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Mini Review
A Bibliometric Investigation of Cloud Computing and Education Research

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Abstract

The educational system comprises a variety of teaching and learning activities and these activities have also benefited from the adoption of cloud computing technologies. The aim of this study was to quantify and analyze the volume of research outputs chronicling the adoption of cloud computing in education using bibliometric methods. A bibliometric analysis was carried out on 840 documents published from 2011-2017 and retrieved from the SCOPUS database based on defined search terms relating to cloud computing and Education. The analysis results revealed that there was an increase of interests in cloud computing and education research since 2011. King Abdulaziz University in Saudi Arabia was the most productive institution in this domain, whereas, China emerged as the country with the highest contribution to this cloud computing and education research. Mariya Shyshkina of National Academy of Sciences in Ukraine emerged as the most prolific author in cloud computing and education research. The trend of cloud computing and education research revealed it had a major impact on engineering education as well as, higher education than elementary and secondary school education. The publication trend in the domain of cloud computing and education portend growth in the future.

Key words: Cloud computing, SCOPUS database, educational system, research outputs, bibliometric methods, productive institution

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INTRODUCTION

Cloud computing is a distributed computing arrangement that provides virtual access to IT resources such as networks, storage space, computer systems, applications or platforms for a variety of computing tasks[1,2]. These resources referred to as "the cloud", can be requested for, configured and provided to the user with very little interaction with the cloud provider. The use of "the cloud" can be metered and users can be charged per-use. There are three major classifications of cloud computing services: Platform as a service (PaaS), software as a service (SaaS), Infrastructure as a service (IaaS)[3-8]. Infrastructure as a service is found at the minimal level, where resources such as storage, networking and processing are given on request to the customer as a reflection of a virtual machine. Examples of IaaS are Amazon EC2, OpenStack and etc. PaaS, such as Goggle App Engine, provides users with application development and hosting platforms, while web-based user applications (e.g., email, multimedia etc.) are provided to users via the SaaS platform, eradicating the need to install such applications on user's devices.

Over the years, the investments of organizations like Amazon, Goggle and Microsoft in the development of cloud computing technologies have popularized the adoption of cloud computing in different contexts such as business, health, government and education. For instance, cloud storage services such as Drop box or One Drive are used daily by millions of users as an online storage facility for files of various formats. Furthermore, a number of organizations currently use cloud-based applications such as Salesforce.com, a CRM application, to manage relationships with their teeming customers[9] as well as applications in employee management information systems[10].

The educational system comprises a variety of teaching and learning activities and these activities have also benefited from the adoption of cloud computing technologies[11-13]. A number of educational institutions provide their students with cloud-based virtual learning environments, email services, collaboration tools and data storage facilities[11,14,15]. There is evidence of increased access to learning resources via cloud-enabled e-learning and m-learning initiatives[12,16]. This has led to a reduction in the cost of education while improving institutional productivity and an increase in the efficiency of the academic process[12,17]. In spite of the overwhelming benefits of cloud computing to education, just like any other ICT, a number of studies have highlighted some disadvantages of cloud computing to qualitative education, e.g. as presented in Olanrewaju *et al.*[12], Sultan[15] and Bennett and Weber[18].

There is a significant amount of research efforts and outputs in the literature cataloguing adoption scenarios, success stories and challenges of the adoption of cloud computing in education[11,13,18-23]. The aim of this paper is to quantify and analyze the volume of research outputs in this domain using bibliometric methods to trace the relationships between cloud computing and education research related endeavors. Such analysis provides an understanding of the global research productivity trends of how cloud computing is being adopted in education.

CLOUD COMPUTING AND EDUCATION RESEARCH

To contextualize this study existing related literature are presented subsequently in this section. Heilig and Vob[24] performed a scientometric analysis of 15,776 cloud computing publications retrieved from the SCOPUS database from 2008-2013. The study provided an insight into the publication patterns as a basis for the trends in cloud computing. In the same vein, other researchers, such as Cai *et al.*[25] and Chaurasia *et al.*[26] performed broad bibliometric studies of global cloud computing research trends to uncover the evolution and state of the topic. Similarly, Baldwin *et al.*[27] reported a bibliometric study of cloud forensics research trends in the literature. In contrast, this study explored the trends of cloud computing research with a specific target on how it intersects with research outputs in the education domain.

