vocational school. We then filter the documents again by selecting the year the document was published. We only use documents published in the last 10 years, starting from 2013 – 2022. Then we also filter the type of source and also the language used by the document. The types of sources that we choose are only journal articles and the language used for the journal articles is English. After filtering these documents, only 1,896 journal articles were found, and we downloaded these documents for metadata.

The second group of keywords we looked for was "deep learning" AND "learning media" OR "instructional media". Documents generated from these keywords are 12 documents. We did not filter these documents because only a few documents related to DL, learning media, and instructional media. The documents are spread from 2006 to 2022.

3.2. Analysis tool

VOSviewer is used to analyse bibliometric networks and visualize the [36]. Van and Waltman are the developers of this VOSviewer software [36]. Some of the visualizations displayed in this study include co-authorship, co-occurrence, and citation [37-39]. VOSviewer will visualize the data in the form of nodes connected by lines between nodes [40-42]. The larger the node size and the font on the

keyword, the more frequently these keywords appear and are used by researchers [43]. Meanwhile, the smaller the distance connecting the nodes, the stronger the correlation between the keywords [43, 44]. The co-occurrence analysis carried out by VOSviewer in analysing keywords is by analysing the keywords with the highest frequency and combining the relationships between the words [45, 46]. Co-occurrence analysis can bring up hotspots and research limitations [47-49].

The analysis display of the similarity of the two components of co-occurrence data using the following Eq. (2) [50, 51]

$$S_{ij}=\frac{c_{ij}}{w_i w_j} \quad (2)$$

The total number of co-occurrence of elements *i* and *j* is symbolized by , while the total number of co-occurrence of elements i is symbolized by, and the total number of co-occurrence of elements j is symbolized by $C_{ij}W_i\,W_j$ [50].

4. Result and Discussion

4.1. Publications trends

The number of documents related to the subject we are looking for is fundamental to seeing the trend of the publication of articles and can adequately reflect the research process in that field [52]. Figure 2 shows the number of documents per year from the results of data collection using the first group of keywords, namely "deep learning" AND education OR "vocational school". It can be seen that in general, the number of articles on DL increases periodically every year. The lowest number of articles was in 2014 with 54 (2.85%) articles published. The highest increase was in the last five years, namely in the range of 2018-2022 with the number of articles on DL in education as many as 1,397 (73.68%) articles from the total publications of DL in education during 2013-2022. This indicates that publications on DL in education began to grow rapidly after 2017. However, before the increase, the number of articles published in 2018 decreased first from 2017 as many as 69 articles. The highest peak of publication of articles on DL in education will be in 2021 with 526 articles (27.74%) published. In 2022, the publication of articles on DL in education decreased to only 137 articles. The decline in the number of articles in 2022 occurs because 2022 is still ongoing, so the possibility of an increase in the number of articles on DL in education at the end of 2022 is quite high. 74%) articles. In 2022, the publication of articles on DL in education decreased to only 137 articles. The decline in the number of articles in 2022 occurs because 2022 is still ongoing, so the possibility of an increase in the number of articles on DL in education at the end of 2022 is quite high. 74%) articles. In 2022, the publication of articles on DL in education decreased to only 137 articles. The decline in the number of articles in 2022 occurs because 2022 is still ongoing, so the possibility of an increase in the number of articles on DL in education at the end of 2022 is quite high.

Next, we analyse the trends that occur in the second keyword group, namely “deep learning” AND “learning media” OR “instructional media”. Figure 3 shows the results of the trend analysis of these keywords. Articles on DL as a learning medium are spread unequally from 2006 to 2022. An anomaly occurred in the number of publications of DL articles as a learning medium. From 2007 to 2015, there was no publication of articles on DL as a learning medium. Newly published articles reappeared in 2016 as many as 1 (8.33%) articles. The highest peak in the publication of DL articles as learning media is in 2021 as many as 8 (66.67%)

articles. That year also became the largest contributor to DL articles as a learning medium from the total publications from 2006-2022. The decline again occurred in 2022 when only one published 1 (8.33%) article.

