Multidisciplinary Reviews

REVIEW ARTICLE
Published Online: December 30, 2023
https://doi.org/10.31893/multirev.2024053

Worldwide research history and trends on Blockchain applications in education: A bibliometric analysis, 2017-2022

Joharri Shuhaimi[a] ✉ | **Hapini Awang**[b] | **Mohd Fairuz Jafar**[a]

[a]School of Education, Universiti Utara, Sintok, Kedah, Malaysia.
[b]Intitute for Advanced and Smart Digital Opportunities, School of Computing, Sintok, Kedah, Malaysia.

Abstract Academic scholars have been studying Blockchain technology since 2017. As a result, the progression of this technology has drawn interest from researchers in various research fields, including education. Because of this tendency, it is imperative that the existing literature be thoroughly reviewed to assist researchers in identifying gaps for future studies. Thus, this study used bibliometric analysis to assess the current research trend on blockchain applications in education. This study compiled all published works on Blockchain in education as of January 8th, 2023, from the Scopus database. The data was integrated using Publish or Perish software, and data visualization was done using VOSviewer. Additionally, Microsoft Excel was used to analyze the data. Fifty-one documents were retrieved in total based on the search results. In particular, from 2018 to 2019, the growth rate of publications in educational Blockchain increased dramatically. Most of the publications were written in English and published in journals and conference proceedings. Computer science has dominated research on educational Blockchain, and most research was done in India. The analysis also revealed that the most commonly used terms, "blockchain" and "blockchain in education," correspond to the main areas of study that have been done on the educational Blockchain. Unfortunately, the assessment component has received very little attention from previous educational blockchain studies. In addition to outlining the development of the scientific literature on the subject, this study also highlights areas of current research interest and possible future research prospects.

Keywords: digital solution, educational assessment, evaluation

1. Introduction

To date, comprehensive studies on Blockchain application in education are growing up, indicating it as a relatively new research field. Most existing research on Blockchain in education mainly focuses on identifying its benefits and challenges as to how it can improve student records management. This focus remains strong despite increasing interest in this field of study (Iyer et al., 2020; Shankar et al., 2021). As a result, it has been noted that most research has focused on managing and delivering records supporting materials and documentation (Farooq et al., 2021). However, there has been a lack of exploration conducted to analyze the research trends in the field of Blockchain applications within education, particularly in identifying specific domains within this field that have received limited attention. Hence, the present study employs bibliometric analysis to discern research trends within the realm of Blockchain applications in education.

Bibliometric analysis is a statistical method used to assess the trend and pattern of published scientific literature. It is used to examine research trends, citation analysis, authorship, publication importance, journal analysis, as well as local and international contributions to a certain topic (Sweileh et al., 2017). Since 2017, researchers have made continuous efforts to examine the role of Blockchain in transforming the technological landscapes of education. Considering the inclination, bibliometric analysis is considered the most appropriate method to assess the current trajectory of research about Blockchain application in education.

The opening section of this paper summarizes the goal of using bibliometric analysis to examine the research trend on Blockchain integration in education. The methodology used is described in the following section. The third section presents the findings derived from the pertinent bibliometric indicators. The study's limitations are outlined in the final section, which also includes suggestions for future research and a conclusion.

2. Method

This study used data from the Scopus database as of January 8th, 2023. Scopus is the most extensive and inclusive abstract and indexing repository ever established (Aghaei Chadegani et al., 2013; Burnham, 2006). The obtained data revealed several analytical insights related to the publications, including the contributed nations, source types, languages,

 Received: August 7, 2023 | Accepted: December 12, 2023

affiliations, authors, subjects, document types, source titles, publication years, and access types. Therefore, the following inquiry was made: (TITLE-ABS-KEY ("Blockchain in education"). This inquiry focused on conducting searches within publications to examine the titles, abstracts, and keywords related to the document and their relevance to the domain of Blockchain integration in education. This search yielded 51 documents pertaining to Blockchain technology in education found in total (Figure 1).

