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VISUALIZATION OF BIBLIOMETRIC ANALYSIS FOR MAPPING RESEARCH TRENDS IN THE ELECTRICAL ENGINEERING EDUCATION CURRICULUM IN THE INDUSTRIAL REVOLUTION 4.0 ERA

IKE YUNI WULANDARI[1,2,*], BUDI MULYANTI[1], ISMA WIDIATY[1], BUDI MULYATI[2], SRI SANTOSO SABARINI[3]

[1]Universitas Pendidikan Indonesia, Jl. Setiabudhi no 299, Bandung, Indonesia
[2]Universitas Nurtanio, Jl. Pajajaran 219 Bandung, Indonesia
[3]Universitas Sebelas Maret, Jl. Ir. Sutami 36 Kentingan, Surakarta, Indonesia
[*]Corresponding author: ikeyuni@upi.edu

Abstract

This study aims to conduct a bibliometric analysis visualized to map research trends in the Electrical Engineering Education curriculum in the Industrial Revolution 4.0 era, based on articles indexed in Scopus published between 2012 and 2021. Research distribution, knowledge base, and research boundaries for curriculum studies in Electrical Engineering Education in the Industrial Revolution 4.0 era were revealed using VOSviewer software and visualization technology. A total of 450 peer-reviewed papers from 76 countries published in 235 different journals have been identified. The United States is the most productive country, with 37.19% of all articles. The most active research journal is the ASEE Annual Conference and Exposition Conference Proceedings with 63 citations and 76 articles in the research field of the Electrical Engineering Education curriculum in the Industrial Revolution 4.0 era. Meanwhile, the organization that was cited the most was Old Dominion University, Norfolk, Virginia, United States of America. Specifically, our findings indicate that research issues regarding "learning tools", "robot automation", "technology utilization", "robotics techniques", "artificial intelligence", "robotics learning trends", and "technological innovation" form the knowledge base of research on the Electrical Engineering Education curriculum in the Industrial Revolution 4.0 era. The analysis results show that research in the field of Electrical Engineering Education curriculum in the Industrial Revolution 4.0 era still has the potential for further exploration, with indications that the number of documents can still be increased by exploring the characteristics of Industry 4.0 technologies related to the Electrical Engineering Education curriculum. This study also provides insight into the overall research trends in the Electrical Engineering Education curriculum during the Industry 4.0 era and can help us better understand this research field and predict its dynamic direction.

Keywords: Bibliometric analysis, Electrical engineering education, Engineering education curriculum; Industrial Revolution 4.0.

1. Introduction

Industrial digitization technologies are playing an increasingly important role in various industrial sectors [1, 2]. Currently, there is a demand from the industry for engineering graduates who have, 3D printing, smart sensors, the Internet of Things, robotics, artificial intelligence, and big data [3-5]. However, not of these skills have been incorporated into the engineering education curriculum [6, 7]. The concept of Industry 4.0 was then adopted as a standard term in the industrial field that utilizes advancements in digitalization technology and is connected to cloud computing and big data facilities to achieve automation technology [8-10]. Industry 4.0 is not only related to the development of digitalization and automation technology but also concerns the role of engineering graduates in the industry [11-13]. This gives rise to thoughts not only related to the learning process in higher education, competencies, and engineering graduate expectations but also related to the curriculum of Electrical Engineering Education within it [14, 15].

In response to the increase in research related to the Engineering Education curriculum and Industry 4.0 [16, 17], several attempts have been made to synthesize literature that provides a theoretical description and reality in the field [18, 19].

For example, technological advancements in the Industry 4.0 sector are closely related to education [20, 21], thus it is necessary to map and explain four core components of education: competencies, learning methods, information and communication technologies, and infrastructure, to design technical education curricula. The same point is also conveyed by researchers [22, 23] that curriculum mapping, design, and evaluation aim to prepare engineering graduates for Industry 4.0 and promote the intensive use of digital technology. Thus, an integrated Electrical Engineering Education curriculum is available with the skills required in digital companies and Industry 4.0 [24]. Since curriculum has a direct impact to the output and quality of students, this must be carefully done. That is why a lot of research on curriculum has been conducted [25-31].