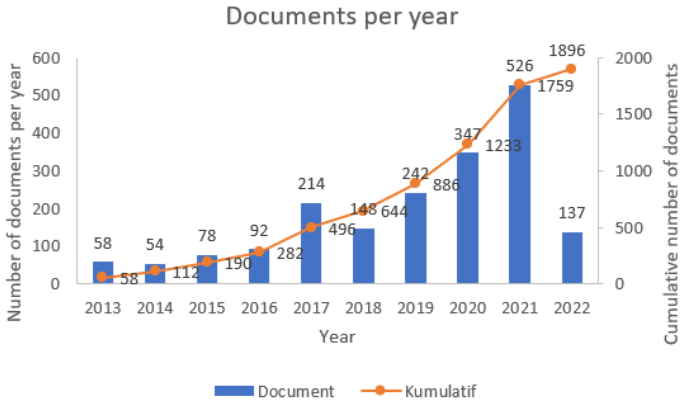

Fig. 2. Trends in DL publications in education.

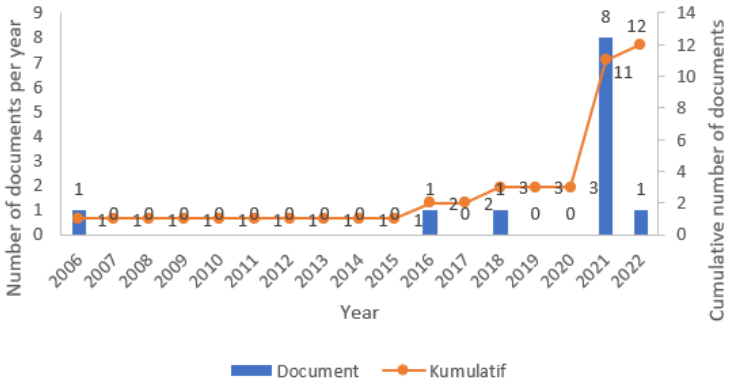

Fig. 3. Trends in DL publication as a learning media.

4.2. Countries and research institutions

The many problems that arise in the field of education, make DL one of the most accurate and comprehensive media for providing solutions to existing problems. This makes the use of DL in education a global concern. Analysis of articles published in several countries is important to know because researchers can get an idea for their future research [53-55]. We can see the relationship between several countries and the productivity of a country on DL research in the field of education.

Based on an analysis using VOSviewer, 154 countries have published articles about DL in education. Table 1 shows the top 10 rankings of the most productive countries in publishing DL articles in the world of education. The ranking is taken from data analysis using VOSviewer. We select data by filtering the minimum number of DL articles in education published by a country as many as 3 articles. The results of the VOSviewer analysis show that the United States ranks first as the most productive country in publishing articles on DL in the world of education. The US

managed to publish 460 articles with a presentation of 24.26% of the total publication of DL articles in the world of education during 2013 – 2022 and 13,162 (23.94%) citations. China is in second place with 435 (22.94%) articles published with 10,619 (19, 32%) citations, and the third place was occupied by the UK with a total publication of 200 articles (10.55%) articles and 2687 (4.89%) citations. Countries ranked fourth to tenth contributed an average of 4.57% articles and 2.67% citations.

The involvement and cooperation between countries in publishing DL articles in the world of education can be seen in Fig. 4. In total, 154 countries publish related articles. Figure 4 only shows countries that publish more than equal to 15 documents and the remaining 32 countries that meet the criteria. The nodes in the image show the countries that publish DL articles in the world of education. The size of the node indicates the productivity of a country in publishing articles. The larger the node size, the more articles that country has published. Figure 4 shows the four largest node sizes, namely US, China, UK, and Australia, which means that these four countries have had the most collaborations with other countries. Countries that are on the same continent usually have more collaboration [52], such as US and UK, Germany and Switzerland, and China and Hong Kong. The closeness of collaboration between different countries is symbolized by the thickness of the line connecting the nodes.

