sustainability

MDPI

Article

Mapping Knowledge Domain Analysis in Smart Education Research

Xing-Rong Guo [1,*], Xiang Li [1] and Yi-Ming Guo [2]

[1] College of Foreign Languages, Shanghai Maritime University, Shanghai 201306, China; 202030810016@stu.shmtu.edu.cn
[2] School of Economics and Management, Shanghai Maritime University, Shanghai 201306, China; ymguo@shmtu.edu.cn
* Correspondence: xmguo@shmtu.edu.cn

Abstract: Smart education is considered an inevitable choice and an important educational trend development in the Information Age. Smart education development can promote learning opportunities to master high-quality education and lifelong learning. It vigorously promotes sustainable development. A bibliometric analysis was performed to better understand smart education research field knowledge structures and help researchers understand smart education research field characteristics. VOSviewer and CiteSpace were used to analyze 2358 Web of Science core collection articles related to smart education. The articles were dated 2000–2021. This study visually presents a systematic overview of smart education literature research, including the publication outputs, main categories, most influential countries, organizations, journals, and authors, important documents, and research academic trends. Using a series of cooperation analyses, this paper looked at research cooperation among countries and regions, organizations, and authors to build a smart education knowledge structure map. A smart education theoretical framework was proposed based on the literature review. A bibliometric analysis of the existing research results provided useful and innovative suggestions for researchers and practitioners in the field of smart education.

Keywords: smart education; mapping knowledge domain; bibliometric analysis; VOSviewer; CiteSpace

Citation: Guo, X.-R.; Li, X.; Guo, Y.-M. Mapping Knowledge Domain Analysis in Smart Education Research. *Sustainability* **2021**, *13*, 13234. https://doi.org/10.3390/su132313234

Academic Editors: Changhyun Roh and Grigorios L. Kyriakopoulos

Received: 30 September 2021
Accepted: 23 November 2021
Published: 29 November 2021

1. Introduction

The United Nations Sustainable Development Goals 2015–2030 (SDG) proposed seventeen key sustainable development goals. One of the main goals (Goal 4) emphasized "Quality Education-Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [1]. Smart education can help achieve high-quality education for all staff in all regions. It can promote the effective implementation and completion of Sustainable Development Goal 4. Education for sustainable development was defined as "develops and strengthens the capacity of individuals, groups, communities, organizations and countries to make judgements and choices in favor of sustainable development" [2].

Backed by modern technology and adhering to an educational philosophy of innovation, intelligence, and openness, smart education has attracted more and more attention and recognition from the global education community. The fast development of technology is reshaping education [3]. Smart education research has developed rapidly to change educational systems. More students, educators, and managers can participate in and pay attention to it more effectively [3]. It has also garnered great interest from many researchers and educational design practitioners. Obtaining a clear overview of smart education in the vast information background is critical.

What is smart education? Many researchers have defined smart education [4–7]. Some conducted a theoretical analysis of smart education and summarized the definitions appearing in the literature [6]. Some stated that "smart education environment incorporates different information and communication technologies active learning process and adjust

to the requirements of different students" [8]. The International Association of Smart Learning Environments (IASLE) defines "smart learning" as "an emerging area alongside other related emerging areas such as smart technology, smart teaching, smart education, smart e-learning, smart classrooms, smart universities, smart society [5]. A research framework for smart education was proposed [7]. In Section 5.1, a definition of smart education will be detailed. A theoretical model for smart education will be presented in Section 5.2.

Implementing smart education needs to occur as an aspect of the educational environment, educational resources, educational management, and educational services. Of these, the educational environment, as an external condition, plays an important role in supporting smart education development. Building a smart learning environment (SLE) is a core task of developing smart education. SLEs have several characteristics, such as being "effective, efficient and engaging" [9,10]. SLEs have been defined as ecosystems integrating technology and pedagogy, providing real-time changes in knowledge and technology. When learners migrate from one learning environment to another, their knowledge and skills are seamlessly absorbed [11]. SLEs are also described as "physical environments that are enriched with digital, context-aware and adaptive devices, to promote better and faster learning" [12]. Three potential criteria for SLEs have been examined [13].

