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How the Evolution and Track of Several Digital Technologies in Science Education?

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ABSTRACT

Objective: *Digital technologies have significantly impacted science education. This research uses a bibliometric analysis to analyze the evolution of various digital technologies in science education.* ***Method:*** *The research uses the PRISMA method to conduct a systematic review using the Scopus database.* ***Results:*** *LMS was the highest publication and citation in the last five years. DL and LMS publications increased, but DA decreased. DL, LMS, DA, and EA publications dominate article papers. SC and ILS dominated conference papers. 57% of DT researchers are European, with 19% from Asian and North American researchers. Twenty-four sources are participating in DT research. Many universities in America, such as Harvard University, Stanford University, MIT, and Berkeley University, the University of California have extensive facilities for participating in DL, LMS, DA, EA, SC, and ILS research.* ***Novelty:*** *This research is essential to educators, researchers, and policymakers to provide insights on improving digital teaching technologies, inform policy, and promote interdisciplinary collaboration. It also offers an overview and research trend of DT in science education research and its opportunities for researchers, librarians, digital developers, educators, and policymakers to develop further research, education, and technology. Further research can be conducted based on the scope of mathematics or physics education, especially to investigate specific skills or STEAM.*

INTRODUCTION

The importance of digital technology (DT) in improving science education has become a significant focus in efforts to increase learning effectiveness (Haleem et al., 2022). In the past five years particularly post-pandemic, international researchers and educators have heavily relied on various digital technologies to enhance science learning. This urgency stems from the significant impact DT has had on educational transformation (Balyer & Öz, 2018), particularly in interactive learning software (LS), smart classrooms (SC), educational applications (EA), digital assessments (DA), Learning Management Systems (LMS), and digital libraries (DL), all of which have expanded the scope of science learning (Zhan et al., 2022). These advancements illustrate the evolution of DT in education (Singh & Miah, 2020), each technology playing a crucial role in improving the science learning process.

Understanding how the use of DT has evolved in science education is essential for assessing its impact and identifying emerging usage trends (Chassignol et al., 2018; Oliveira et al., 2021). Utilizing a bibliometric analysis model, a scientific approach that employs bibliographic analysis and scientific publications, can shed light on these trends, patterns, and impacts (Aristovnik et al., 2020; Bielecka, 2020). Specifically, in the context of DT in science education, bibliometrics can assist in tracking relevant research,

identifying leading researchers, and evaluating the impact of that research on advancing science education (Li & Wong, 2022; Wang et al., 2023).

Bibliometric analysis quantitatively analyzes scientific publications to understand trends, patterns, and impacts in a particular research field (Islam et al., 2022). The bibliometric approach can provide a wide range of data (metadata) (Robinson-Garcia et al., 2017). This analysis involves metrics such as several publications, citations, journal impact factors, and collaboration between researchers to provide insight into scientific developments and contributions. In the context of this research, a bibliometric approach helps capture the role of current digital technologies in science education and their implications for future educational research and practice.

Thus, the aim of writing a scientific article with the topic "How is the Evolution and Track of Several Digital Technologies in Science Education?" is to identify several things, such as the evolution of some DT-es in science education, the most productive and influential authors, sources, institutions, and countries that contributed to DT, and the research topics of DT in science education. It is hoped that this research will have implications for improving the quality of education. Apart from that, this research can be used as a basis for thinking or a reference source for writers who will research similar topics within the scope of bibliometrics.

RESEARCH METHOD

This type of research is a systematic review using the PRISMA method that simplifies the research process (Rethlefsen et al., 2021). In addition, this research integrated bibliometric analysis methods to obtain metadata with a wide range (Heradio et al., 2016). The data source comes from the Scopus database because it can provide complex data and provides various complete components (country, bibliographic coupling, citation, and co-citation) so that it is more complex when illustrated using VOSviewer (Farooq, 2023; García-Lillo et al., 2021). Data from the Scopus database is saved in .csv format and processed using Ms. Excel and Datawrapper. The data was collected on March 2024.