We also analyse the involvement of institutions that research DL in education. 4,668 institutions are researching related topics. We re-select these institutions with the minimum criteria of the number of articles and article citations in a country of at least 2 articles and 2 citations. The results show that there are only 72 countries that are included in the qualification. Figure 5 shows the top 10 most productive institutions in researching DL in education. The institution that ranked first was Stanford University with a total of 21 (1.11%) articles successfully published, followed by the Chinese Academy of Sciences ranked second with 18 (0.95%) articles, and continued by The University of Queensland is in third place with a total of 17 (0.90%) articles published. Institutions ranked 4 to 10 contributed articles on average 0.74% articles from the total published articles from 2013 – 2022.

Table 1. Top 10 most productive countries in DL research in education, 2013 – 2022.

Rating	Country	Number of Documents (minimum number of documents for a country is 3)	Number of Citation (minimum number of citations of a country is 3)
1	United States	460	13162
2	China	435	10619
3	United Kingdom	200	2687
4	Australia	149	1441
5	India	104	818
6	Canada	100	2981
7	South Korea	89	1616
8	German	63	1256
9	Spanish	53	1272
10	Dutch	48	875

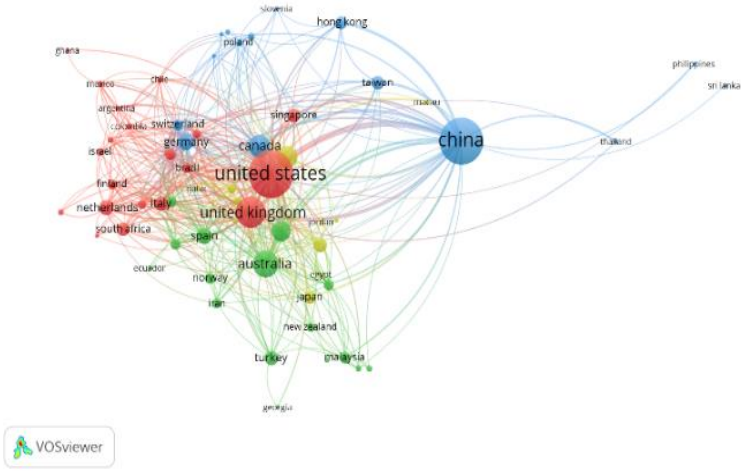

Fig. 4. 10 cooperation network between research countries.

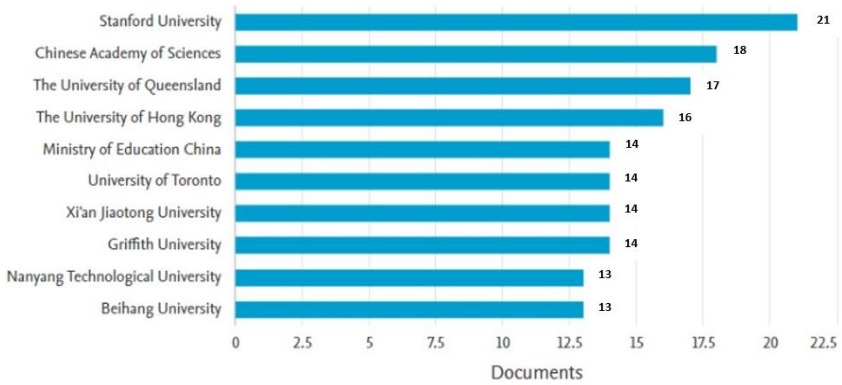

Fig. 5. 10 Most productive institutions in researching DL in education, 2013 – 2022.

4.3. Co-authorship analysis

Linkage analysis and co-authoring can provide collaborative opportunities and information on research networks, school theory, and co-authoring for individual authors [52, 56-58]. It is indicated that there are 5,938 authors out of a total of 1,896 articles analysed. We filtered related to co-authoring with the minimum criteria of the number of documents that have been published by an author as many as 4 documents and the minimum number of documents from a cited author is 2 documents. Figure 6 displays the results of document filtration and only 111 authors who meet the criteria remain.