Recently, smart education has attracted more and more attention in contemporary academia. Over the long run, in the academic field, "smart education" has referred to a variety of education activities, including participation, intelligence, and scalability [5,7]. Smart education can bring personalized and customized knowledge services. This provides examinees with situational awareness, deductive reasoning, logical awareness, and adaptivity. It can provide accurate sensing, remote monitoring, self and team interactive learning activities, collaborative practices facilitating a self-confident attitude, and instant assessment and feedback. Learners can participate in the process of learning as a pleasant, effective, positive, and resourceful education environment. The relationships between these smart features are connected and meaningful, including "(1) software, (2) hardware, (3) technologies, (4) classrooms, (5) campus, (6) university, (7) pedagogy, and (8) stakeholders, and main gears, i.e., (1) deducing logical reasons, (2) effective adaption, (3) precise sensing, (4) remote monitoring, (5) self-learning, (6) team-based learning, (7) logical awareness, and (8) self-organization in a confident manner" [5]. This conclusion is comprehensive. Smart education research has developed rapidly to change the educational system [6].

In summation, smart education has become a "hot" global educational concept in recent years. The essential aspect of smart education is to improve the intelligence of the current education system and realize the intelligence of education-related management ideas, teaching resources, the surrounding environment, service support, and other elements. Finally, it involves forming an integrated, open, flexible, and smart education system. The birth and development of smart education is closely related to the current rapid development of information technology. Smart technology development promotes the emergence of smart education, such as these areas of science and technology: "cloud computing, learning analysis, big data, the Internet of things (IOT), wearable technology", and other intelligent technologies [7]. Education 4.0 has built a creative and innovative era [14]. More and more educators, teachers, students, and others closely related to education are deeply aware of the benefits of Education 4.0 and intend to implement Education 4.0 in many disciplines [15]. Education 4.0 aims to provide a new perspective on teaching and learning methods and facilitate accommodation with the latest emerging technologies so that students can deal with current and future problems [16]. Due to the technological promotion of Education (4.0), the smart education system has undergone fundamental changes [17].

2. Literature Review on the Bibliometric Analysis

With the integration of intelligent information technology such as Internet Plus, big data, cloud computing, and the IoT, smart education hot topics and frontiers are also evolv-

ing. Effectively grasping the evolutionary path, hot spots, and frontiers of smart education research is one key to carrying out relevant research. The study of a large number of documents, which is the traditional literature review method, is time-consuming, resulting in a slow research process. Important documents may be missed due to incomplete retrieval. This reduces research accuracy.

Bibliometric analysis is used to judge research trends in a large number of documents. It analyzes various elements of academic publications with the help of statistical analysis. The number of articles published or cited and the cooperation involved reveals how an article affects subsequent research [18]. Bibliometric analysis is "the statistical analysis of books, articles or other publications to measure the output of individuals/research teams, institutions and countries, to identify national and international networks" and draw a development map of new multidisciplinary science and technology fields [19,20].

Bibliometrics is an important research field of information and library science which is widely used [21]. Quantitative methods analyze bibliographic data such as the publication year, publication number, citation number, authors, journals, countries, organizations, and keywords [21–24]. Bibliometric analysis can classify groups of bibliographic documents and provide a descriptive overview [21]. Bibliometric software draws scientific literature maps to supplement the limitations of traditional structured literature reviews. This has several advantages, in that it can (1) provide further extensive research and analysis [25]; (2) provide a wider perspective through analytical coverage and literature review depth [26]; and (3) analyze various journals with different research topics to explore and understand specific research fields and research trends in the past few years [24]. Its most valuable feature is that its output is "quantity". An analysis of the total number of citations of a particular publication can reflect a publication's quality and impact.

Presently, some scientific software has been used for bibliometric analysis, such as CiteSpace and VOSviewer. These have features that display the evolutionary process of the field with a knowledge map of the citation network through a spatial layout in a diversified, time-sharing, and dynamic citation analysis visual method.

This study uses bibliometric analysis to retrieve the smart education field's core literature in the core collection of the Web of Science (WoS) database for the last 20 years. This study aims to analyze the academic status and research hotspots in the smart education research field. Through the analysis of a visual atlas, it will investigate and analyze smart education research's evolutionary paths, hot spots, and frontiers. This provides a reference for researchers on related topics.