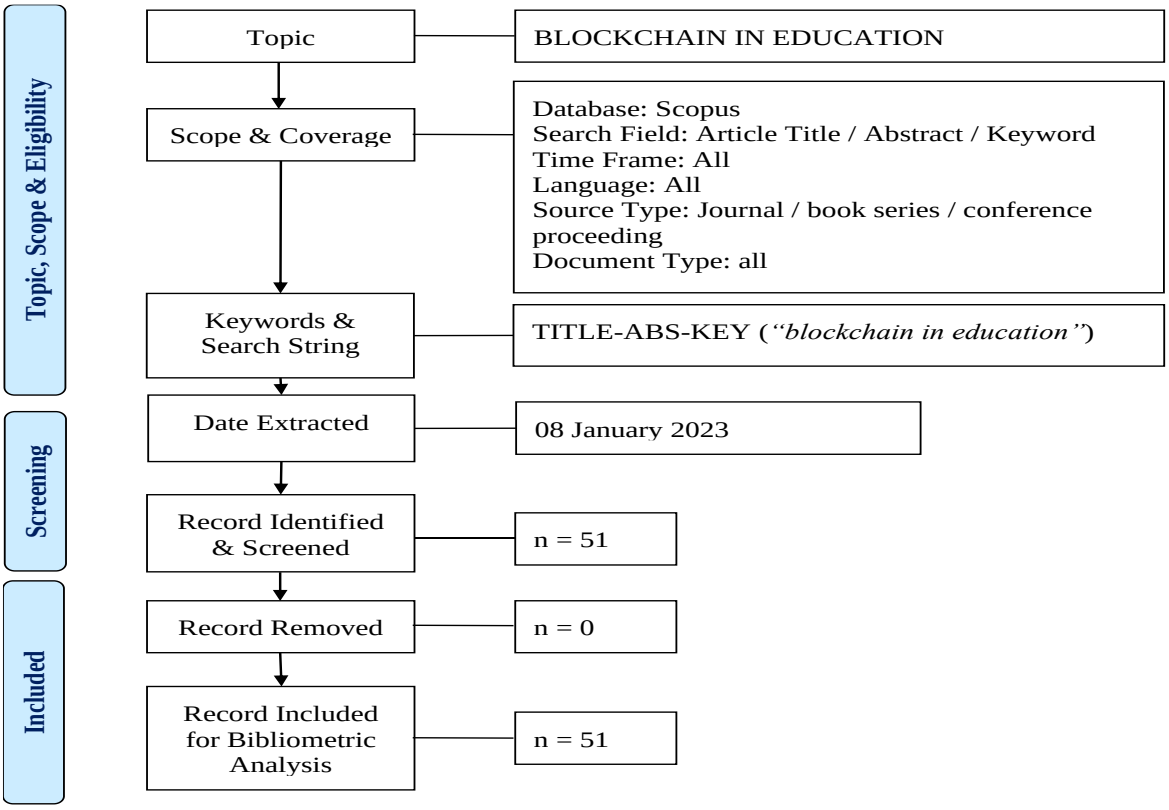


Figure 1 Flow Diagram of The Search Strategy.

The whole range of the identified publication years items was covered by this inquiry. Each of the retrieved documents was then examined using bibliometric analysis procedures. The following tools were used in the study: (i) VOSviewer for creating and visualizing bibliometric networks; (ii) Microsoft Excel for calculating percentages and frequencies related to published materials; and (iii) Harzing's Publish and Perish software for calculating citation metrics.

3. Results and Discussion

Comprehensive data analysis was done to identify a wide range of parameters, such as authorship, citations, languages, subject areas, yearly growth, document types, and source types. For the most part, frequency and percentage are used to present the findings, which offered valuable information on the trend of publications.

3.1. Document and Source Types

The first stage of inquiry involves a thorough classification of the collected data in order to identify different types of sources and documents. Journals, book series, conference proceedings, and books are clustered under the source types, while conference papers, articles, reviews, book chapters, and conference reviews are categorized as document types. Accordingly, this study made an expected discovery whereby certain conference papers showed inconsistent source and document type classifications (Sweileh et al., 2017). Further investigations showed that some conference papers within a document type were likely published as complete journal articles and presented at conferences. Even though the source type was originally a conference paper, some were published as book chapters or in conference proceedings (Ahmi & Elbardan, 2021).

This study identifies five different categories of publications related to Blockchain in education: conference papers, articles, book chapters, reviews, and conference reviews. As figured in Table 1, conference papers occupy the majority of the publications (43.14%), followed by articles (25.49%) and reviews (13.73%). Book chapters and conference papers represent the other two categories of documents, respectively, taking up less than 10% of the total amount of documents.

Table 1 Document Type.