The first most prolific writer is occupied by Zhang Y. with number of published articles as many as 24 (1.27%) articles, the second and third ranks were occupied by Li Y. and Wang J. with the same number of published articles, namely 18 (0.95%) articles. Co-authored network displayed in Fig. 6 is arranged with a

minimum criterion of 40 members of each cluster. The results show that the group of authors of the articles displayed is divided into 10 groups. Each group is dominated by one to two authors. Authors who dominate the group are measured by the number of co-authored articles.

Figure 6 shows the two major author networks, namely the Zhang Y network with a total of 24 article writings and the second network is the De Kleijn RAM and Van Rijen HVM network with the same total article writing of 21 articles. In addition, other independent authors are Chen, Currey, Kumar, Lin, Zhuy, Yang, and Imran M. Independent authors mean that their clusters are studied without correlation or an agreement between others [59-63].

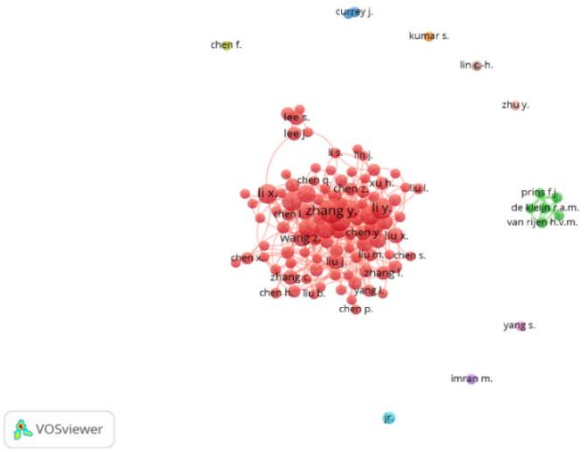

Fig. 6. Co-writing network between researchers.

4.4. Main journal publishing

Research on DL in education has been published in various international journals. This proves that DL in education is a global issue that is a lot of articles on topics related to the period 2013 - 2022.The top position is occupied by the journal IEEE Access with a total of 58,219 articles and a citation score of 4.8. The citation score is taken based on the scoring done by Scopus still hot. Table 2 shows the ranking of the top 10 most productive journals that publish using its database. The citation score is made to know how much impact a source or journal has on real-life or future research.

Furthermore, the second rank was occupied by Frontiers in Psychology journal with the number of published documents as many as 25,213 documents and a citation score of 3.5. The third place was occupied by Computers and Education journals with a total publication of 1,977 articles and a citation score of 14.4. Although the Computers and Education journal is ranked third in terms of the number of documents published on DL in education, its citation score is higher than IEEE Access. Other journals that contribute to DL research in education include the Journal of Intelligent and Fuzzy Systems (7,601 articles), Computational Intelligence and Neuroscience (1,898 articles), Neural Computing and Applications (6,146 articles), BMC Medical Education (3,369 articles).

Table 2. Ranking of the top 10 most productive journals, 2013-2022.

Rank	Journal	Number of Citation	Number of Documents	Citation Score[a]
1	IEEE Access	518,908	58,219	4.8
2	Frontiers in Psychology	288,967	25,213	3.5
3	Computers and Education	187.154	1977	14.4
4	Journal of Intelligent and Fuzzy Systems	49,590	7,601	2.8
5	Computational Intelligence and Neuroscience	26,101	1,898	5.4
6	Neural Computing and Applications	29,113	6.146	7.3
7	BMC Medical Education	48,632	3.369	2.9
8	Nurse Education in Practice	21.186	1.478	3
9	Anatomical Sciences Education	19,341	720	7.2
10	Applied Sciences (Switzerland)	156.221	33,590	3

4.5. Highly cited papers in deep learning for education research

Table 3 displays the most cited documents for the period 2013-2022. This analysis is filtered by using a minimum number of citations for each document of 60 citations. After being filtered, there were only 118 documents that met the criteria out of a total of 1,896 documents. The articles with the most citations were written by Zhang et al. with the article title "Beyond a gaussian denoiser: residual learning of deep CNN for image denoising" which was cite as many as 2,990 [64]. The article is sourced from IEEE transactions on image processing, 26(7), 3142-3155. The article writes about the construction of feedforward denoising convolutional neural networks (DnCNNs) for DL architecture.