Smart education bibliometric analysis requires attention to some questions, such as "What is the distribution of smart education research in the WoS core database"? There are few studies of smart education literature co-citation and keyword co-occurrence analysis. This study attempts to capture the overall smart education research picture and explore its frontiers and knowledge bases. It investigates research hotspots using keyword co-occurrence. It systematically collects, describes, analyzes, and summarizes research papers related to smart education using bibliometric analysis methods. A knowledge domain was mapped using VOSviewer and CiteSpace. The goal was to provide useful guidance for scholars and teachers interested in smart education and provide references for those seeking cooperation opportunities with other scholars or research institutions.

This paper mainly discusses the following research questions:

Q1. What are the publication and citation trends in research related to smart education?

Q2. What are the publication categories?

Q3. Which countries, regions, organizations, and co-authors have actively collaborated in smart education research and are more influential than others?

Q4. What are the journals and references cited most often in smart education research?

Q5. What are the hot research topics and emerging trends in smart education research?

3. Methodology

3.1. Data Source and Processing

The data were retrieved from the WoS core collection on 31 July 2021. The term "smart education" was searched for in the topic field, so articles in which "smart education" appeared in either the title, abstract, or keywords were collected. A literature search of articles published before 2000 rarely returned smart education. The literature published before 2000 appears to have little correlation with smart education. The research on smart education began in 2003 in China [27]. Therefore, the time span implemented was from 2000 to 2021.

3.2. Analytical Methods and Tools

Knowledge mapping, also called knowledge domain mapping in the library and information disciplines, is a series of different graphs showing relationships between knowledge development processes and structures. Researchers use visualization technology to describe knowledge resources and their carriers. It is used to mine, analyze, construct, draw, and display knowledge and the relationships between them [28]. Visualization maps can show relationship maps between documents related to a certain subject. It can show the relationship and development of knowledge and find what may be hidden in the statistical data [29,30].

Two pieces of software were used in this study to conduct bibliometric analysis: CiteSpace and VOSviewer. CiteSpace is a Java-based program developed by Dr. Chen Chaomei [31]. CiteSpace was present to remove duplicated papers. CiteSpace was used to generate knowledge maps, including maps of references with the strongest citation bursts, keywords with the strongest citation bursts, and keyword clusters. VOSviewer, a visualization tool developed by Eck and Waltman, is widely used [32]. In this study, VOSviewer generated visualization network maps, such as visualization network maps of co-authorship, countries and regions, organizations, journals, and keywords.

In the visualization network map, clusters were generated to provide better network structural views [30]. Each unit was represented as a node. A node could be a journal, category, author, article, or keyword. The node size was proportional to the centrality calculated by CiteSpace or VOSviewer. The distance between two nodes was directly proportional to their correlation. The links between two nodes represented a direct co-occurrence or co-citation relationship. The link strengths were directly proportional to the co-occurrence or co-citation frequency. This study created a map to display only the largest nodes and the strongest links. Strong correlation nodes were divided into a cluster. Each cluster was color coded. The nodes in the same cluster were highly homogeneous, and the nodes in different clusters were heterogeneous. The technical roadmap of this study appears in Figure 1.

In stage 1, the key term "smart education" was searched in WoS. WoS is the largest database of scientific publications in the world [33]. Here, 2358 documents were collected. There were 1096 publications in the SCIE index, 934 in the SSCI index, 811 in the ESCI index, and 23 in the A&HCI index. Some publications appeared in both indexes.

In stage 2, 2358 documents were analyzed by CiteSpace [31] and VOSviewer [32]. This included publication growth trend analysis, category analysis, co-authorship analysis, country or region cooperation analysis, co-citation journal analysis, cited references analysis, co-keyword and keyword citation burst analysis, and emerging trend analysis. Based on this bibliometric analysis, an integrated knowledge map of smart education was constructed to illustrate smart education research's evolution.

In stage 3, a research framework of smart education was constructed based on the bibliometric review of significant works.

In stage 4, future research directions were examined, and conclusions were made.