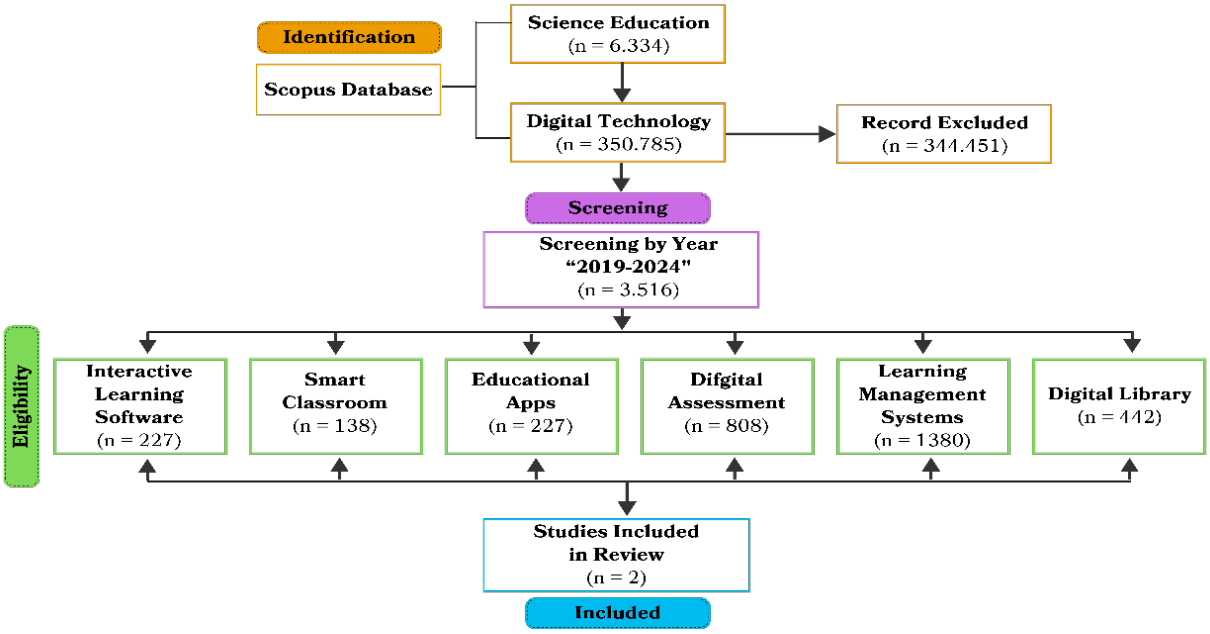


Figure 1. PRISMA stages in research

Based on Figure 1, the search process is carried out by entering each keyword on the Scopus page and filtering by adding year intervals (2019-2024). A specific number of each keyword used is obtained when the filtering process has been carried out. The final stage shows that the selected documents are highly relevant to the research topic.

RESULTS AND DISCUSSION

Overview of the Evolution of Digital Technologies Field

The average number of LMS publications per year during the last five years was the highest, at 230 documents. EA and SC publications get the same average number of publications, at 37 documents. Besides, SC publications are the lowest. The DL and LMS publications were increased significantly. The others get picked and down publications each year. International researchers started DA publication in 2023 with 57 documents, which will increase in 2024 because its publication during the first quartal recorded 43 documents.

LMS publications get the highest average citations per year, at 1521, with the highest number of publications occurring in 2020. DA publications get the lowest average citation per year, at 28 for two years. According to Figure 2, ILS got the highest CPP (citation per year) in 2019, but its publication decreased significantly until the first quartal, with no citation. DT research decreased significantly from 2021 until the first quarter of 2024.

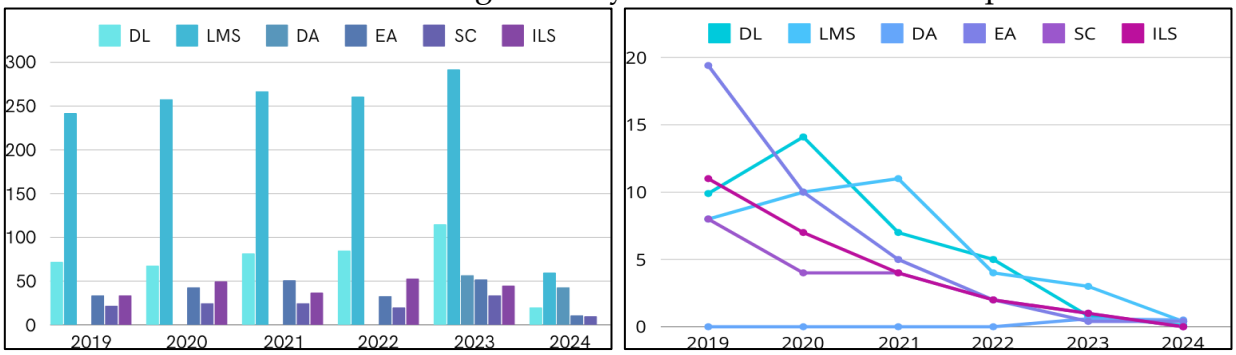


Figure 2. Overview of DT publication by years (left) and citations (right).