Document Type	Total Publications	Percent
Conference Paper	22	43.14%
Article	13	25.49%
Review	7	13.73%
Book Chapter	5	9.80%
Conference Review	4	7.84%
Total	51	100.00%

Table 2 distinguishes five distinct sources. Journals have the highest proportion (33.23%), followed by conference proceedings. Furthermore, book series contribute to 21.57% of the total document count. Books have the smallest share, representing only 5.88% of the sum.

Table 2 Source Type.

Source Type	Total Publications	Percent
Journal	20	39.22%
Conference Proceeding	17	33.33%
Book Series	11	21.57%
Book	3	5.88%
Total	51	100.00%

In terms of publication count, only one paper was published in each of the years 2017 and 2018. Skiba (2017) published the first report on Blockchain technology in education, titled "The Potential of Blockchain in Education and Health Care," in 2017. Furthermore, there was a significant increase in the number of publications between 2018 and 2019, followed by consistent growth until 2022, as shown in Figure 2. However, it is crucial to highlight that the pattern should not be regarded as a valid predictor of publications in 2023. This is mostly due to the lack of publications scheduled or indexed in the Scopus database for that year as of the date of document acquisition.

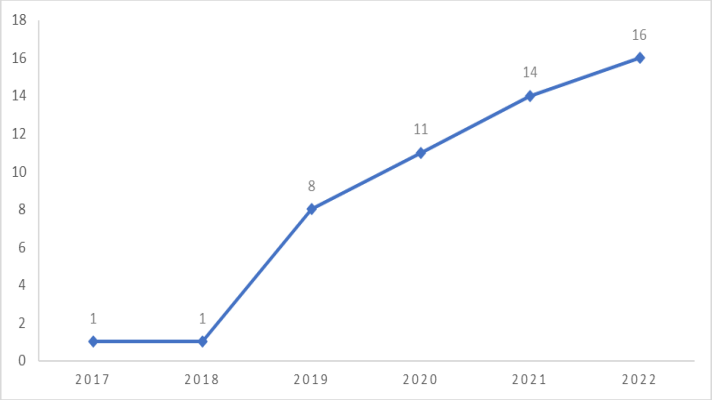


Figure 2 Total Number of Publication by Year.

3.2. Language of Documents

Table 3 shows that English has become the most common language used in the examined collection of publications. Notably, one document, making up only 1.96% of the entire collection was found to have been delivered in other languages, specifically Spanish.

Table 3 Language of Documents.

Language	Total Publications	Percent
English	50	98.04%
Spanish	1	1.96%
Total	51	100.00%

3.3. Subject Area

The present study further characterized the documents based on their respective themes. Interestingly, computer science made up the majority of research on Blockchain in education, comprising 76.47% of the entire collection. Following this, 35.29% of the documented articles were in engineering studies, and 49.02% were in social sciences. Table 4 displays the topics studied within the context of Blockchain in education.

Table 4 Subject Area.

Subject Area	Total Publications	Percent
Biochemistry, Genetics and Molecular Biology	1	1.96%
Business, Management and Accounting	3	5.88%
Chemical Engineering	4	7.84%
Computer Science	39	76.47%
Decision Sciences	8	15.69%
Economics, Econometrics and Finance	1	1.96%
Energy	2	3.92%
Engineering	18	35.29%
Environmental Science	1	1.96%
Materials Science	6	11.76%
Mathematics	6	11.76%
Medicine	1	1.96%
Nursing	1	1.96%
Physics and Astronomy	4	7.84%
Psychology	1	1.96%
Social Sciences	25	49.02%

3.4. Keywords Analysis

Next, the author-supplied keywords went through cartographic visualization using VOSviewer, a software used to represent bibliometric networks graphically. Figure 3 illustrates an overlay visualization generated on the basis of item scores. The default color scheme denotes escalating scoring levels, ranging from the lowest score denoted by blue, progressing to green, and culminating in yellow. It is pertinent to highlight that the score indicates temporal recency, wherein more recent items are given higher scores (Ahmi, 2022). Blockchain in education (green) was at a modest degree of currentness in this study. In this sense, the assessment was ranked 91st, with only one article using the term, despite its best score in this context (see Table 5).