Despite several efforts that have been made, the development in the field is still not optimal in responding to the industry's needs by adapting the education curriculum to the era of Industry 4.0 [32, 33]. Therefore, this paper aims to contribute by conducting a systematic review of the research trends on the curriculum of Electrical Engineering Education in the era of Industry 4.0. Additionally, this paper also seeks to provide an understanding of the analysed objects, methods used, and future research directions in the field of Electrical Engineering Education curriculum. Discussing these questions can provide a useful basis for further research in curriculum development.

2. Methods

To conduct a systematic review [34], it is not possible to read all relevant books, hence the search was limited to peer-reviewed articles that use the terms: ‘curriculum and electrical engineering’; ‘curriculum and industrial revolution’; ‘curriculum and Industry 4.0’; ‘curriculum and higher education’; ‘curriculum and university’. The search was only conducted on English-language articles published between 2012 and 2021, and the document types were limited to ‘articles’ and ‘reviews’ while removing duplicates. Articles that are not related to curriculum and

Higher Technical Education will be excluded from the search. Detailed information for the searching method is shown in previous studies [35, 36].

This approach can provide valuable insights for studies in the field of Curriculum of Electrical Engineering Education and Industrial Revolution 4.0 and is used to construct and display bibliometric maps, as well as to identify clusters and citation networks. This research is limited to the sub-field of the Electrical Engineering Education Curriculum in the Industrial Revolution 4 era and is expected to provide interesting information on developments in this field. An algorithm that considers the number of links between nodes and related clusters can also be used to depict authors who have published more frequently together.

3. Results and Discussion

3.1. Countries and research institutions

Based on the analysis conducted using VOSviewer, it is observed that in Table 1, there is a visual map of co-authorship networks based on countries. Out of 450 documents retrieved from the Electrical Engineering Education Curriculum related to Industrial Revolution 4.0, 76 countries are involved in 12 clusters. The United States is the country with the highest number of publications, in over 100 publication data sets, accounting for 16.89% of the total documents. South Africa also shows a significant contribution with 8%. In Southeast Asia, Indonesia ranks first among 10 countries with a publication rate of 6.67%, followed by Malaysia with 5.11% and Thailand with 2.89%. However, in terms of citation count, Malaysia is more popular than Indonesia and Thailand, ranking first in Southeast Asia. Overall, the United States is the most dominant country in the study of the Electrical Engineering Education Curriculum.

Table 1. Top ten countries based on the number of publications.

Country	Document	Citation
United States	121	285
South Africa	36	164
Indonesia	30	53
China	28	75
Malaysia	23	110
Germany	18	114
United Kingdom	14	122
Brazil	14	44
Meksiko	14	107
Thailand	13	25

To further deepen the analysis of countries that collaborate in writing the Curriculum of Electrical Engineering Education documents, VOSviewer creates a network map of inter-country cooperation, as visualized in Fig. 1. The size of the nodes on the map reflects the influence of a country in the research field, while the thickness of the links between countries indicates their cooperation proximity. Based on the statistical data presented in Table 1, the three most productive countries (the US, China, and Indonesia) are displayed with the largest circle size on the map. Furthermore, as seen in Fig. 1, countries located on the same continent tend to have cooperation, such as Indonesia and Malaysia, China, and Taiwan.