The Most Influential Publication and Authors in Digital Technologies Field

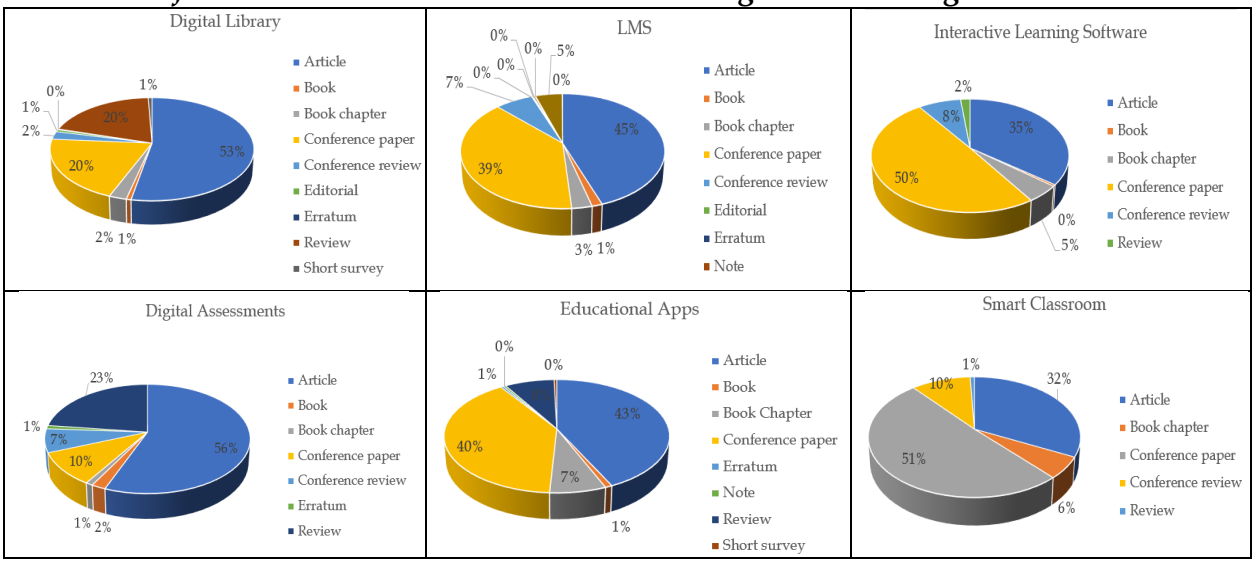


Figure 3. Document types

Figure 3 shows that the type of document that dominates in general for DL, LMS, DA, and EA is articles because technological conditions are developing rapidly, so many researchers are publishing their work in the form of articles (a publication site that is rapidly growing) (Horbach & Halffman, 2018). The article functions as a reference source for practitioners in education or other communities in the process of further technological development (Brundiers et al., 2021). Meanwhile, the document type of SC and ILS that dominates is conference paper because SC and ILS are relatively innovative in the world of education (Cebrián et al., 2020; Cress & Kalthoff, 2023). Conferences serve as a platform for researchers to present their innovative ideas, ensuring they have a broad and impactful influence on society in the realm of technological advancements. (Berchin et al., 2018).

Globally, 57% DT researchers are European, 19% from Asian and North American researchers, and one Australian researcher. European researchers especially Austrian, Greece, and Finland collaborated in EA and DA publications. In addition, Researchers from Spain and Ukraine focused on DL research. Sabitzer and Lavicza from Austria have made significant contribution who published EA and DA papers. Papadakis from Greece get highest citation in EA and Mikkonen from Finland in DA, and Martzoukou from UK in DL. Many EA publications highlighted that EA offer a new way to engage students in learning, particularly in preschool. Most apps in Europe are developed by commercial companies without considering students and teachers' pedagogical practices (Tazouti et al., 2024). So, it makes several European researchers developing EA that follows instruction, activity, task (DA), and sources (DL). DL in Europe significantly enhance lecturers' self-development, facilitate and access academic references (González et al., 2022). Offline libraries in several universities and educational institutions were closed during pandemic so government and lectures were developed website or DL (Aliyyah et al., 2024). According to Table 1, Asian researchers from Hong Kong and Indonesia focused on SC and DL publications. North American researchers such as Leyva from Mexico focused on ILS and three from US focused on SC and LMS research. Australian researcher focused on DA. In addition, four LMS researchers do not have affiliation.

Table 1. Top Influential Authors.

Type	Author	TD	TC	Affiliation	Country
ILS	Leyva Carrillo, A.	3	**11**	Universidad Autónoma de Baja California sur	Mexico
SC	Wong, B. T. M.	3	**24**	Open University of Hong Kong	Hong Kong
	Swindle, T.			University of Arkansas for Medical Sciences	US
	Li, K. C.			Open University of Hong Kong	Hong Kong
	Curran, G. M.			University of Arkansas for Medical Sciences	US
EA	Schmidthaler, E.	3	4	Johannes Kepler University	Austria
	Sabitzer, B.		4	Johannes Kepler University	Austria
	Papadakis, S.		**13**	University of Crete	Greece
	Lavicza, Z.		4	Johannes Kepler University	Austria
	Kalogiannakis, M.		13	University of Crete	Greece
DA	Sabitzer, B.	5	10	Johannes Kepler University	Austria
	Nielsen, W.	4	50	University of Wollongong	Australia

Type	Author	TD	TC	Affiliation	Country
LMS	Mikkonen, K.	5	**186**	University of Oulu	Finland
	Lavicza, Z.		12	Johannes Kepler University	Austria
	Crick, T.		110	Swansea University	UK
	Gonzalo, J. D.		125	Virginia Tech Carilion School of Medicine, Penn State College of Medicine	US
	Zace, D.		**144**		
	Yeung, J.	4	142	-	-
	Smyth, M. A		**144**		
	Semeraro, F.		**144**		
DL	Rosmansyah, Y.	4	9	Bandung Institute of Technology	Indonesia
	Putri, A.		6	Bandung Institute of Technology	Indonesia
	Martzoukou, K.		**128**	Robert Gordon University	UK
	Kolesnykova, T. O.	3	8	Ukrainian State University of Science and Technology	Ukraine
	Bote-Vericad, J. J.		9	Universitat de Barcelona	Spain

The Most Productive and Influential Sources in Digital Technologies Field

Table 2 lists the top productive sources in each DT field. There 24 sources participated in DT research including from Q1 to Q4 Scopus. Many DL and EA research paper published in Journal of Medical Internet Research, with highest citation of DL research at 232. DL, ILS, and EA research paper published in Computer and Education, with highest citation of ILS research at 231. ACM International Conference Proceedings Series dominated EA, ILS, and SC research and total 32 conference papers published. ILS and SC published in Research in Science and Technological Education. There eighteen papers published in Library Philosophy and Practice. which discontinued journal from University of Science and Technology Beijing since 2021.

Table 2. The productive sources

Q	Name Sources	*Type*	*SA*	*Publisher*	*F*	*TC*	*CPP*
Digital Libraries							
1	Journal of Medical Internet Research	J	M	JMIR Publication	9	**232***	25.78
Dis	Library Philosophy and Practice	J	SS	USTB	**18***	16	0.88
1	Computers and Education	J	CS, Ed	Elsevier	1	191	191
3	Journal of Library Science in China	J	SS	Editorial Office	9	32	3.56
2	Library Hi Tech	J	SS, CS	Emerald Group Publishing	8	26	3.25
LMS							
1	International Journal of Information Management	J	BMA, CS, DS, SS	Elsevier	2	**1456***	728
	ASEE Annual Conference and Exposition	C	CS		**39***	46	1.18
1	International Journal of Production Research	J	BMA, DS, E	Taylor and Francis	1	257	257
	CEUR Workshop Proceedings	C	CS		37	167	4.51

