A Five-Year Bibliometric Analysis of Education 4.0 and Direction for Education 5.0 Future Research

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Abstract. Education 4.0 is a conceptual education framework for current generations. The evolution of education has continued to evolve, which in turn creates a research niche for innovation development in higher education institutions. This study aimed to analyse articles on Education 4.0 research from 2018 to 2022 using the Scopus database as well as identifying current trends in the field of education. This research examined trends in publication and citation performance, journal-related performances, most frequently cited articles, top affiliated countries, and emerging research trends. A bibliometric study was employed in achieving the objectives of the study, guided by five research questions. The study began by extracting metadata and analysing keyword co-occurrence using VOSviewer software and Microsoft Excel. Results showed that Malaysia, Mexico, and Indonesia are three of the top countries to which authors who publish about Education 4.0 research are affiliated. It was also found that there were five emerging research trends related to Education 4.0, namely (a) Education 4.0 on various educational mechanisms, features, and applications; (b) the effect of COVID-19 on the engineering education learning system and the role of Education 4.0; (c) Education 4.0 by means of modern information technologies; (d) developing a framework for innovation in Education 4.0, and (e) technology and digital transformation in Education 4.0. Two suggestions are also made for the direction of future study. Lastly, the implication of this bibliometric study on Education 4.0 informs and shapes the direction of the upcoming Education 5.0 research.

Keywords: bibliometrics; Education 4.0; Education 5.0; research trend; Scopus

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1. Background of the study

The educational system has advanced to a new level in the twenty-first century with distinct contexts to develop quality students and nations in various ways. Teaching and learning have undergone significant changes for the betterment of educational systems. Education 1.0 to Education 4.0 are four levels of education that demonstrate how technology and educational systems have transformed teaching and learning. Different system phases are introduced at each educational level. Education 1.0, 2.0, 3.0, and 4.0 are formulated as downloadable, accessible, knowledge-production, and invention education, respectively (Himmetoğlu et al., 2020). According to Sharma (2019), the four educational eras signify the era of memorization generation, the beginning of World Wide Web education, the era of consumption-based education, and the emergence of education that is change driven. Butt et al. (2020) described the four phases of education as follows: (a) a passive and one-way educational process; (b) an education with combination of passive and active learning; (c) an open, collaborative, flexible, and creative education; and (d) an education characterized by dynamic, independent, proactive, inventive, and self-guided learning. Despite the numerous definitions given to these four systems of education, it is evident that the most recent education phase (Education 4.0) is conceptually very different from its three predecessors.

Education 4.0 is a conceptual education for current generations. Malaysia Higher Education 4.0 or Education 4.0 launched in 2018 by Malaysia's Ministry of Higher Education was directed at the modernization of technology in parallel with the upgrade to students' and industry's needs. Chaka's (2022) investigation was to examine the direction of Education 4.0 and determine whether it is an adequately innovative and disruptive educational trend for higher education institutions. However, based on the bibliographic database used, it was found that Education 4.0 technologies were categorized as transformative, capable of expansion, and environmentally viable. All these technologies are embedded with the innovation activities and require attention, especially for the educators involved in teaching and learning.

Taib and Awang (2020) characterised the nine trends of Education 4.0 as the reasons for the shift in teaching and learning strategies. These trends encompass diverse learning opportunities in terms of time and location, individualized learning experiences, enhanced freedom of decision-making, project-based learning, real-world field experiences, data interpretation, transformative changes in exams, increased student ownership, and a heightened emphasis on mentoring. Although there is much advancement in technology, it did not change the underlying character behind teaching and learning. However, technology has empowered machine-driven approaches to deal with teaching, learning, and assessment. Some technological advancements in Education 4.0 include 3D printing, big data, smart sensors, virtual reality (VR), cloud computing, holograms, drones, and biometrics (Bongomin et al., 2020; Butt et al., 2020; Chaka, 2020, 2021; Halili, 2019; Keser & Semerci, 2019; Reaves, 2019; Salmon, 2019; Sharma, 2019).

The application of digital technology in Education 4.0 is intended to respond to the Fourth Industrial Revolution (IR 4.0) (Lase, 2019). The IR 4.0 aims to transform education in the future through automation and cutting-edge technology (Anggraeni, 2018). Recognizing its potential can significantly enhance the technological innovation capabilities of Education 4.0 in both public and private higher education institutions in Malaysia. This, in turn, can lead to the creation of innovative products that will serve as valuable assets for the country as it strives to excel in the era of IR 4.0. The primary goal of the educational revolution is driven by the enhancement and evolution of the education system. The utilization of the Internet and virtual environments, which integrate technology into various facets of the teaching and learning processes, is found to be the key manifestation of the evolution within the Education 4.0 paradigm.

Some of the researchers who have focused on the application of technology in the education system were Ghavifekr and Wong (2022), Srivani et al. (2022), Lutfiani et al. (2021), Mukhadis et al. (2021), Himmetoğlu et al. (2020), Anggraeni (2018), Maria et al. (2018), and Shahroom and Hussin (2018). The conceptual Education 4.0 model also has been applied to support the field of perioperative cardiothoracic surgical care (Awang Harun et al., 2022), entrepreneurship and social development in Latin America (Caballero et al., 2020) finance (Bilan et al., 2019; Muhsin & Ahmad, 2019), and mobile technology (Abd Karim et al., 2018).