Knutas *et al.*[28] proposed a cloud-based tool for performing systematic mapping studies used for tacking the state-of-the art in specific research areas, this study focused on the quantitative aspects of research outputs for cloud computing and education research.

Baldassarre *et al.*[29] performed a systematic mapping study on cloud computing for education. This study, based on 623 documents published from 2012-2016, analyzed the scientific development trends of researches in this domain in line with empirical validation practices. Gonzalez-Martinez *et al.*[16] presented a systematic review of the research and practice of cloud computing and education, the study categorizes and examines the benefits and disadvantages of cloud computing in education, based on 112 relevant research documents. Similarly, the possible ways that education can benefit from cloud computing as well as the opportunities and challenges of the adoption of cloud computing technologies in higher educational institutions were highlighted by Olanrewaju *et al.*[12] and Kumar *et al.*[13]. Sultan[15] showcased the distinctiveness of adopting cloud computing in education,

while revealing some concerns that likely prevent its adoption. In recognition of cloud computing implementation in education, this study provides a bibliometric justification of the intersection by studying the volume of research outputs in the domain under review.

So far, to the best of author's knowledge, this study was the first to conduct a bibliometric analysis that presented the quantitative aspects of the research outputs for cloud computing and education research domain.

In order to accomplish the main focus, these sets of objectives were outlines: (1) To determine the top contributing authors and researchers in cloud computing and education research, (2) To examine the yearly global distribution of research productivity in cloud computing and education, (3) To identify the most research-active institutions on cloud computing and education, (4) To show the publication outlets that widely publish cloud computing and education research, (5) To enumerate the national contributions of countries to research in cloud computing and education, (6) To identify the issues and trends in cloud computing and education research.

Based on a carefully crafted search query, the bibliometric data of the documents used in this study were retrieved from SCOPUS, which is one of the largest indexed academic databases[30]. The data downloaded was used to answer the research questions posed in this study. Search strings containing "cloud", "computing" and "education" were used to obtain relevant documents and the publication years was limited to 2011-2017. A total of 1951 research papers with the search string contained in their title, abstract or keyword was returned from the search made. The contents of the title, abstract and keyword sufficiently reflected the main content of a paper[31,32]. The data contained details such as source title, authors' name, affiliation and country, year of publication, authors' and indexed keywords, abstract, citation count, publication outlet and language.

To ascertain that only relevant documents were used for the bibliometric analysis, a pre-processing of the data downloaded was performed. The pre-processing entailed that only documents in line with the domain of study, i.e., cloud computing and education were included in the corpus. To achieve this, the title, abstract and keywords of each document was reviewed for words such as "education", "e-learning", "school", "university", "curriculum", "assessment", "academic", "classroom", "teaching" and "learning". In cases where there were ambiguities, the full papers were reviewed to confirm its relevance to the focus of this study. Eventually, all irrelevant papers were excluded leaving a total of 840 documents that formed the corpus used for this study. The 840 documents were written in English, Spanish, Chinese, Russian, Arabic and Portuguese. The corpus was exported as a Comma Separated Version (CSV) file format for ease of analysis on MS-Excel. The part of the data that were considered in the study included Year, Author Name, Subject Area, Document Type, Source Title, Keywords, Affiliation, Countries, Source Type and Language.

In this study, a bibliometric approach was employed to answer the research question posed in this study. The analysis covered the annual research outputs, academic publishers, source titles and the citation count. Other analysis includes the top productive institutions and authors. Furthermore, the subject area and keywords was analyzed to uncover the specific trends of research in the adoption of cloud computing in education.

The aim of the study was to quantify and analyze the volume of research outputs in this domain of adopting cloud computing in education. The answers to the research questions posed in this study were presented in the following subsections.