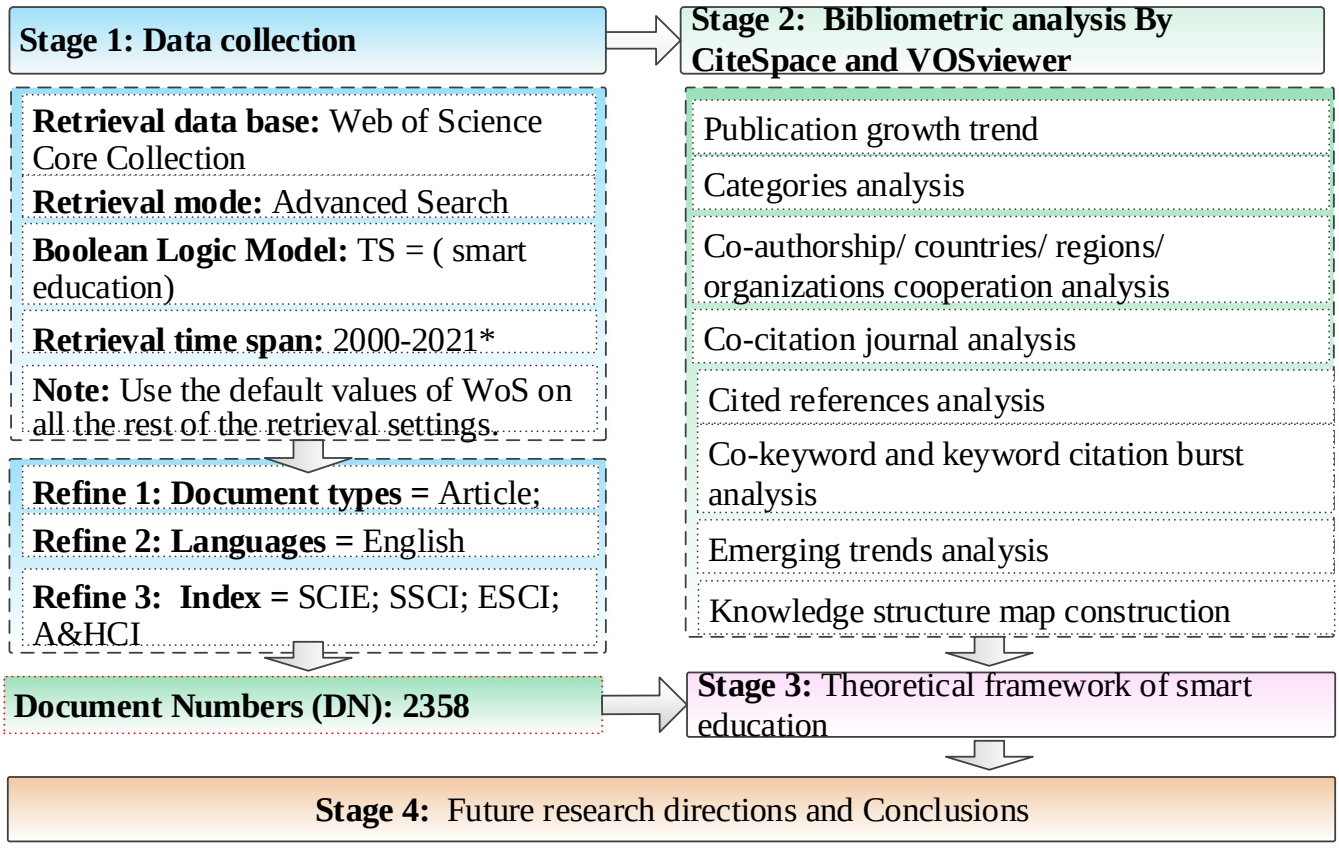

Figure 1. This study's technical roadmap. Note: * = the data collection time in WoS was 31 July 2021.

4. Results

4.1. Publication Growth Trend and Category Analysis

A statistical analysis of the number of publications revealed development trends in scientific research on a topic. The citation frequency is an important standard for academic circles to evaluate the quality of publications. Figure 2 shows the number of published and cited articles in smart education over time.