Several studies have investigated the application of Education 4.0 in higher education throughout various parts of the world. Miranda et al. (2021) investigated the solution of transportation problems in Mexico City by using a decision-making laboratory in conjunction with elements of Education 4.0, aimed at enhancing the preparation of exceptionally skilled professionals. Alda et al. (2020) examined the preparedness of teachers in the education institutions in the Philippines to embrace Education 4.0, considering aspects such as faculty, instructional methods, facilities, and research capabilities. Pangandaman (2019) conducted research on the state of higher education in the Philippines regarding its transition to Education 4.0, with a focus on research initiatives, technological advancements, and facilities development. Bonfield et al. (2020) examined Education 4.0 through a comprehensive evaluation, focusing on a specific set of higher education institutions in the United Kingdom and on an international scale. Jamaludin et al. (2020) investigated the perspective, preparedness, and the transformation process associated with introducing Education 4.0 in the Association of Southeast Asian Nations (ASEAN) region, involving policymakers, educators, and students. As research methodology, this study employs quantitative data sourced from the Scopus database and a qualitative approach to summarize the keywords extracted from articles.

Recently a few studies focused on Education 4.0 in higher education in the context of Malaysia. These were conducted by researchers and most pertained to the readiness, pedagogical, and technological adaptation. Nugroho et al. (2021) researched innovation capabilities with quantitative methodologies. The two main key variables introduced to support innovation capabilities were individual soft skills and organizational learning. Their study's findings revealed that specific

soft skills had a substantial and positive impact on the innovation capacity of lecturers. This influence was observed both directly and indirectly, with the latter occurring through the intermediary factor of organizational learning.

In contrast, the research conducted by Iqbal (2021) pinpointed two key facilitators for accelerating innovation and improving quality in higher education: management's knowledge value, culture, rewards, and the knowledge-sharing process. These enablers are underpinned by the theory of the knowledge-based view (KBV) and the knowledge management (KM) capability model. The findings suggested that the value of knowledge held by top management and the rewards based on knowledge had a favorable impact on the pace and quality of innovation. In addition, the exploration of a case study was conducted by Miranda et al. (2021) to highlight core components of Education 4.0 and to identify innovativeness in higher education. The components proposed were competencies, learning methods, infrastructure, information, and communication technologies. The results obtained through the case study demonstrated favorable outcomes, including the creation of new knowledge, the sharing of information among colleagues, the development of inventive solutions, and the utilization of technological assets. Lastly, Al Dulaimi et al. (2022) reviewed innovation capabilities and human development competitiveness in education in the context of the United Arab Emirates, focusing on human capital theory as the basis for investigation for deriving the key variables through a qualitative survey.
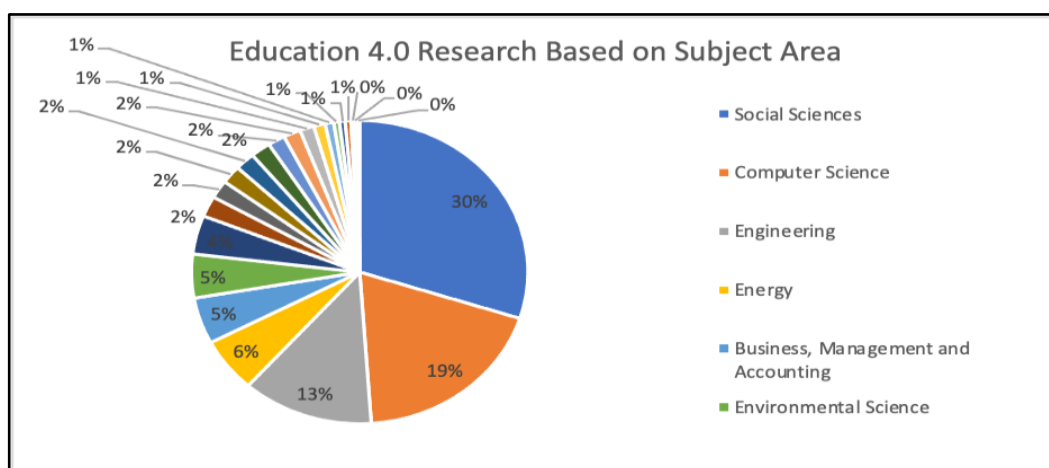
Figure 1: Education 4.0 research clusters based on the subject area

There is a need for conducting a bibliometric study on Education 4.0 in social sciences and computer sciences perspectives. Figure 1 indicates that social sciences dominated the subject area by 30%, followed by computer sciences by 19%, engineering by 13%, and energy by 6%, followed by others. However, based on a combined cluster, social science, accounting, finance, business, economics, econometrics, management, humanities, and arts comprised 41.2%, compared with 58.8% on combined science clusters. Owing to differently combined clusters, scholars from social science, accounting, finance, business, economics,

econometrics, management, humanities, and arts need to pay more attention to publishing more papers based on future research directions as suggested in the later section.

The main objective of this study is to provide an overview of five years of Education 4.0 research in terms of publication and citation trends, journal performance, affiliated countries, top cited articles, and emerging research trends. The following five research questions are then addressed in the context of those gaps:
1) What is the performance trend of top articles published related to Education 4.0 research from the year 2018 to the year 2022?
2) Which journals are contributing the most articles to Education 4.0 research?
3) Which countries substantially have the most affiliation with Education 4.0 research?
4) Who are the authors and what article ranked among the top 10 most cited articles during five years of Education 4.0 research?
5) What are the most frequently discussed research topics in relation to Education 4.0 study to predict the forthcoming research course for Education 5.0?