Most productive authors: The first research question seeks to identify the top contribution authors to cloud computing and education research globally. The analysis showed that there were a total of 1969 authors for all 840 publications used in this study. It was also observed that some authors had more than one affiliation and the most recent affiliation was selected in the final analysis. Table 1 showed the top 8 most productive authors, with more than five articles, affiliation and country. Mariya Shyshkina of National Academy of Sciences in Ukraine emerged as the top author with eight articles. While Agustin Caminero had five publications, the following authors had six publications each: Llanos Tobarra, Habib Moussa Fardoun, Manuel Castro, Rafael Pastor, Salvador Ros and Xiaodi Huang.

Global distribution of total research outputs: The second objective aimed to determine the yearly global distribution of research productivity in cloud computing and education. The trend of publication over the years (2011-2017) based on the number of publications was shown in Fig. 1. It was obvious that the number of publications increased through the years,

Table 1: Affiliation and country of top authors in cloud computing and education

Authors	No. of articles	Affiliation	Country
Shyshkina, Mariya	8	National Academy of Sciences in Ukraine	Ukraine
Tobarra, Llanos	6	Universidad Nacional de Educacion a Distancia	Spain
Fardoun, Habib Moussa	6	King Abdulaziz University	Saudi Arabia
Castro, Manuel	6	Universidad Nacional de Educacion a Distancia	Spain
Pastor, Rafael	6	Universidad de Salamanca	Spain
Ros, Salvador	6	Universidad Nacional de Educacion a Distancia	Spain
Huang, Xiaodi	6	Charles Sturt University, School of Computing and Mathematics	Australia
Caminero, Agustin	5	Universidad Nacional de Educacion a Distancia	Spain

Table 2: Document types published per year (2011-2017)

Sources	2011	2012	2013	2014	2015	2016	2017	Total
Conference paper	67	72	95	75	93	100	98	600
Article	10	11	27	14	39	49	68	218
Book chapter	0	0	0	2	1	4	1	8
Review	0	0	0	0	1	2	2	5
Editorial	0	0	0	0	1	1	0	2
Article in press	0	0	0	0	0	0	7	7
Grand total	71	83	121	91	135	156	176	840

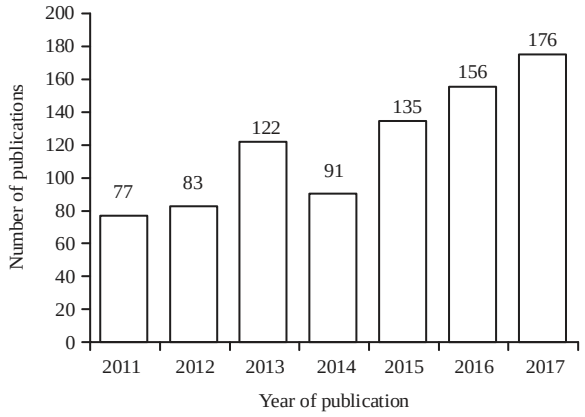

Fig. 1: Yearly publication spread (2011-2017)

but dropped in 2014. In 2017, publications focusing on cloud computing and education had more than doubled since 2011 as there were 77 documents in 2011 compared to 176 documents in 2017. This trend showed an increase in interest in the research domain.

Productive research institutions: The third objective seeks to enumerate the most research-productive institutions in the cloud computing and education research domain. From the analysis of the data used for this study, there were 927 institutions that had contributed to cloud computing and education research output. Figure 2 showed the top nine institutions with King Abdulaziz University, Saudi Arabia, emerging tops with 10 publications out of all 840 publications (1.19%). This was closely followed by Universidad Nacional de Educacion a Distancia and Huazhong Normal University with nine publications each (1.07%), Institute of Information Technologies and Learning Tools and Capital Normal University both had 7 publications (0.83%). Universita Degli Studi di Genova, King Saud University, Covenant University and Beijing Normal University all had 6 publications each (0.71%).