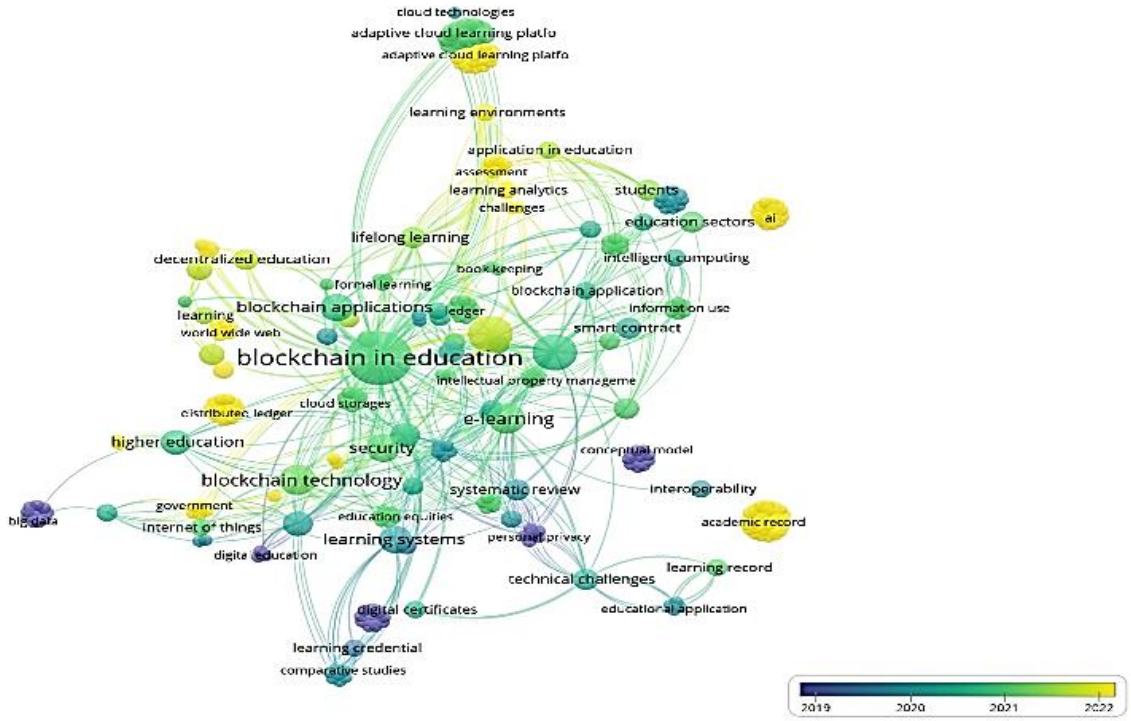


Figure 3 Overlay Visualization of Keyword Map.

Table 5 shows the 20 most common keywords pertinent to research concerning Blockchain in educational contexts. Following a thorough data cleaning process on author-supplied keywords, it is identified that "Blockchain" and "Blockchain in Education" stood out as the most frequently employed keywords in studies pertaining to Blockchain within educational frameworks. The context of educational assessment, however, has received less focus.

Table 5 Keywords.

Rank	Keywords	Total Publications
1	Blockchain	32
2	Blockchain In Education	19
3	Engineering Education	10
4	Blockchain	9
5	Education	9
6	Blockchain Technology	6
7	E-learning	6
8	Educational Technology	6
9	Blockchain Applications	5
10	Learning Systems	5
11	Security	5
12	Higher Education	4
13	Privacy	4
14	Systematic Literature Review	4
15	Decentralization	3
16	Decentralized Education	3
17	Distributed Ledgers	3
18	Education Sectors	3
19	Information Management	3
20	Lifelong Learning	3
91*	Assessment	1

3.5. Geographical Distribution

The collection of resources was made available to the public due to the cooperative efforts of researchers from 29 different nations. Table 6 lists the top 20 countries that have contributed to the academic discussion around the application of Blockchain technology in education. India was the largest contributor with nine papers overall, followed by Saudi Arabia and Sweden, each with four, and Spain with six publications. But when it came to the total number of citations received by a country, Saudi Arabia had the most (132), followed by Oman (79), India (50), and other countries. Notably, Malaysia held the final spot on the list with one article and five total citations.

Table 6 Top 20 Countries Contributed to The Publications.

Rank	Country	Total Publications	Total Citation
1	India	9	50
2	Spain	6	24
3	Saudi Arabia	4	132
4	Sweden	4	4
5	China	3	15
6	Hong Kong	3	22
7	Japan	3	3
8	Brazil	2	5
9	Chile	2	12
10	Indonesia	2	14
11	Oman	2	79
12	Pakistan	2	43
13	Romania	2	6
14	Thailand	2	5
15	Ukraine	2	3
16	United States	2	0
17	Bangladesh	1	2
18	Finland	1	0
19	France	1	12
20	Malaysia	1	5

Furthermore, the analysis also revealed that most publications were prepared by multiple authors, except for five (10%) single-authored publications. Other papers mostly had two or three authors, and four publications were without an identified author. One document in particular had thirteen authors, which was the largest number of authors in the dataset. Table 7 presents the number of authors per document.