These research issues are addressed in this study, which makes two contributions. First and foremost, this study aims to help future researchers who are starting their research on the education revolution. This contribution will help them remain updated on emerging developments in Education 4.0 research. Second, highlighting the study trend and potential future direction offers advice and motivates other researchers to carry out more research in this field. As a result, it supports current, innovative, widely acknowledged, and impactful research content.

2. Methodology

This study adopted bibliometrics and content analysis to review the literature data analysis on Education 4.0 research to become more objective and make the literature content analysis more systematic. Some researchers who applied this bibliometric analysis to examine the research trends for Education 4.0 are Gudyanga (2013) and Dao et al. (2022). Bibliometrics is an application of quantitative data analysis that employs mathematical and statistical methods to explore and assess a substantial body of scientific data (Donthu et al., 2021; Lee et al. 2020). This analysis application has benefited considerably from computerised data processing, and there has been a notable increase in the volume of publications on this topic in recent years (Ellegaard & Wallin, 2015). This phenomenon is partly attributed to the utilization of computerized methodologies; however, it also arises from the requirement of a sufficient volume of data for statistical validity in bibliometric techniques. Thus, the method of conducting a bibliometric analysis is to examine books, papers, and other publications using statistical approaches (Özdemir & Dede, 2022).

The analysis was divided into two components: (a) conducting bibliometric mapping to examine Education 4.0 trends, and (b) scrutinizing the indexed

keywords in the articles to determine research groups and identify research themes related to Education 4.0.

2.1 The Protocol and Bibliometric Analysis

In order to provide the quantitative dimension of the literature, the bibliometric review was combined with systematic, integrative, descriptive, or meta-analytic studies to assure reliability and validity (Martínez-Climent et al., 2018). The approach provided by Donthu et al. (2021), which comprises four distinct steps as outlined in Figure 2, is the basis for this bibliometric analysis:
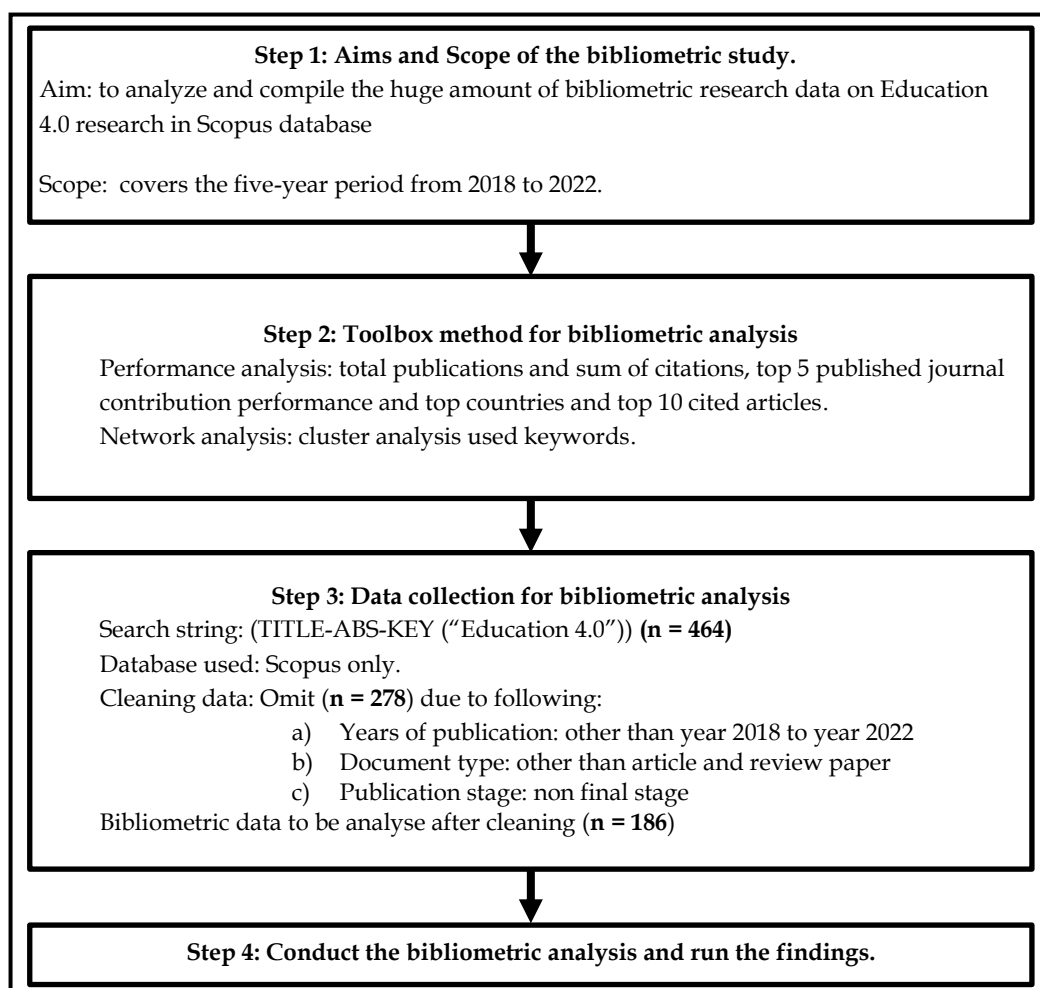
Step 1: Aims and Scope of the bibliometric study.
Aim: to analyze and compile the huge amount of bibliometric research data on Education 4.0 research in Scopus database

Scope: covers the five-year period from 2018 to 2022.