Table 3. The most cited paper.

Authors	Title	Year	Source	Cited by	Refs.
Zhang at al.	Beyond a gaussian denoiser: residual learning of deep CNN for image denoising	2017	IEEE transactions on image processing, 26(7), 3142-3155	2.990	[64]

Authors	Title	Year	Source	Cited by	Refs.
Bronstein et al.	Geometric deep learning: going beyond Euclidean data	2017	IEEE signal processing magazine, 34(4), 18-42	1.053	[65]
Shen et al.	Deep learning with coherent nanophotonic circuits	2017	Nature photonics, 11(7), 441-446	964	[66]
Zhou et al.	Places: a 10 million image database for scene recognition	2018	IEEE transactions on pattern analysis and machine intelligence, 40(6), 1452-1462	886	[67]
Ting et al.	Digital technology and COVID-19	2020	Nature medicine, 26(4), 459-461	495	[68]
Abramoff et al.	Improved automated detection of diabetic retinopathy on a publicly available dataset through integration of deep learning	2016	Investigate ophthalmology and visual science, 57(13), 5200-5206	424	[69]
Chartrand et al.	Deep learning a primer for radiologists	2017	Radiographics, 37(7), 2113-2131	390	[70]
Madabhushi et al.	Image analysis and machine learning in digital pathology: challenges and opportunities	2016	Medical image analysis, 33, 170-175	374	[71]
Jing et al.	A convolutional neural network based feature learning and fault diagnosis method for the condition monitoring of gearbox	2017	Measurement journal of the international measurement confederation, 111, 1-10	373	[72]
Supratak et al.	Deepsleepnet: a model for automatic sleep stage scoring based on raw single-channel EEG	2017	IEEE transactions on neural systems and rehabilitation engineering, 25(11), 1998-2008	361	[73]

4.6. Keyword analysis

Keyword analysis in bibliometric analysis serves to show keywords that are currently trending research topics [74-77]. Keyword analysis can also help researchers to find research gaps that have not been studied much, it can provide greater novelty

opportunities for researchers [78-80]. In addition, keyword analysis can show the boundaries and research areas of our discipline based on the class or group [81-83].

The keyword analysis that we carried out was using VOSviewer and the results of the VOSviewer analysis were generated in the form of network visualization as shown in Fig. 7. VOSviewer will read all the keywords from the data we input. There are 5,165 keywords that are read by VOSviewer and from 5,165 keywords there are several keywords that appear repeatedly. The occurrence of repeated keywords is due to the writing of keywords that are slightly different but have the same meaning, such as "convolutional neural network", "convolutional neural network (CNN)", and "convolutional neural networks", as well as "long short-term memory" and "long short-term memory (LSTM)". We need to combine these repeated keywords into one so that they do not occur repeatedly in the network visualization displayed by VOSviewer. Therefore, the thesaurus is used to put together keywords that have the same meaning. In this research, we found 33 keywords that a thesaurus needs to create.

The visualization of the keyword analysis network that is displayed is filtered first by filtering keywords that have a minimum number of occurrences of 6 times. So, of the 5,165 keywords that appeared, only 98 keywords met the criteria. Figure 7 displays a network visualization of keywords that already meet the criteria. Appears 5 clusters on the network. The clusters are distinguished by colour, namely: cluster 1 (red coloured), cluster 2 (green coloured), cluster 3 (blue coloured), cluster 4 (yellow coloured), and cluster 5 (purple coloured). In general, cluster 1 (red coloured) are terms related to higher education and learning approaches such as learning models, learning methods, learning situations, etc. Keywords related to the scope, database, algorithm, method, and application of DL and ML are in cluster 2, cluster 3, and cluster 4. Cluster 5 is a keyword related to AI in education.