Q	Name Sources	*Type*	*SA*	*Publisher*	*F*	*TC*	*CPP*
4	Journal of Physics: Conference Series	C	PA	IOP Publishing	33	86	2.60
			Digital Assessments				
	AIP Conference Proceedings	C	PA	AIP	4	0	
	E3S Web of Conferences	C	En, ES	EDP Sciences	4	0	
4	Lecture Notes in Network and Systems	B	CS, E	Springer	4	0	
1	Journal of Computers in Education	J	CS, SC	Springer	1	**17***	17
1	Nature Reviews Nephrology	J	M	Nature Publishing	1	5	5
			Educational Apps				
1	Cyberpsychology, Behavior, and Social Networking	J	CS, SS, M, P	Mary Ann Liebert	1	140	140
1	Journal of Medical Internet Research	J	M	JMIR Publication	4	81	20.25
	Sustainability				5	**197***	39.4
1	Computers and Education	J	CS, E	Elsevier	3	56	18.66
	ACM International Conference Proceeding Series	C	CS	ACM	**7***	6	0.86
			Smart Classroom				
	ACM International Conference Proceeding Series	C	CS	ACM	**11***	18	1.64
2	Research in Science and Technological Education	J	SS	Taylor and Francis	1	**37***	37
	Academic Medicine				1	32	32
1	Procedia Computer Science	J	M, SS	Lippincott and Williams and Wilkins	3	27	9
2	Computer Applications in Engineering Education	J	CS, E, SS	John Wiley and Sons	2	33	16.5
			Interactive Learning Software				
	ACM International Conference Proceeding Series	C	CS	ACM	**10***	17	1.7
1	International Journal of Educational Technology in Higher Education	J	CS, SS	Springer	1	72	72
2	Journal of Applied Research in Higher Education	J	SS	Emerald Group Publishing	1	32	32
1	Computer and Education	J	CS, E	Elsevier	2	**231***	115.5
2	Research in Science and Technological Education	J	SS	Taylor and Francis	2	39	19.5

Note: J: Journal; C: Conference; B: Book series; M: Medicine; SS: Social sciences; BMA: Businees, Management and Accounting; DS: Decision Sciences; E: Engineering; Ed: Education; PA: Physics and Astronomy; P: Psychology; En: Energy; ES: Environmental Science.

The Most Productive and Influential Institution and Countries in Digital Technology Field