Step 2: Toolbox method for bibliometric analysis
Performance analysis: total publications and sum of citations, top 5 published journal contribution performance and top countries and top 10 cited articles.
Network analysis: cluster analysis used keywords.

Step 3: Data collection for bibliometric analysis
Search string: (TITLE-ABS-KEY ("Education 4.0")) **(n = 464)**
Database used: Scopus only.
Cleaning data: Omit (**n = 278**) due to following:
      a)   Years of publication: other than year 2018 to year 2022
      b)   Document type: other than article and review paper
      c)   Publication stage: non final stage
Bibliometric data to be analyse after cleaning (**n = 186**)

Step 4: Conduct the bibliometric analysis and run the findings.

Figure 2: The procedure for bibliometric analysis by Donthu et al. (2021)

The initial step is to set clear objectives and scope for this bibliometric analysis. The researcher must find the answers to the research questions for this study from the collection of articles. As an outcome, the goal is to review and synthesise the enormous body of bibliometric data on Education 4.0 research. This analysis includes papers from every discipline and covers the years 2018 through 2022.

The second step is to determine the toolbox method for bibliometric analysis. In other words, analytical tools need to be created for this investigation. In this research, two analyses were conducted. The first was performance analysis (total

publications and citation count, top journal performance, top country performance, and top 20 cited articles). The second is network design and network analysis (cluster analysis by means of keyword occurrences).

Next, the third step involves gathering data for bibliometric analysis. The data were gathered using Microsoft EXCEL for generating the information. Using the search string shown in Figure 2, a search was executed from the Scopus database. Thus, 464 articles were found. The data cleaning and filters are tailored to this study since it falls under the scope described in step 1 of the research process. As a result, the Scopus database now has 186 publications.

The final step entails executing the analysis using the bibliometric approach toolbox from step 2 by means of performance analysis and network analysis. This step utilized VOSviewer to cluster research trends in Education 4.0 through co-occurrence keyword analysis. The outcomes and findings are then presented in the following section.

3. Bibliometric Result
3.1 Performance trend of top article published related to Education 4.0 research from 2018 to 2022
Between 2018 and 2022, Scopus contained 186 papers on Education 4.0 research. This Education 4.0 research recorded a total of 1220 citations during the past five years. Figure 3 illustrates the publication and citation performance. The publication trend (bar) shows an increasing trend from 2018 to 2022, with 2022 recording the most papers published, namely 61 papers. The citation count (line), shows fluctuating wave movement, with papers published in 2020 receiving the highest number of citations, reaching 374 citations. However, there was a downward trend by the end of 2022.
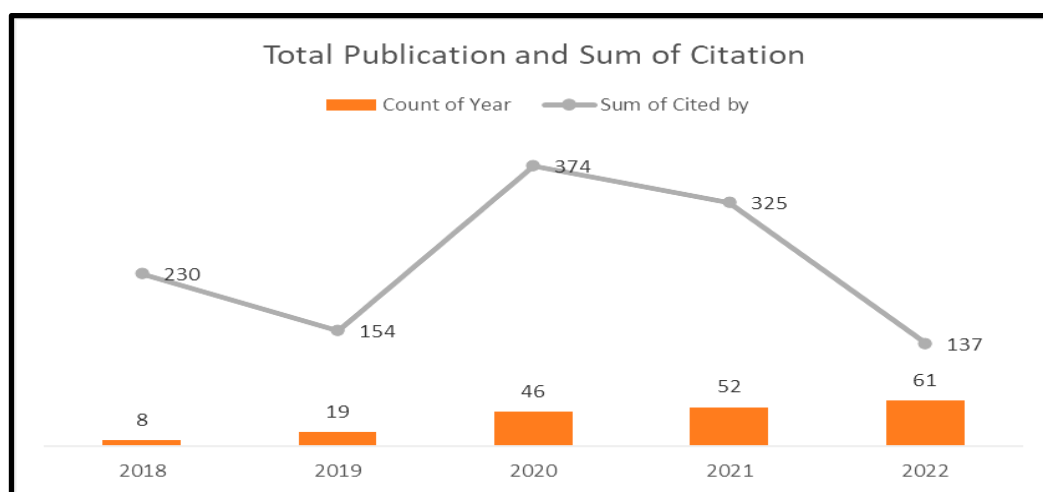

Figure 3: Scopus' publication and citation count performance on Education 4.0 research

Given the observed upward trajectory in the number of publications, it can be reasonably inferred that the field of Education 4.0 research is poised for sustained growth and may continue to thrive over the coming years.