Table 7 Author Count.

Author Count	Total publications	Percent
0	4	7.84
1	5	10.00
2	15	29.41
3	12	24.00
4	9	17.65
5	2	3.92
6	1	1.96
7	1	1.96
8	1	1.96
13	1	1.96
Total	51	100.00

3.6. Citation Analysis

This study used Harzing's Publish or Perish software to analyze the documents' citation metrics. Table 8 provides citation metrics for a set of papers within the reference date of January 8, 2023. These papers were published between 2017 and 2022 and received a total of 441 citations over the span of six years (2017-2023). The table also reveals that there are 51 papers, with an average of 8.65 citations per paper, 2.9 authors per paper, and notable author metrics, such as a Hirsch h-index of 10 and an Egghe g-index of 20. The "PoP hI,norm" and "PoP hI,annual" values suggest other citation-based metrics, with "PoP hI,annual" indicating an annual h-index of 1 for this set of papers.

Table 8 Citation Metric.

Reference date:	8/1/2023
Publication years:	2017-2022
Citation years:	6 (2017-2023)
Papers:	51
Citations:	441
Citations/year:	73.5
Citations/paper:	8.65
Authors/paper:	2.9
Hirsch h-index:	10
Egghe g-index:	20
PoP hI,norm:	6
PoP hI,annual:	1

Next, Table 9 lists the top 20 cited articles on Blockchain in education. The most cited paper was "Blockchain-based applications in education: A systematic review" by Alammary et al. (2019), which garnered a total of 126 citations (31.5 citations per year).

Table 9 Top 20 Cited Articles in Blockchain in Education Study.

No.	Authors	Title / Source	TC	C/Y
1	(Alammary et al., 2019)	Blockchain-based applications in education: A systematic review / Applied Sciences (Switzerland)	126	31.5
2	(Skiba, 2017)	The Potential of Blockchain in Education and Health Care / Nursing Education Perspectives	68	11.33
3	(K. Al Harthy et al., 2019)	The upcoming Blockchain adoption in Higher education: Requirements and process	40	10
4	(Bhaskar et al., 2020)	Blockchain in education management: present and future applications / Interactive Technology and Smart Education	39	13
5	(Yumna et al., 2019)	Use of Blockchain in Education: A Systematic Literature Review	38	9.5
6	(Zhong et al., 2018)	A Blockchain Model for Word-Learning Systems	15	3
7	(Ma & Fang, 2020)	Current status, issues, and challenges of Blockchain applications in education / International Journal of Emerging Technologies in Learning	14	4.67
8	(Hardini et al., 2020)	Ontology of Education Using Blockchain: Time Based Protocol	13	4.33
9	(Loukil et al., 2021)	Blockchain adoption in education: a systematic literature review / Education and Information Technologies	12	6
10	(Vargas & Soriano, 2019)	Blockchain in the university: A digital technology to design,	12	3

		implement and manage global learning itineraries / Digital Education Review		
11	(Delgado-Von-eitzen et al., 2021b)	Blockchain applications in education: A systematic literature review / Applied Sciences (Switzerland)	5	2.5
12	(Delgado-Von-eitzen et al., 2021a)	Application of Blockchain in education: GDPR-compliant and scalable certification and verification of academic information / Applied Sciences (Switzerland)	5	2.5
13	(Park, 2021)	Promises and challenges of Blockchain in education / Smart Learning Environments	5	2.5
14	(Hashmani et al., 2020)	Blockchain in Education - Trackability and Traceability	5	1.67
15	(Sousa & Machado, 2019)	Blockchain technology reshaping education: Contributions for policy / Blockchain Technology Applications in Education	5	1.25
16	(Sathya et al., 2021)	Enabling smart education system using blockchain technology / Intelligent Systems Reference Library	4	2
17	(Chivu et al., 2022)	The Role of Blockchain Technologies in the Sustainable Development of Students' Learning Process / Sustainability (Switzerland)	4	4
18	(Mahankali & Chaudhary, 2019)	Blockchain in education: A comprehensive approach - utility, use cases, and implementation in a university / Blockchain Technology Applications in Education	4	1
19	(San et al., 2020)	Blockchain-based Learning Credential Revision and Revocation Method	3	1
20	(Ocheja et al., 2022)	Visualization of education Blockchain data: trends and challenges / Interactive Learning Environments	3	3