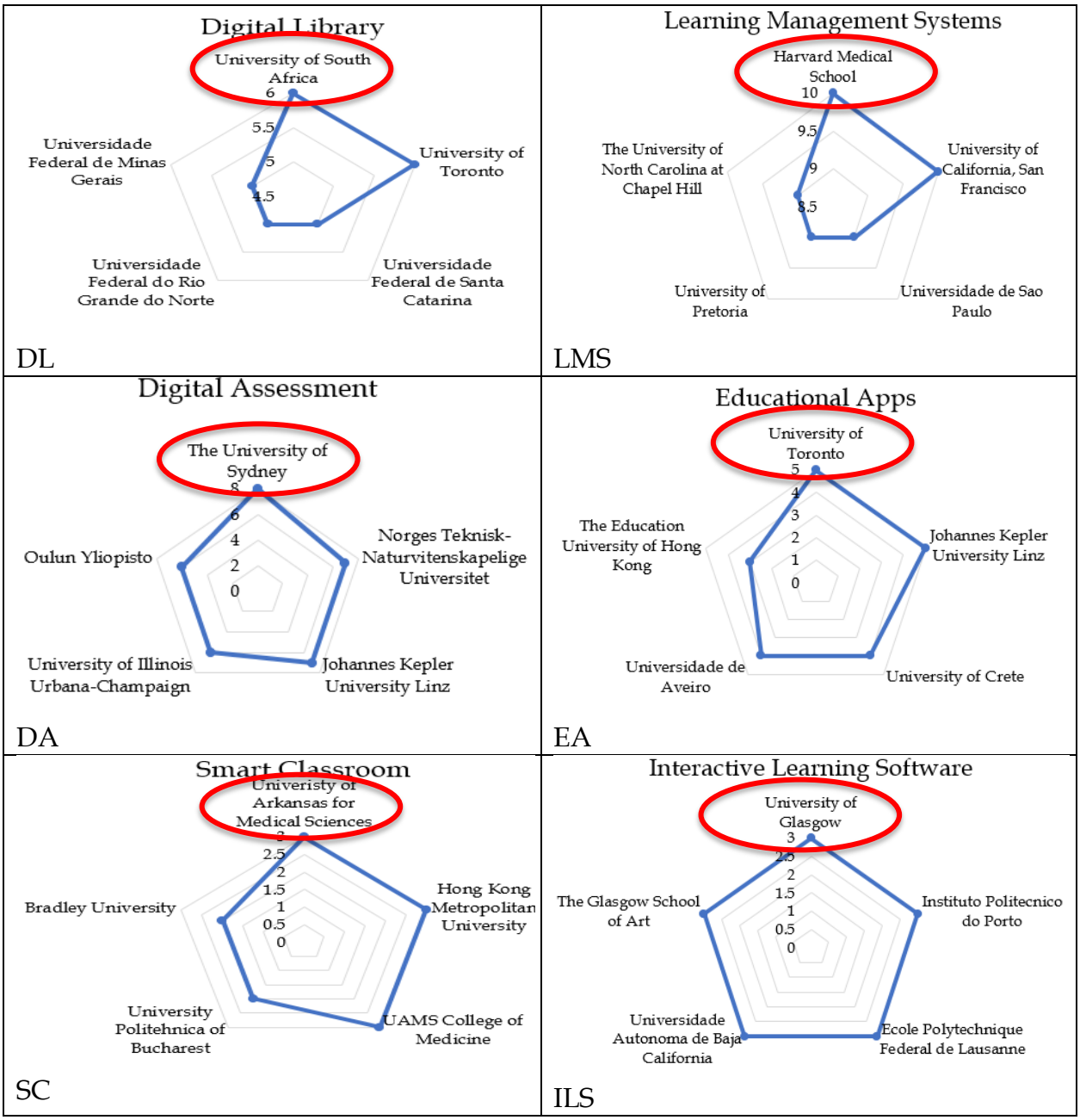


Figure 4. The most productive and influential institution

According to Figure 4, research on DL is led by South African Universities which have a commitment to distance education and significant resource allocation for such research (Lembani et al., 2020). The LMS is mastered by Harvard Medical School with supporting facilities such as educational technology laboratories and innovation centers (McDaniel et al., 2021). The University of Sydney dominates DA research because of its digital evaluation laboratory facilities and study programs related (Marks & Thomas, 2022). While the University of Arkansas for Medical Sciences dominates SC research due to its excellence in the health sector (Norton et al., 2023). The University of Glasgow excels in ILS due to its large investment in the development of interactive technology and the expertise of its faculty in the field (Awaji, 2021).

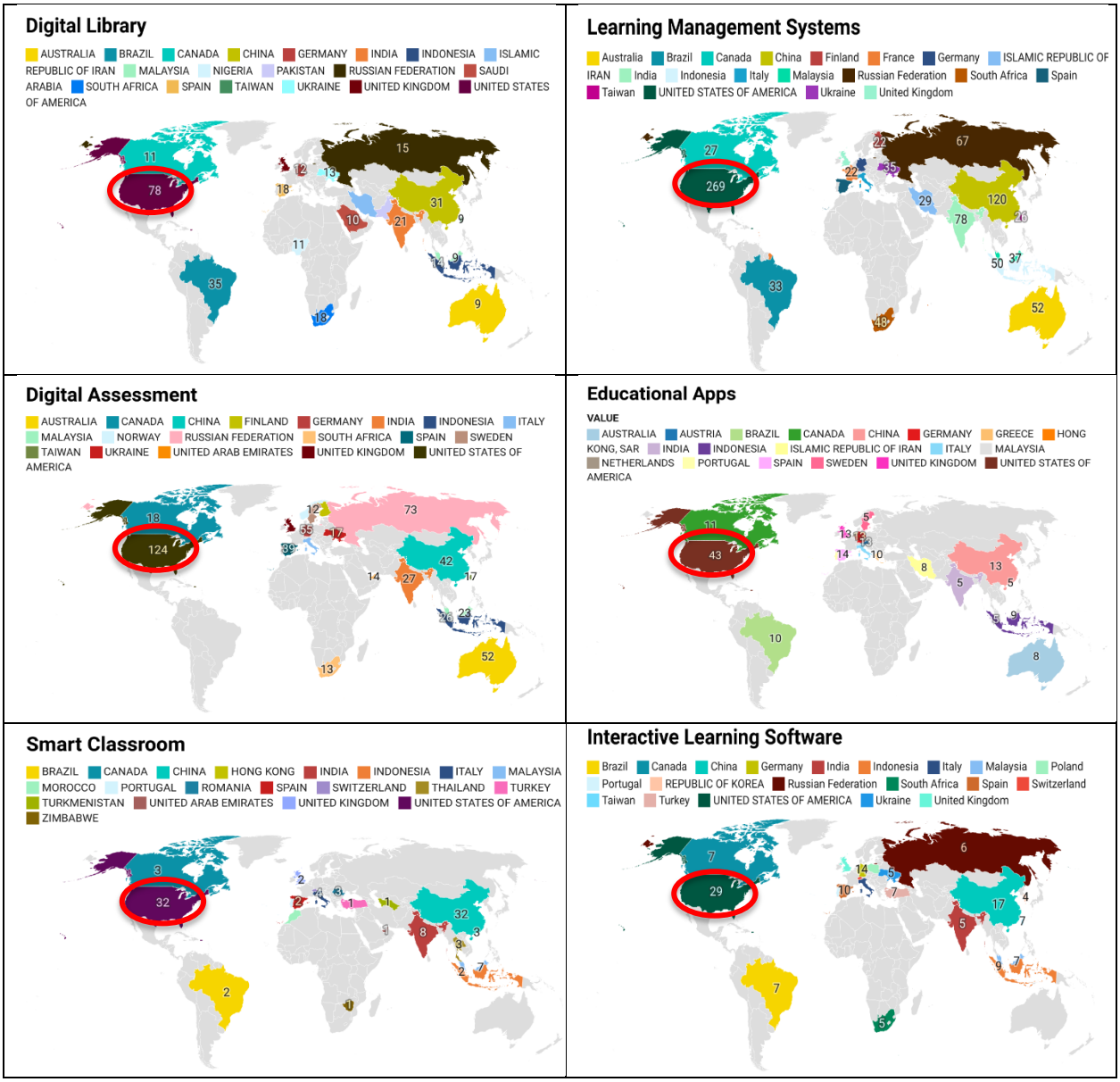


Figure 5. The most productive countries in the field of digital technology research

Based on Figure 5, it shows that the USA is the first top country that contributes highly to the six keywords in this research. This is because the United States excels in educational technology research with various major facilities (Schoeneberger et al., 2020). Harvard Graduate School of Education, for example, focuses on developing educational applications and learning management systems (Ameli, 2020). Additionally, universities such as Stanford and MIT have Digital Evaluation Labs to test educational technologies, including DA (Dede & Lidwell, 2023; Hernandez-de-Menendez & Morales-Menendez, 2019). The University of California, Berkeley, for example, the Center for Educational Technology Innovation, supports the development and implementation of new technologies (Zhong & Zheng, 2022). The United States also has Testing and Implementation Facilities, such as SC at Columbia University and the University of Illinois at Urbana-Champaign (Smith, 2018). This combination of facilities allows the United States to lead research on topics such as DL, LMS, DA, EA, SC, and ILS.