3.2 Journals contributing the most articles in Education 4.0 research

Table 1 summarises the top five journal contributions to Education 4.0 research. The *Journal of Social Science* ranks first with a total of 105 citations, closely followed by *Sustainability* with 101 citations, *Contemporary Educational Technology* with 78 total citations, *Computers and Electrical Engineering* with 65 citations, and *Higher Education Pedagogies* with 60 citations. These top five journals were predominantly affiliated with Switzerland and the United Kingdom. *Sustainability* exhibits the greatest influence among the top five journals, boasting the highest index of 109, followed by *Computers and Electrical Engineering* with an H-index of 73, and *Higher Education Pedagogies* with an H-index of 27.

Table 1: Top 5 total articles published performances related to Education 4.0 research

Rank	Article sources	Origin	TC	TA	YB	H-Index
1	*Social Science*	Switzerland	105	1	2012	27
2	*Sustainability*	Switzerland	101	15	2009	109
3	*Contemporary Educational Technology*	Turkey	78	1	2018	10
4	*Computers and Electrical Engineering*	United Kingdom	65	1	1973	73
5	*Higher Education Pedagogies*	United Kingdom	60	1	2016	9

Notes: TC = Total citations received, TA = Total Articles published (2018-2022), YB = journal's year begin

In summary, these findings highlight the prominent role of the top five journals in Education 4.0 research, with the *Journal of Social Science* leading in total citations. Additionally, Switzerland and the United Kingdom emerged as notable contributors to these journals, with *Sustainability* exhibiting the greatest influence as evidenced by its high H-index.

3.3. Countries with the most affiliation in Education 4.0 research

Table 2 shows the lists of the top 19 countries affiliated with authors who have publications in the field of Education 4.0 within the past five years. Malaysian authors dominated the list by producing 42 articles, followed by Mexico which produced 22 articles, and Indonesia with 20 published articles.

Table 2: Top countries affiliated with authors producing articles in Education 4.0 research

Rank	Country	Number of articles	Rank	Country	Number of articles
1	Malaysia	42	11	Romania	4
2	Mexico	22	12	Turkey	4
3	Indonesia	20	13	Portugal	4
4	India	11	14	Poland	3
5	Philippine	10	15	Thailand	3
6	Russia	5	16	Colombia	3
7	Australia	5	17	Vietnam	3
8	Brazil	5	18	Germany	2
9	Spain	4	19	United Kingdom	2
10	South Africa	4			

As a result, Malaysian, Mexican, and Indonesian authors were identified as active contributors to the Education 4.0 research. The remaining top 10 countries affiliated with authors producing articles on Education 4.0 research are India, the Philippines, Russia, Australia, Brazil, Spain, and South Africa.

3.4 Authors and articles that rank among the top 10 most cited articles during five years of Education 4.0 research

The most frequently cited papers concerning Education 4.0 are shown in Table 3. Hariharasudan and Kot's (2018) work, "A Scoping Review on Digital English and Education 4.0 for Industry 4.0," was the most cited article at 105. This was followed by Almeida and Simoes's (2019) article titled "The Role of Serious Games, Gamification and Industry 4.0 Tools in the Education 4.0 Paradigm" which received 78 citations. Miranda et al.'s (2021)'s article, "The Core Components of Education 4.0 in Higher Education: Three Case Studies in Engineering Education," earned a total of 65 citations. Next were Bonfield et al.'s (2020) "Transformation or Evolution? Education 4.0, Teaching and Learning in the Digital Age" and Buasuwan's (2018) "Rethinking Thai Higher Education for Thailand 4.0" which earned 54 citations, respectively. Additional noteworthy articles are those by Ramírez-Montoya et al. (2021), Mogos et al. (2018), Bongomin et al. (2020), Abdul Bujang et al. (2020), and Bernate and Vargas Guativa (2020).

Table 3: Top 10 most frequently cited Education 4.0 articles between years 2018 to 2022

Rank	Year	Author(s)	Title	Article Sources	TC*
1	2018	Hariharasudan, A. and Kot, S.	A Scoping Review on Digital English and Education 4.0 for Industry 4.0	Social Sciences	105
2	2019	Almeida, F. and Simoes, J.	The Role of Serious Games, Gamification and Industry 4.0 tools in the Education 4.0 Paradigm	Contemporary Educational Technology	78
3	2021	Miranda, J. et al.	The Core Components of Education 4.0 in Higher Education: Three Case Studies in Engineering Education	Computers and Electrical Engineering	65
4	2020	Bonfield et al.	Transformation or Evolution? Education 4.0, Teaching and Learning in the Digital Age	Higher Education Pedagogies	60
5	2018	Buasuwan, P.	Rethinking Thai Higher Education for Thailand 4.0	Asian Education and Development Studies	54
6	2021	Ramírez-Montoya, M.S. et al.	Characterization of the Teaching Profile within the Framework of Education 4.0	Future Internet	29

Rank	Year	Author(s)	Title	Article Sources	TC*
7	2018	Mogos R.-I. et al.	Technology enhanced Learning for Industry 4.0 Engineering Education	Revue Roumaine des Sciences Techniques Serie Electrotechnique et Energetique	27
8	2020	Bongomin, O. et al.	Industry 4.0 Disruption and its Neologisms in Major Industrial Sectors: A State of the Art	Journal of Engineering (United Kingdom)	26
9	2020	Abdul Bujang, S.D. et al.	Digital Learning Demand for Future Education 4.0 - Case Studies at Malaysia Education Institutions	Informatics	23
10	2020	Jayson, A. B. and Javier Andrés, V.G.	Challenges and Trends of the 21st Century in Higher Education	Revista de Ciencias Sociales	21

Notes: *Total Citation

3.5 Most frequently discussed research topics in relation to Education 4.0 study to predict the forthcoming research course for Education 5.0

The clustering of research trends on Education 4.0 by means of co-occurrent keyword analysis in this study was employed to identify the predominant research topics within these themes. The analysis further extends to anticipate potential research directions for Education 5.0, as elucidated in the discussion section.