TC = Total Citations, C/Y = Citation per Year

4. Final considerations

This study presents a bibliometric review to better understand the trends, historical reviews, forecasts, and contributions of the Blockchain in education literature. Since it began in 2017, this topic has been the subject of more and more investigations. With eight publications in 2019 compared to just one publication in 2018 and 2017, the number of publications has dramatically increased. While the total number of publications has already reached 16 documents as of December 2022, this number is anticipated to rise further in 2023.

Geographically, although Saudi Arabia and Oman publish only four and two documents, respectively, those countries have greater citation influence than India (this country has the highest number of publications). As the educational influence of technology is expanding globally, it is suggested that studies on Blockchain in education be performed in other nations, particularly those that have published fewer than ten papers, such as Malaysia.

The results of this study are susceptible to some limitations; therefore, they should be interpreted with care. First, a single Scopus database served as the source for all documents. Therefore, it must be stressed that although Scopus is one of the biggest databases covering a greater number of journals, it also contains papers with a lesser impact. It took a while for the most recent papers to be fully indexed and included in the database; thus, only a few were recently added (Aghaei Chadegani et al., 2013).

Furthermore, the documents retrieved were limited because they focused mostly on subjects related to "Blockchain in education." Researchers purposefully eliminated other works that use the terms "education" and "Blockchain" in isolation. It is crucial to emphasize that any search query has the potential to be flawed and that false positives or negatives might still happen (Ahmi & Elbardan, 2021). Finally, as the citation analysis presented in this study only used data from the Scopus database, the total number of publications and citations is accurate as of the time the keyword search was conducted.

Despite these drawbacks, the unique aspect of the current study should be emphasized in relation to the earlier research carried out by Shalatska et al. 2020 and Yeop et al. (2018). In contrast to those studies that just examined keywords in publications about Blockchain in education, the current study is among the first to comprehensively analyze specific bibliometric indicators within the body of literature dedicated to Blockchain in education. It opens up several possible fresh grounds to be explored in greater detail by future researchers.

The analysis of publications related to the integration of Blockchain technology in education has indicated an overwhelming amount of focus on these particular subject areas. Up to this point, most existing research on Blockchain in education mainly focuses on identifying its benefits and challenges on managing student records, supporting materials and documentation (Farooq et al., 2021). However, by examining the authors' keywords, the need for additional research in several overlooked areas under this heading has become apparent. For example, the field of Blockchain-based assessment stands out as one that requires more investigation because it has received relatively less attention from previous works.

Assessment is highly important in the field of education. The domain in education that could potentially benefit the most from Blockchain technology is learner evaluation and assessment (Jayne Fleener, 2022). Traditional evaluation methods

are not flawless as they face issues such as a number of difficulties, including security concerns, instructor preparedness, time constraints, ability gaps, and accuracy issues (Doğan et al., 2020; Jani et al., 2018; Mahat et al., 2021; Maslan & Mohd Nor, 2020; Rasheed et al., 2020; Shalatska et al., 2020). Given the growing trend of virtual learning in education, there is great potential for using Blockchain technology in educational assessments. Research suggests that Blockchain is highly effective in protecting data, which could make it easier to implement Bring Your Own Device (BYOD) initiatives in schools and colleges (Yeop et al., 2018).

Ethical considerations

Not applicable.

Conflict of Interest

The authors declared no conflict of interest.

Funding

This research is supported by the Universiti Utara Malaysia Generation Grant: S/O Code: 21361.

References

Aghaei Chadegani, A., Salehi, H., Md Yunus, M. M., Farhadi, H., Fooladi, M., Farhadi, M., & Ale Ebrahim, N. (2013). A comparison between two main academic literature collections: Web of science and scopus databases. *Asian Social Science*, *9*(5), 18–26. https://doi.org/10.5539/ass.v9n5p18

Ahmi, A. (2022). *Bibliometric Analysis for Beginners*. Universiti Utara Malaysia.