Social Interaction between Countries

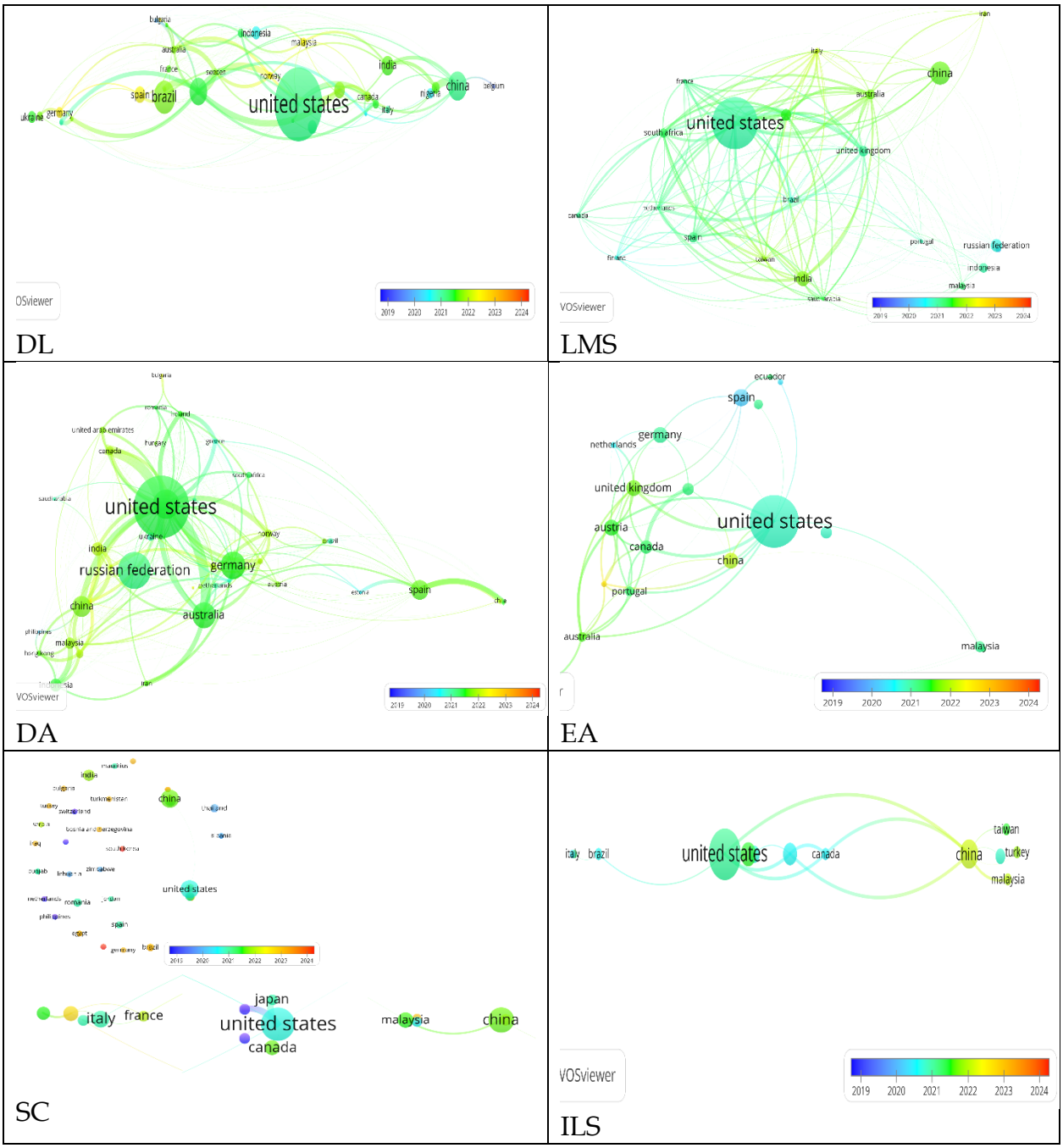


Figure 6. Visualization the most productive country in the field of digital technology research

Apart from visualization in map form as shown in Figure 5, Figure 6 is the result of metadata visualization using VOSviewer. Based on Figure 6, shows that the most productive country (high contribution) to the six research topics is the United States of America. This is shown by the presence of large nodes which indicate the level of contribution of a country (Peng & Dai, 2020). The larger the node displayed by VOSviewer, the greater the country's contribution to the research topic.