The purpose of cluster analysis is to identify the research trend associated with the study's main aim and scope (Donthu et al., 2021). Each cluster contains indicators or key terms that are highly associated with one another and thus may be described by a single representative metric (Franceschet, 2009). The performance of the study is captured by numerous clusters, also referred to as representatives. There are five clusters as shown in Figure 4 in this section after 186 articles had been analysed using co-occurrence keyword analysis. Figure 5 shows developments of publication over time (2018-2022).

Cluster 1 (Red Colour). The first cluster is presented as Education 4.0 research focused on different aspects of education features and applications, comprising the empirical study and quantitative analysis using questionnaires. It is the largest cluster, involving 119 article links, year of publication from 2020 and 2021, and with a total of 79 citations. This cluster connected nine keywords – education, human, human experiment, leadership, learning, questionnaire, student, training, and teaching. Specifically, these articles explore e-readiness measurement tool usage for higher Education 4.0 (Goh & Blake, 2021), leadership style models in the Education 4.0 era (Kadiyono et al., 2020; Wahidin et al., 2020), and electronic learning features in Education 4.0 (Mansor et al., 2020). The most frequently cited article in this cluster with 60 citations is that by Bonfield et al. (2020), which emphasised the Education 4.0 aspect of teaching and learning in the digital age. The authors highlighted how digital personal assistants and lifelong learning

would play a crucial role in delivering exceptional education and teaching in the future.

Cluster 2 (Green Colour). The second cluster comprises the Education 4.0 research on the engineering education learning system applied during the COVID-19 pandemic. The set combines seven keywords, namely COVID-19, e-learning, engineering education, higher education, learning systems, students, and teaching and learning. This cluster is associated with 89 linked articles and received 75 citations between 2020 to 2021. In particular, this cluster discussed the lessons learnt from the COVID-19 pandemic (Alakrash & Razak, 2022), the challenges of education evolution (Huk, 2021), and sustainability in education (Hernández-Chávez et al., 2021; Yerel et al., 2021). In this cluster, Hernández-Chávez et al. (2021) recorded the most frequently cited article at 11. This cluster also discussed sustainability in education related to the COVID-19 pandemic period. Since it was a matter of keeping higher education institutions alive, looking for sustainable higher education strategies played an essential role in the sector.

Cluster 3 (Blue Colour). The third cluster focuses on Education 4.0-related application of modern information technologies. This cluster combines six main keywords, namely artificial intelligence, augmented reality, Education 4.0, Fourth Industrial Revolution, Industry 4.0, and Internet of Things. This cluster contains 74 linked articles with 65 citations, all published between 2018 to 2021. Specifically, this cluster focuses on the possibility of integration between the Industrial Revolution and the Internet of Things (IoTs) in Education 4.0 (Butt et al., 2020) as well as developing a comprehensive student performance analysis using artificial intelligence (Chen et al., 2020), and disruptive innovation learning media with augmented reality in the era of Education 4.0 (Putra et al., 2021). The most impactful article under this cluster is that by Majid and Majid (2018), suggesting that augmented reality can promote discovery learning for science, technology, engineering, and mathematics (STEM).

Cluster 4 (Yellow Colour). The fourth cluster provides a framework for innovation in Education 4.0. This cluster pools three main keywords – educational innovation, higher education, and innovation. This cluster involves 44 article links, the most published in 2021 and which earned a total of 23 citations. In particular, this cluster deals with designing a framework by identifying components of Education 4.0 (González-Pérez & Ramírez-Montoya, 2022; López et al., 2021; Miranda et al., 2021; Ramírez-Montoya et al., 2021; Sarango-Lapo et al., 2021) and for the sustainability for higher education programs (Membrillo-Hernández et al., 2021). The article by González-Pérez & Ramírez-Montoya (2022) was the most frequently cited article in this cluster with 16 citations. The authors introduced research that integrated innovative educational practices and the fundamental components of Education 4.0.

Cluster 5 (Purple Colour). The fifth cluster concentrates on digital transformation and technology adapted in Education 4.0. This cluster only bonds two main keywords, namely digital transformation and technology. This cluster encompasses 10 related articles linked with 13 citations, with most being