Leading publication outlets: The goal of this analysis was to uncover the various outlets where cloud computing and education research works had been published. The publication outlets were profiled and ranked in terms of the number of documents published. The publications in the domain area of focus of this study belong to the following categories: Conference papers, articles, book chapter, review, editorial and article in press. Table 2 showed the spread of this document types over the years of publication (2011-2017), with conference paper being the most type of publication with 600 documents (71.43%), followed by Articles having 218 documents (25.95%). There were eight documents (0.95%) classified as Book chapters, while there were five Review documents (0.60%). Finally, seven (0.83%) and two (0.24%) documents are classified as articles in press 7 documents and editorial two documents respectively.

The Table 3 showed the yearly distribution of the top seven sources where research works focused on cloud computing and education had been published. The Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) published the highest number of documents, with 39 publications.

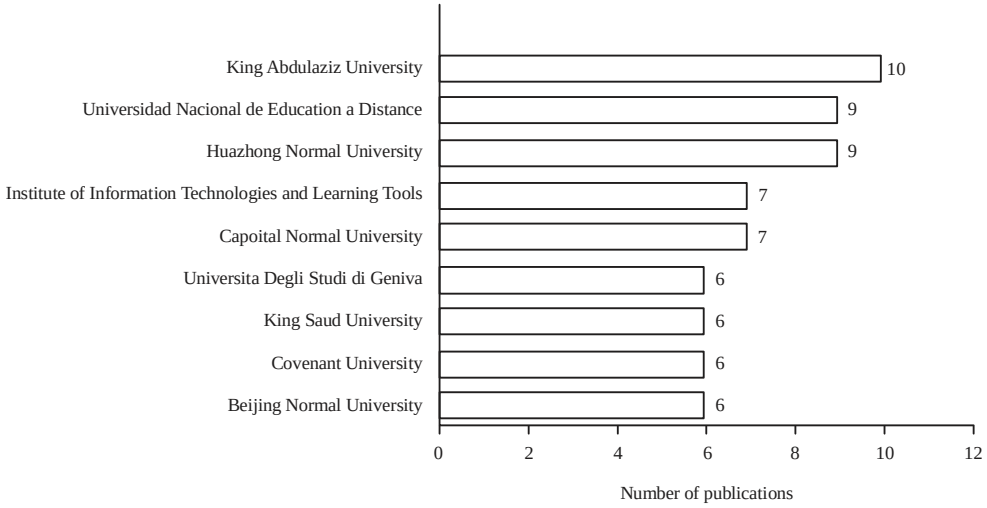

Fig. 2: Top 9 institutions contributing to cloud computing and education research

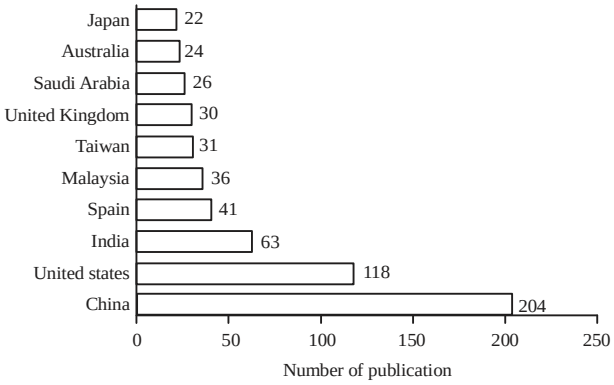

Fig. 3: Top 9 countries contributing to cloud computing and education research

Table 3: Top 7 major sources

Sources	2011	2012	2013	2014	2015	2016	2017	Total
Lecture notes in computer science	4	3	5	5	11	3	8	39
ACM international conference proceeding series	1	0	7	4	4	4	4	24
Communications in computer and information science	7	2	3	1	2	1	3	19
IEEE global engineering education conference	0	3	3	2	3	3	3	17
Applied mechanics and materials	0	0	8	9	0	0	0	17
Ceur workshop proceedings	0	0	1	0	1	9	5	16
Revista De La facultad De ingenieria	0	0	0	0	0	0	14	14