Most Frequent Terms in Digital Technologies

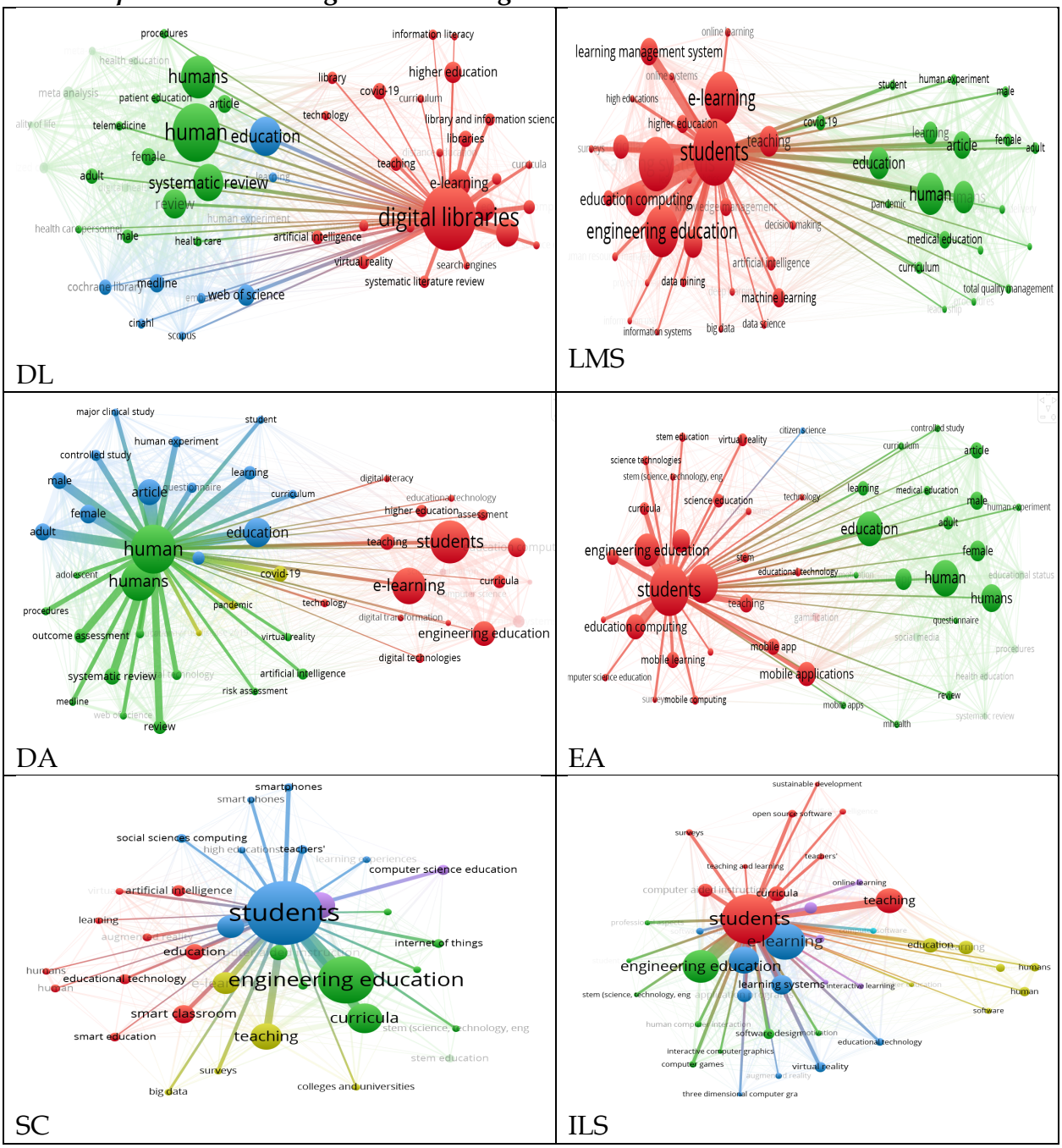


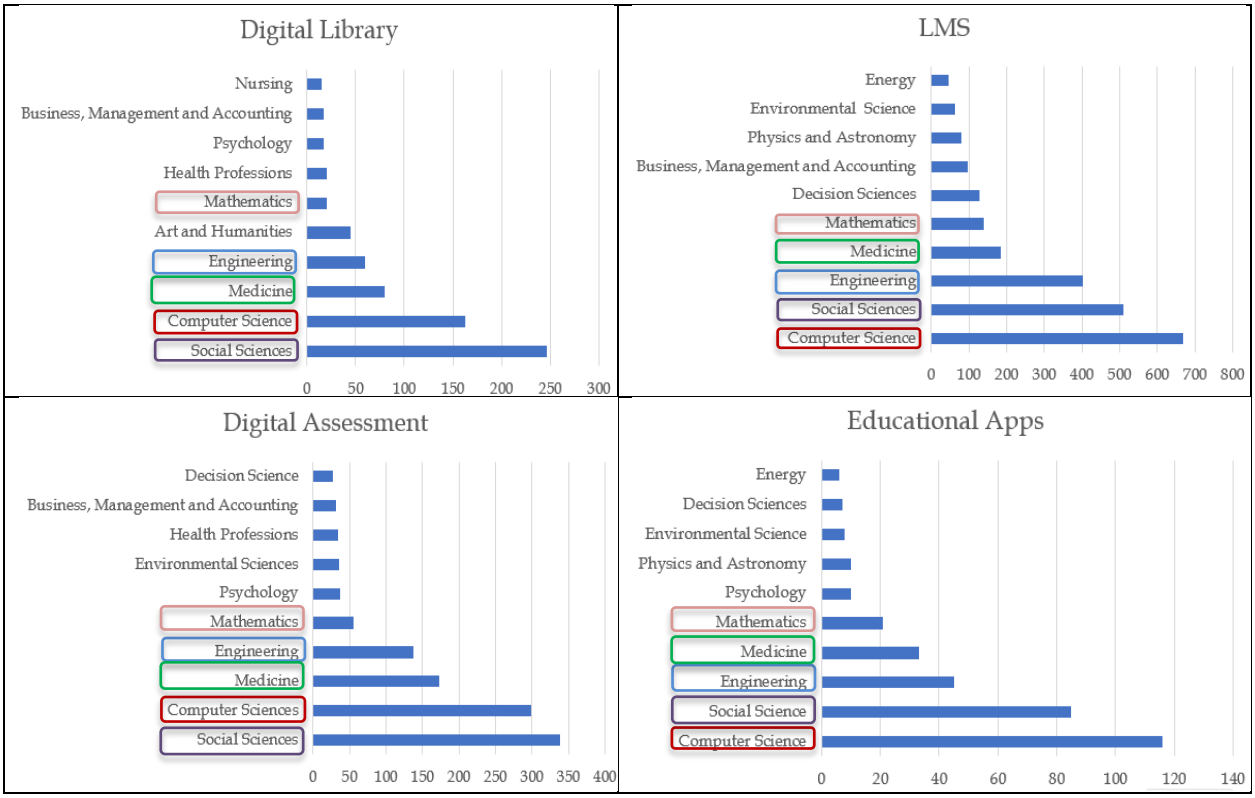
Figure 7. Visualization the most frequent terms in digital technologies