published in 2021. Specifically, this cluster is related to technology leadership through information and communication technology (ICT) utilization and digital transformation (Ghavifekr & Wong, 2022) as well as the framework to structure the digital learning environment (Connolly et al., 2020). In this cluster Oliveira and Souza (2021) received the highest number of citations at 26. The authors discussed digital transformation towards Education 4.0 by developing an experimentation method. The experiment method was applied in the context of classes in fundamental subjects in primary and higher education. The purpose was to create projects that would help mitigate environmental issues brought on by anthropogenic activities while, at the same time, helping students develop their soft and hard skills.
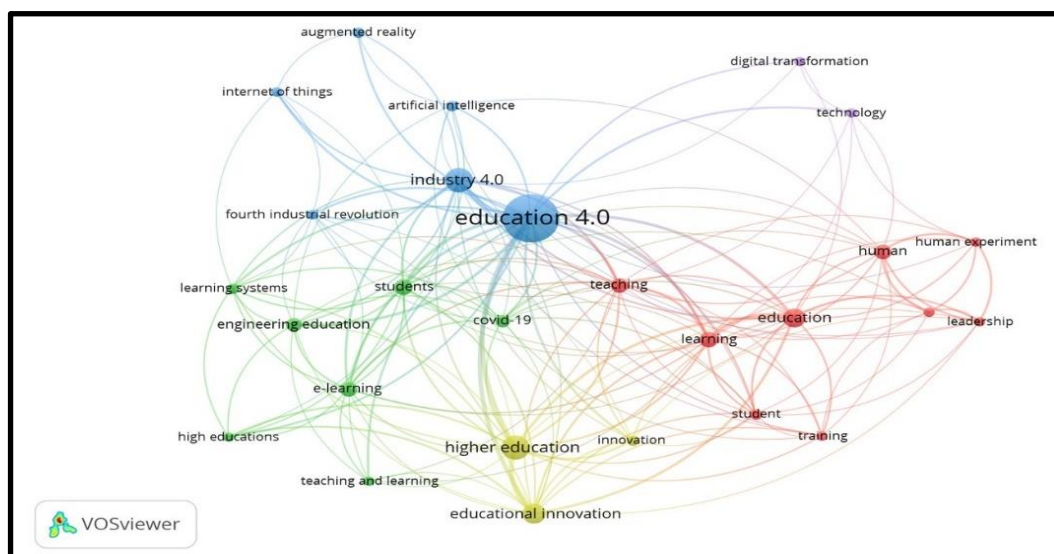
Figure 4: Authors' keyword network analysis on Education 4.0 research

Figure 5 illustrates the trends in publications from 2018 to 2022, focusing on the development of Education 4.0. The keywords 'leadership', 'human management', 'Internet of Things', and 'augmented reality' were identified as having received relatively less intention in recent years.
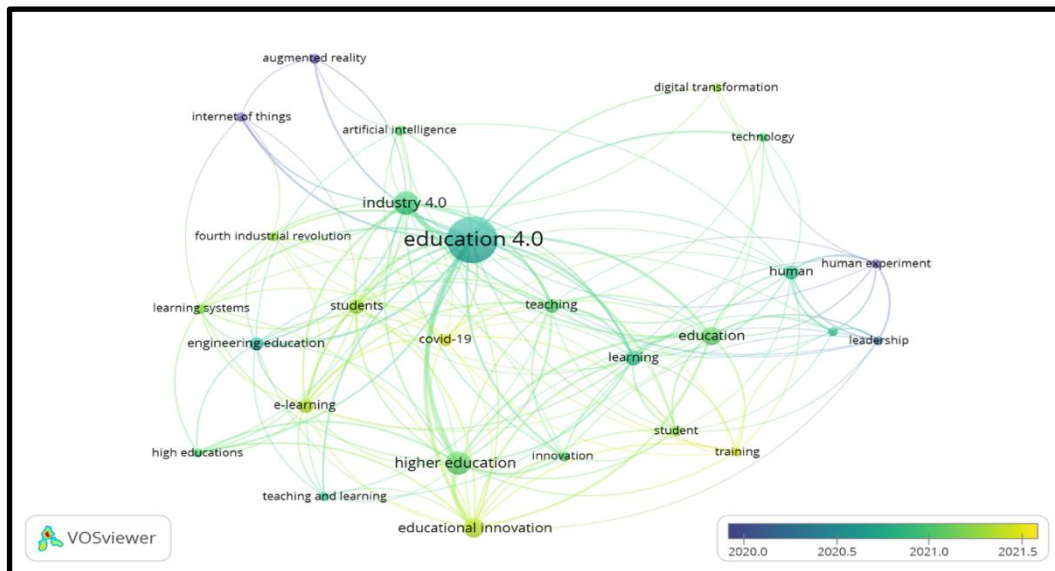
Figure 5: Overlay visualisation of the author's keyword on Education 4.0 research area

4. Discussion

Based on the findings of the performance and network analyses, the following are suggested for future research in Education 4.0. Firstly, extensive study on Education 4.0 is needed in specific countries or regions (see Table 2). The study's results highlight that the top three most prolific authors are currently from developing countries. Nonetheless, there is a crucial requirement to disseminate research findings from both developed and underdeveloped countries.