Ahmi, A., & Elbardan, H. (2021). Bibliometric Analysis of Published Literature on e-Wallet. *Webology*, *18*(SpecialIssue2), 79–91. https://doi.org/10.14704/WEB/V18SI02/WEB18013

Alammary, A. (2019). Blockchain-based applications in education: A systematic review. In *Applied Sciences (Switzerland)* (Vol. 9, Issue 12). https://doi.org/10.3390/app9122400

Alammary, A., Alhazmi, S., Almasri, M., & Gillani, S. (2019). Blockchain-based applications in education: A systematic review. *Applied Sciences (Switzerland)*, *9*(12). https://doi.org/10.3390/app9122400

Bhaskar, P., Tiwari, C. K., & Joshi, A. (2020). Blockchain in education management: present and future applications. In *Interactive Technology and Smart Education, 18*(1). https://doi.org/10.1108/ITSE-07-2020-0102

Burnham, J. F. (2006). Scopus database: A review. *Biomedical Digital Libraries*, *3*, 1–8. https://doi.org/10.1186/1742-5581-3-1

Chivu, R.-G., Popa, I.-C., Orzan, M.-C., Marinescu, C., Florescu, M. S., & Orzan, A.-O. (2022). The Role of Blockchain Technologies in the Sustainable Development of Students Learning Process. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031406

Delgado-Von-eitzen, C., Anido-RifÃ³n, L., & FernÃ¡ndez-Iglesias, M. J. (2021a). Application of Blockchain in education: GDPR-compliant and scalable certification and verification of academic information. *Applied Sciences (Switzerland)*, *11*(10). https://doi.org/10.3390/app11104537

Delgado-Von-eitzen, C., Anido-RifÃ³n, L., & FernÃ¡ndez-Iglesias, M. J. (2021b). Blockchain applications in education: A systematic literature review. In *Applied Sciences (Switzerland)* (Vol. 11, Issue 24). MDPI. https://doi.org/10.3390/app112411811

Doğan, N., Kibrislioğlu Uysal, N., Kelecioğlu, H., & Hambleton, R. K. (2020). An overview of e-assessment. *Hacettepe Egitim Dergisi*, *35*(Special Issue), 1–5. https://doi.org/10.16986/HUJE.2020063669

Farooq, M. S., Tehseen, R., & Omer, U. (2021). Blockchain based Online Examination Assessment models for Educational. *VFAST Transactions on Software Engineering*, *9*(3), 57–67.

Hardini, M., Aini, Q., Rahardja, U., Izzaty, R. D., & Faturahman, A. (2020). Ontology of Education Using Blockchain: Time Based Protocol. In *2020 2nd International Conference on Cybernetics and Intelligent System, ICORIS 2020*. https://doi.org/10.1109/ICORIS50180.2020.9320807

Hashmani, M. A., Junejo, A. Z., Alabdulatif, A. A., & Adil, S. H. (2020). *Blockchain in Education - Track ability and Traceability* (pp. 40–44). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICCI51257.2020.9247760

Iyer, S. S., Seetharaman, A., & Maddulety, K. (2020). Education Transformation Using Block Chain Technology - A Student Centric Model. In *IFIP Advances in Information and Communication Technology* (Vol. 617, Issue December). https://doi.org/10.1007/978-3-030-64849-7_19

Jani, J., Muszali, R., Nathan, S., & Abdullah, M. S. (2018). Blended Learning Approach Using Frog Vle Platform Towards. *Journal of Applied and Fundamental Science*, *10*(5), 1130–1141. https://doi.org/10.4314/jfas.v10i5s.94

Jayne Fleener, M. (2022). Blockchain Technologies: A Study of the Future of Education. *Journal of Higher Education Theory and Practice*, *22*(1), 26–45. https://doi.org/10.33423/jhetp.v22i1.4956

K. Al Harthy, F., Al Shuhaimi, K. K., & Ismaily, J. Al. (2019). The upcoming Blockchain adoption in Higher-education: Requirements and process. In *2019 4th MEC International Conference on Big Data and Smart City, ICBDSC 2019*. https://doi.org/10.1109/ICBDSC.2019.8645599

Loukil, F., Abed, M., & Boukadi, K. (2021). Blockchain adoption in education: a systematic literature review. *Education and Information Technologies*, *26*(5), 5779–5797. https://doi.org/10.1007/s10639-021-10481-8

Ma, Y., & Fang, Y. (2020). Current status, issues, and challenges of Blockchain applications in education. *International Journal of Emerging Technologies in Learning*, *15*(12), 20–31. https://doi.org/10.3991/ijet.v15i12.13797