The word "deep learning" is the keyword that appears the most. This can be seen from the size of the "deep learning" node which is the largest node size. The keyword "deep learning" is directly related to the words "AI" and "Data Analytics". In addition, keywords that often appear in DL research in the world of education are "education, higher education, machine learning, CNN, DNN, neural networks, and computer vision". Keywords related to databases, algorithms, and methods regarding DL and machine learning also appear, such as, "DNN, recurrent neural network, deep reinforcement learning, feature extraction, and training". Keywords that appear in Fig. 7 can provide researchers with an overview of the subsets of DL research in education over the last 10 years.

The important thing that needs to be considered in choosing a research topic is the trend and also the updated topic that the researcher will discuss. Figure 8 shows trending topics based on frequently occurring keywords and also the trend year. We can see the keywords that are currently trending based on colour indicators. The colour indicator is listed in the lower right corner of Fig. 8. Nodes with a dark colour indicate that the keyword has emerged and has become a trend in the previous year, while colours that show the current trend are marked with bright green and bright yellow. For example, for the keyword DNN, a bright green node indicates the keyword is trending in late 2019 towards early 2020. As for the dark blue learning approach node keyword, this indicates that the keyword has become a trend in the previous year, namely 2017. The keyword that is expected to become a trend in DL research in the world of education in the future is the correlation between DL and virtual reality and educational psychology.

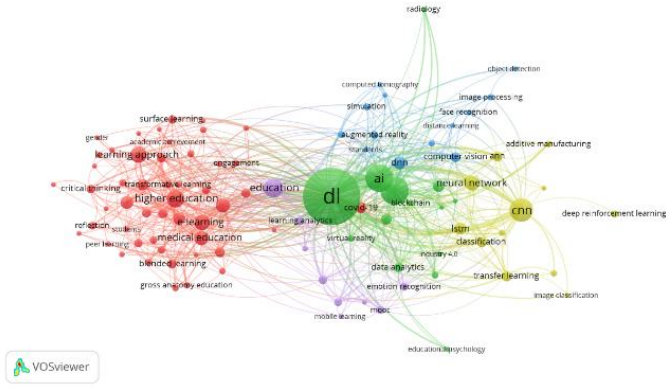

Fig. 7. Analysis of keywords in DL research in education.

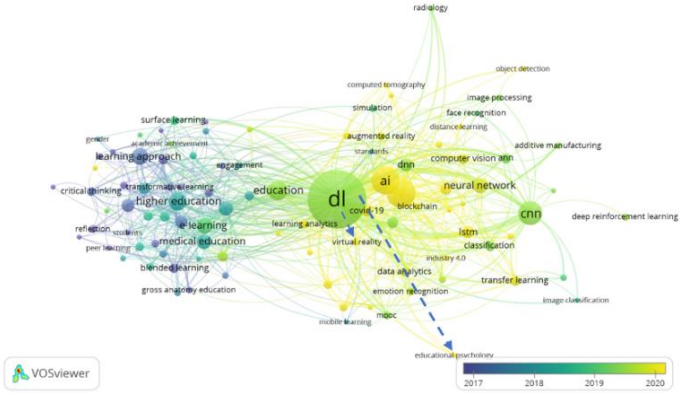

Fig. 8. Analysis of keyword trends by year.

5. Conclusion

The use of DL in education is expected to continue increasing to improve the quality of education in this digital technology era. The purpose of this research is to find out the role, trend, and development of DL that already exists in the world of education today. The research method used in this research is the bibliometric analysis method. Bibliometric analysis was carried out using the VOSviewer tool. After being analysed using VOSviewer, it can be seen that the trend of DL publications in the world of education increased by 31.69%. This shows that DL is a concern for global researchers to continue to be applied in the field of education. The US is the most productive country in publishing articles with a total of 460 related documents and 13,162 citations. Stanford University is the most productive institution that researches DL in the world of education with a total of 21 article publications. Furthermore, IEEE Access is the most productive journal with a total publication of 58,219 articles and a citation score of 4.8. The relationship between authors shows that the co-authoring network with Zhang Y. is the largest network with a total of 24 co-authored articles. The keyword “deep learning” is the keyword that appears the most that are directly related to “Data Analytics” and “AI”. It is also seen that the topics that may arise for future research are topics related to the keyword “deep learning” which is related to "Virtual Reality" or "Educational Psychology".

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