National contribution to cloud computing and education research: A total of 81 countries had contributed to cloud computing and education research from 2011-2017. As Fig. 3 captured the 10 leading host countries of researchers in this domain. From the analysis shown in Fig. 3, China leads the pack with 204 publications out of 840, amounting to 24.29% of all publications in the period under review. China was followed by the United States with 118 publications (14.05%), India came in as the 3rd country with 63 publications (7.5%), while Spain produced 41 publications (4.88%). Others in the rank included Malaysia (36 publications, 4.29%), Taiwan (31 publications, 3.69%), United Kingdom (30 publications, 3.57%), Saudi Arabia (26 publications, 3.10%), Australia (24 publications, 2.86%) and Japan (22 publications, 2.62%).

Research trend in cloud computing and education: Research question 6 explored the trend of cloud computing and education by analyzing subject area and keywords of the

Table 4: Top 7 subject classification of cloud computing and education research

Subject area	Publication counts
Computer science	608
Social sciences	251
Engineering	233
Mathematics	96
Decision sciences	65
Business, management and accounting	39
Medicine	21

Table 5: Top 10 keywords used in cloud computing and education research

Keyword	Occurrence
Education computing	816
Engineering education	201
Virtual learning experience	154
Higher education	123
Distance education	101

documents published in this domain. From the data analyzed cloud computing and education research was classified into 24 subject areas including Computer Science, Social Sciences, Engineering, Mathematics, Decision Sciences, Business, Management and Accounting and Medicine. Others include Earth and Planetary Sciences, Arts and Humanities, Materials Science, Psychology, Physics and Astronomy, Agricultural and Biological Sciences, Chemistry, Environmental Science, Biochemistry, Genetics and Molecular Biology, Economics, Econometrics and Finance, Energy, Health Professions, Chemical Engineering, Immunology and Microbiology, Multi disciplinary, Pharmacology, Toxicology and Pharmaceutics and Veterinary. The data in Table 4 showed the top 7 subject areas and the number of publications in each category.

A total number of 5087 keywords from 840 publications were identified. The top five most frequent keywords used in the documents published in this domain were highlighted in Table 5. General keywords such as "cloud computing", "education", "cloud", "clouds", "teaching", "student" etc. were excluded from the list. Keywords that belong to the same family were grouped together, for example, these keywords "e-learning", "elearning systems", "M-learning", "Mobile learning", "e-learning platforms", "online learning", "computer-aided instruction" and "learning systems" were grouped into one category as "Education Computing". Also, keywords such as "Virtual Reality", "VLE" and "virtual learning environments", "virtual labs", "virtual classrooms", were grouped as "Virtual Learning Experiences".

The analysis of the keywords revealed that most research publications focused a lot on how cloud computing aids education computing, particularly in the area of mobile and electronic learning. Largely, research attention is paid to how cloud computing technologies are used in the teaching of students in engineering related-programmes as identified by Rudas[33]. It can also be observed that cloud computing was adapted to provide virtual learning experiences for students[16], while how cloud computing contributed to enabling open and distance education was also an area of emphasis. Cloud computing and education research was focused mostly on higher education than any other level of education[15].

CONCLUSION

Based on the bibliometric analysis performed in this study, the research outputs chronicling the adoption of cloud computing technologies in the education domain had improved globally from 2011-2017. Although majorly, research attention had been paid to cloud computing applications in higher education context, more research should be carried out to include other level of education in order to improve the quality of and/or measure the impact of cloud computing for educational service delivery. Furthermore, there are greater prospects for an increase of research outputs in this domain in the nearest future, providing researchers in developing countries with opportunities to leverage this research space to proffer solutions to education challenges in their region.

SIGNIFICANCE STATEMENT

This paper analyses the research activities in the intersection of cloud computing and education domain. This study presents the research efforts in the implementation cloud computing technologies to enhance the quality of education delivery. The trend of cloud computing and education research reveals it has a major impact on higher education than elementary and secondary school education.

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