Figure 7 shows that in research on DL, the dominant keywords are digital libraries and human. They are closely related to concepts such as e-learning, education, and systematic reviews (Rouleau et al., 2019; Shvets et al., 2020). This relationship can be seen from the distance and thickness of the lines connecting them to "digital libraries" (Oyewola & Dada, 2022). In LMS research, the dominant keyword is "students", which is also closely related to e-learning, education, and educational engineering (Pham et al., 2022). Just as before, this relationship is indicated by the thickness of the lines connecting "students" with other keywords. For DA, the main keywords are education, article, students, and e-learning. This relationship is also shown through the distance and thickness of the lines.

In EA, the main focus is on "students", which is related to engineering education, educational computing, and mobile applications (Nami, 2020). The SC is dominated by "students", who are closely connected to engineering education, the Internet of things, curriculum, and artificial intelligence. Lastly, ILS is also led by "students", which is related to e-learning, education, and learning systems (Rajan & Pandit, 2022).

Trending Topics of Digital Technologies in Science Education

Figure 8 displays fields related to educational science research. Figure 9 data shows five fields overlapping with the six keywords: mathematics, engineering, medicine, computer science, and social sciences. These subjects significantly contribute to science education research. Mathematics provides a foundational understanding of scientific concepts. Engineering and computer science offer practical ways to use educational technology (Alam, 2022; Wu & Rau, 2019). Medicine contributes knowledge about human learning and its medical applications in science education (Radanović & Likić, 2018). Social sciences offer insights into psychological and social factors influencing science learning (Miller, 2019). These fields collectively enrich educational science, integrating multidisciplinary approaches and understanding human learning processes.



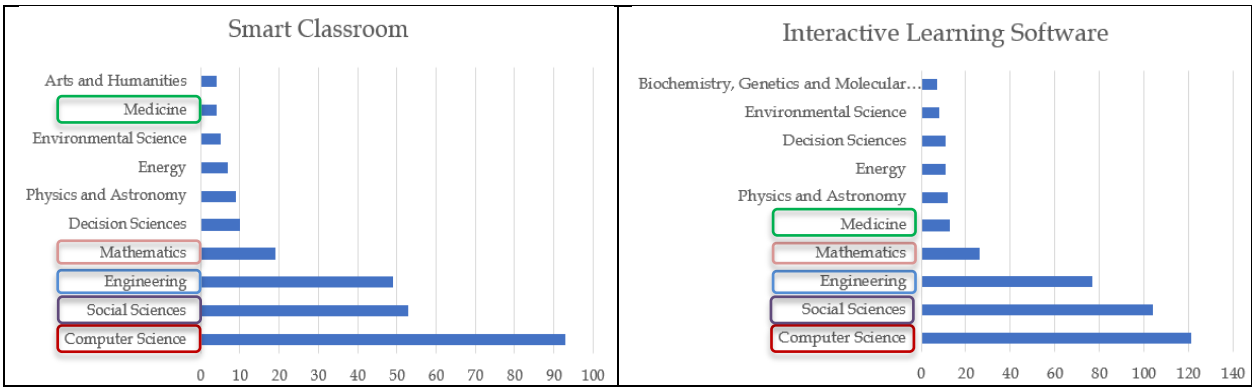


Figure 8. Trending topics of digital technologies in science education

CONCLUSION

Fundamental Finding: LMS and EA were the most common publications in the last five years, with 230 documents. SC publications were the lowest. DL and LMS publications increased significantly, while DA publications decreased. LMS publications received the highest average citations, peaking in 2020. Articles dominate DL, LMS, DA, and EA, while conference papers dominate SC and ILS. 57% of DT researchers are European, with 19% from Asia and North America. European researchers from Austria, Greece, and Finland collaborate on EA and DA publications. Asian researchers focus on SC and DL publications, while North American researchers focus on ILS, SC, and LMS research. Twenty-four sources are involved: The Journal of Medical Internet Research publishes numerous DL and EA research papers; Computer and Education has the highest citation rate for ILS research; ACM International Conference Proceedings Series dominates EA, ILS, and SC research. South African universities lead research on distance education, Harvard University excels in LMS, The University of Sydney dominates DA research, The University of Arkansas excels in SC research, and The University of Glasgow excels in ILS. The USA is the top productive country in DL, LMS, DA, EA, SC, and ILS research due to extensive facilities at Harvard University, Stanford University, MIT, and the University of California, Berkeley. **Implication:** Librarians, educators, researchers, digital developers, and policymakers will get insight from an overview of the latest research trend for DT in science education. **Limitation:** However, it is essential to recognize the limitations of relying solely on Scopus databases, as they may only partially capture the breadth of research contributions, mainly from non-indexed sources and publications in languages other than English. **Future Research:** Further research can be developed based on the scope of mathematics or physics education, investigating specific skills or STEAM, and combining it with other databases like Web of Science.

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