Mahankali, S., & Chaudhary, S. (2019). Blockchain in education: A comprehensive approach - utility, use cases, and implementation in a university. In *Blockchain Technology Applications in Education* (pp. 267–293). IGI Global. https://doi.org/10.4018/978-1-5225-9478-9.ch014

Mahat, H., Anuar, N. A., Hashim, M., Nayan, N., & Saleh, Y. (2021). Pelaksanaan Pentaksiran Pembelajaran dan Pemudahcaraan (PDPC) Berasaskan Teknologi di Sekolah. *E-Jurnal Penyelidikan Dan Inovasi*, *8*(1), 1–24. https://doi.org/10.53840/ejpi.v8i1.1

Maslan, M., & Mohd Nor, M. Y. (2020). Kebolehlaksanaan Pentaksiran Bilik Darjah (PBD) Secara Atas Talian Sepanjang Perintah Kawalan Pergerakan (PKP) Di

Daerah Sentul, Kuala Lumpur. *Prosiding Seminar Nasional FIP 2020*, 213–218.

Ocheja, P., Flanagan, B., Ogata, H., & Oyelere, S. S. (2022). Visualization of education Blockchain data: trends and challenges. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2022.2026406

Park, J. (2021). Promises and challenges of Blockchain in education. *Smart Learning Environments*, *8*(1). https://doi.org/10.1186/s40561-021-00179-2

Rasheed, R. A., Kamsin, A., & Abdullah, N. A. (2020). Challenges in the online component of blended learning: A systematic review. *Computers and Education*, *144*(March 2019), 103701. https://doi.org/10.1016/j.compedu.2019.103701

San, A. M., Chotikakamthorn, N., & Sathitwiriyawong, C. (2020). *Blockchain-based Learning Credential Revision and Revocation Method* (pp. 42–45). Association for Computing Machinery, Inc. https://doi.org/10.1145/3368308.3415456

Sathya, A. R., Panda, S. K., & Hanumanthakari, S. (2021). Enabling smart education system using Blockchain technology. In *Intelligent Systems Reference Library* (Vol. 203, pp. 169–177). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-69395-4_10

Shalatska, H. M., Zotova-Sadylo, O. Y., & Makarenko, O. Y. (2020). Implementation of E-assessment in Higher Education. *Psiholoska Obzorja*. https://doi.org/10.20419/2020.29.515

Shankar, S. K., Mukesh, R., & Badrinarayanan, M. K. (2021). *Challenges in Adoption of Secure Digitization of Graduate Assessments: Scope for Blockchain Technologies* (Vol. 1270, pp. 1–9). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-15-8289-9_1

Skiba, D. J. (2017). The Potential of Blockchain in Education and Health Care. *Nursing Education Perspectives*, *38*(4), 220–221. https://doi.org/10.1097/01.NEP.0000000000000190

Sousa, M. J., & Machado, A. B. (2019). Blockchain technology reshaping education: Contributions for policy. In *Blockchain Technology Applications in Education* (pp. 113–125). IGI Global. https://doi.org/10.4018/978-1-5225-9478-9.ch006

Sweileh, W. M., Al-Jabi, S. W., AbuTaha, A. S., Zyoud, S. H., Anayah, F. M. A., & Sawalha, A. F. (2017). Bibliometric analysis of worldwide scientific literature in mobile - health: 2006-2016. *BMC Medical Informatics and Decision Making*, *17*(1), 1–12. https://doi.org/10.1186/s12911-017-0476-7

Vargas, P. R., & Soriano, C. L. (2019). Blockchain in the university: A digital technology to design, implement and manage global learning itineraries. *Digital Education Review*, *35*, 130–150.

Yeop, Y. H., Othman, Z. A., Abdullah, S. N. H. S., Mokhtar, U. A., Fauzi, W. F. P., & Ahmad, N. (2018). Key Factors to Implement BYOD in Schools. *IEEE Access*, 1–3. https://doi.org/10.1109/CR.2018.8626864

Yumna, H., Khan, M. M., Ikram, M., & Ilyas, S. (2019). Use of Blockchain in Education: A Systematic Literature Review. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 11432, pp. 191–202). https://doi.org/10.1007/978-3-030-14802-7_17

Zhong, J., Xie, H., Zou, D., & Chui, D. K. W. (2018). A Blockchain Model for Word-Learning Systems. In *Proceedings - 2018 5th International Conference on Behavioral, Economic, and Socio-Cultural Computing, BESC 2018* (pp. 130–131). https://doi.org/10.1109/BESC.2018.8697299