Secondly, there are two suggested research directions and proposals for Education 5.0 as depicted in Figures 6 and 7. In Figure 6, the more faded words indicate less density, while Figure 7 highlights the network for the less frequent keywords involved. The keywords from two clusters are identified based on less frequent keywords used, which need the attention of other scholars to conduct Education 4.0 research. In the first cluster, the two research directions are the integration of Education 4.0 and the 4IR in developing the innovation, and the leadership model of academicians in Education 4.0. The second cluster suggested two research directions based on learning and human experimentation which are explained as Education 4.0, utilizing advanced technology, and ethical human experimentation to enhance personalized learning experiences and to improve education continuously. Apart from those two suggested clusters, it is expected that there will be more published papers on education revolution research.
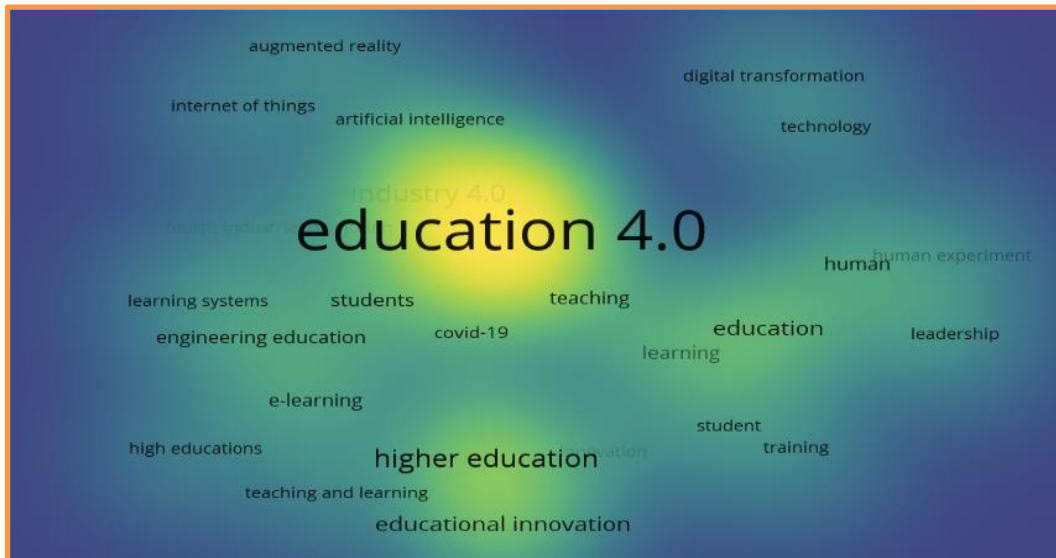
Figure 6: Density visualisation of frequent keywords in Education 4.0 research
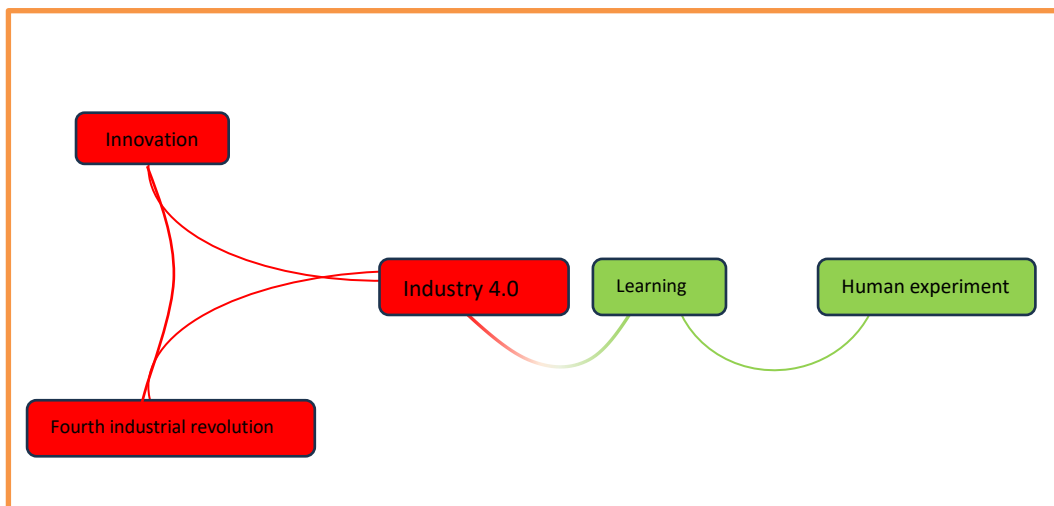
Figure 7: Network analysis on less frequent keywords in Education 4.0 research

5. Conclusion

This study analyzed the progression of Education 4.0 research from 2018 to 2022, examining publication activity, citation performance, country affiliations, top-cited articles, and research themes. The findings revealed a total of 186 publications with 1,220 citations to date. Over this period, there was a rising trend in publications, with 61 papers published in 2022, while 2021 saw the highest citation count at 325. The second research question identified the top-performing journals in Education 4.0 research while the third research question revealed that Malaysia, Mexico, and Indonesia were the top three countries associated with authors who published articles on Education 4.0 research. Hariharasudan and Kot (2018), Almeida and Simoes (2019), and Miranda et al. (2021) were the top three most cited authors among the leading 19 Education 4.0 research articles over the past five years, addressing the fourth research question. Additionally, the five emerging trends in Education 4.0 research were identified, responding to the final

research query. These trends encompass (a) various mechanisms and applications of Education 4.0, (b) the impact of COVID-19 on engineering education learning systems in the context of Education 4.0, (c) Education 4.0 facilitated by modern information technologies, (d) the development of innovative frameworks within Education 4.0, and (e) the role of digital transformation and technology mechanisms in Education 4.0.

Although the study featured only five clusters, future research in the discussion section was proposed on the related network analysis of less frequently occurring keywords and regional analysis. This research made two significant contributions: firstly, it assisted emerging scholars in initiating Education 5.0 research, keeping them abreast of evolving developments in educational revolution studies. Secondly, it highlighted research trends and suggested future directions, as well as motivating fellow researchers to engage in further exploration in this field in the interests of updated, novel, widely recognized, and impactful research.

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