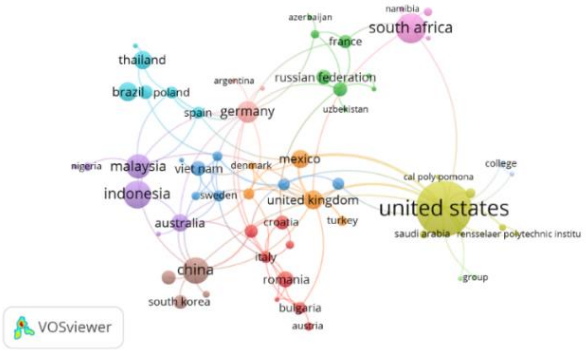

Fig. 1. Distribution of main countries of research.

We also analysed leading research institutions in the study of the Electrical Engineering Education curriculum. From the articles retrieved, there were 770 organizations involved, and Fig. 2 shows the top 15 most cited institutions. Although only publishing one document, the publication count from these 15 institutions is relatively small. However, the affiliated institution of Old Dominion University, Virginia, has more citations (46 citations) than any other institution, although the difference in citation count is not significant. The fact that Old Dominion University only published one article in this field indicates that the paper's theme from this organization is still under-researched. The statistical results also show that five out of the top fifteen institutions are from the United States, while the other ten are from ten different institutions. This indicates that the United States has a significant influence on Electrical Engineering Education curriculum research.

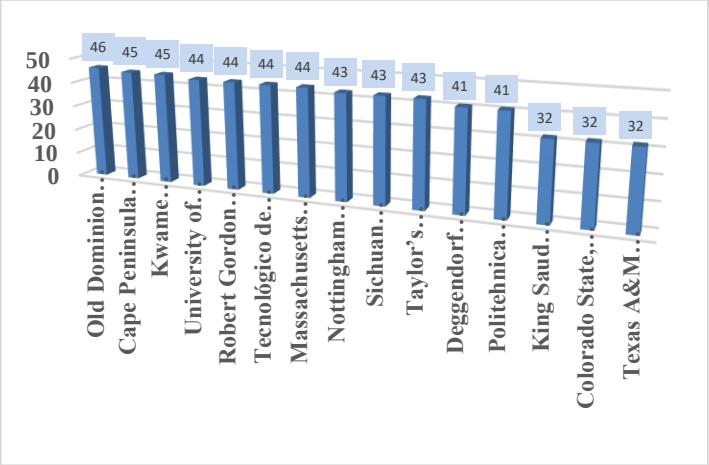

Fig. 2. Fifteen most productive organizations.

3.2. Co-authorship analysis

Based on the co-authorship analysis, we can gain opportunities for collaboration and insights into research networks and their theoretical direction. According to the analysed data, 1,373 authors contributed to 450 papers on the curriculum of

Electrical Engineering Education in the Industrial Revolution 4.0, with an average of 3.05 authors per article. VOSviewer was used to create a researcher network map (Fig. 3) to conduct co-authorship analysis.

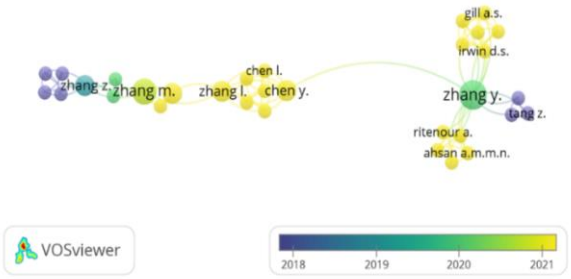

Fig. 3. Overlay visualization on the curriculum of higher education in electrical engineering.

The research results show that several scientific collaboration networks are grouped into 6 clusters that can be displayed on the Vosviewer database. The yellow-coloured cluster indicates that the authors have recently published their works, around 2021. This indicates that the yellow cluster is becoming the center of publications in the near future, as the darker the visualization of bibliometric analysis, the longer the research has been conducted, while if the visualization is brighter, the more research is conducted recently. Each node in the visualization represents an author, and the size of the node increases with the number of publications produced by the author. The closeness of collaboration among authors is reflected through links. Based on the analysis results, in the field of curriculum research in Electrical Engineering Education in the era of the Industrial Revolution 4.0, co-authorship collaboration is still limited and small in scale.

3.3. Main source journals

Based on the papers related to the Electrical Engineering Education Curriculum in the Industry 4.0 era, 235 journals have published 450 articles, with an average of 1.92 articles per journal. Of the 235 journals, 184 (78.29%) only published one article, 27 (11.49%) published two articles, and 18 (10.21%) journals published more than two articles. Table 2 lists the most productive journals in publishing papers on the curriculum of Electrical Engineering Education in the Industry 4.0 era, ranked by the number of citations. ASEE Annual Conference and Exposition Conference Proceedings is the journal with the highest number of citations (63 citations), having published 76 articles. From second to fifth place are the IEEE Global Engineering Education Conference (EDUCON) with 60 citations and 9 articles, Procedia Computer Science with 56 citations and 3 articles, International Journal on Interactive Design and Manufacturing (IJIDeM) with 42 citations and 35 articles, and Procedia Manufacturing with 29 citations and 5 articles. The core journals that publish papers on research in the curriculum of Electrical Engineering Education in the Industry 4.0 era are multidisciplinary or interdisciplinary journals in computer science, civil engineering, electrical engineering, mathematics, and other disciplines. This study gives additional data for the use of bibliometric in giving research trend, as discussed in other reports [37-43].

Table 2. Ten most productive source journals for Engineering Education in the Industrial Revolution 4.0 era, 2012–2021.

Journal	Country	Citations	Articles
ASEE Annual Conference and Exposition Conference Proceedings	USA	63	76
IEEE Global Engineering Education Conference (EDUCON)	Austria	60	9
Procedia Computer Science	UK	56	3
International Journal on Interactive Design and Manufacturing *(IJIDeM)*	Switzerland	42	35
Procedia Manufacturing	Netherlands	29	5
IEEE Transactions on Education	USA	27	4
European Journal of Engineering Education	UK	27	13
Advances in Intelligent Systems and Computing	Germany	21	14
Journal of Physics*:* Conference Series *(JPCS)*	UK	18	4
International Journal of Engineering Education (IJEE)	Irland	15	12

4. Conclusion

Several scientific maps have been constructed to cover the number of publications, countries, research institutions, author productivity, researcher collaboration, and journal sources. Through co-citation document analysis, co-occurrence of keyword analysis, knowledge base analysis, and research limitations on the Electrical Engineering Education curriculum during the Industrial Revolution 4.0 has been discussed. From this analysis, it can be concluded that the increasing number of publications related to the Electrical Engineering Education curriculum during the Industry 4.0 Revolution indicates that this topic still has potential for broader research.

Based on the analysis of research distribution, only the United States stands out as productive in research on the Electrical Engineering Education curriculum during the Industry 4.0 Revolution, while research from other continents is still limited. Publications on the Electrical Engineering Education curriculum during the Industry 4.0 Revolution have an evenly distributed citation pattern among research institutions, with slight differences in citation numbers between Old Dominion University, Norfolk, Virginia, and other institutions. Regarding journal sources, the ASEE Annual Conference and Exposition Conference Proceedings have the most significant influence among all academic journals publishing research on the Electrical Engineering Education curriculum during the Industry 4.0 Revolution.

We found that research related to the study of the Electrical Engineering Education curriculum during the Industry 4.0 Revolution focuses on the use of robotics technology, artificial intelligence, robotics learning trends, and technological innovation. The reason is that the utilization of such technology represents the characteristics of Industry 4.0 progress.

The results of this study indicate that the Electrical Engineering curriculum in the era of Industry 4.0 is evolving in an interdisciplinary field with the integration of the latest technological advancements developed by research groups, institutions, and countries applying theoretical and conceptual approaches to understand sustainable education. In this regard, field research groups can conduct comparative studies between countries to form an international understanding and develop the Electrical Engineering education curriculum in the era of Industry 4.0 to enhance more advanced educational concepts.

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