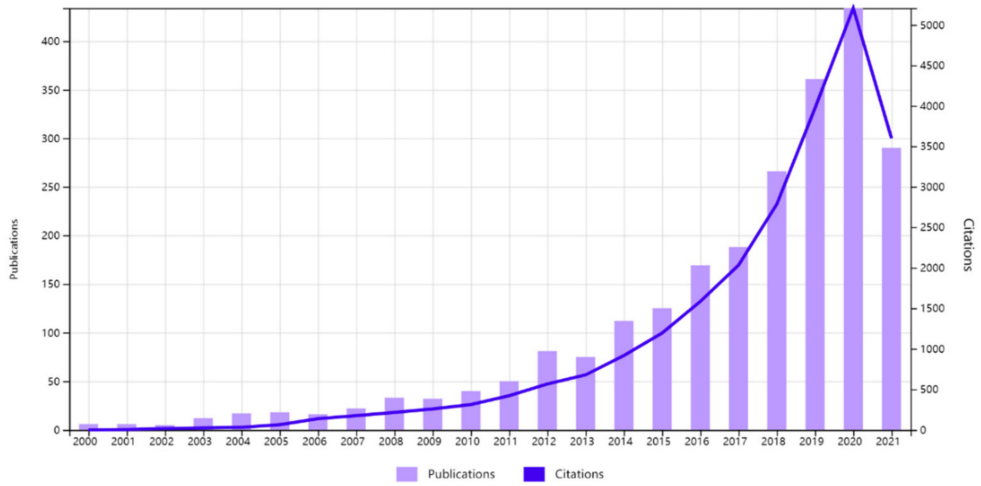

Figure 2. The number of annual publications and citations related to research on smart education from 2000 to 2021 (downloaded from WoS).

Figure 2 shows the yearly trends in publications and citations on the topic of "smart education". There were 2358 publications with 22,551 cited articles. Apart from self-citing

articles, there were 22,172 in all. These articles were cited 24,189 times and 23,593 times without self-citations. In terms of annual productivity, six articles were available in both 2000 and 2001 and five in 2002. For the period of 2003-2006, on average, 16 papers were published every year. Twenty-two articles were published in 2007, 33 in 2008, 32 in 2009, 40 in 2010, 50 in 2011, 81 in 2012, and 75 in 2013. In 2014, the number of articles jumped to 112. In 2015, 125 articles were published, 169 in 2016, 188 in 2017, 266 in 2018, 361 in 2019, 434 in 2020, and 290 by July 31, 2021. In 2020, the number of publications peaked at 434. The trends showed research on "smart education" to be a growing topic. More papers are expected to be released in 2021 than in 2020. The number of publications and citations increased year by year. Publications were cited more than 100 times since 2006. For example, there were 138 in 2006, 175 in 2007, 215 in 2008, 258 in 2009, 312 in 2010, 421 in 2011, 566 in 2012, 678 in 2013, and 916 in 2014. The publications cited were more than 1000 since 2015. For instance, there were 1194 in 2015, 1583 in 2016, 2031 in 2017, 2784 in 2018, 3973 in 2019, 5207 in 2020, and 3598 in 2021.

There was little research on smart education before 2003, and it was sporadic for the period of 2000–2010. Up to 2013, the number did not exceed 100 annually. A steady increase began after 2014 and soared after 2019. The number of papers and citations related to smart education is increasing year by year. One reason for this may be because countries are adapting to the problems brought about by the development of information technology in life and education.

The 2358 articles were subdivided into 194 categories. The top 10 categories appear in Table 1.

Table 1. The top 10 categories.

Rank	WoS Categories	Number	Proportions
1	Education Educational Research	460	19.508
2	Computer Science Information Systems	165	6.997
3	Engineering Electrical Electronic	160	6.785
4	Education Scientific Disciplines	135	5.725
5	Public Environmental Occupational Health	115	4.877
6	Environmental Sciences	112	4.75
7	Telecommunications	110	4.665
8	Engineering Multidisciplinary	104	4.411
9	Environmental Studies	90	3.817
10	Green Sustainable Science Technology	87	3.69

The category "education educational research" was the main category with 460 related papers, equivalent to 19.51% of the total. The second category with the most related papers was "Computer Science Information Systems" with 165 papers, followed by "Engineering Electrical Electronic" with 160 papers. It is worth mentioning that a paper could belong to different categories, which may have affected some or all of the statistics.

In the last 20 years, interdisciplinary research has become very popular. Cooperative learning has become a trend in scientific research. Multidisciplinary researchers work together to promote the research and development of smart education.

4.2. Co-Authorship Analysis

International cooperation has received more and more attention in the field of scientific research, and many researchers have used bibliometric methods to investigate international collaboration [34]. VOSviewer analyzes cooperative relationships between countries, institutions, and authors [32]. Co-authorship is an important indicator of collaboration [35]. Scientific cooperation means that researchers collaborate in the common purpose of attempting to produce new scientific knowledge. A co-authorship function was used by VOSviewer to detect cooperation relationships among authors, organizations, and countries. A total of 8235 authors contributed to 2358 publications related to smart education. Figure 3 shows the cooperative relationships among smart education research

field collaborators. If individual authors used different names in their papers, there was a merger only if the ORCID was identical [33,36,37].

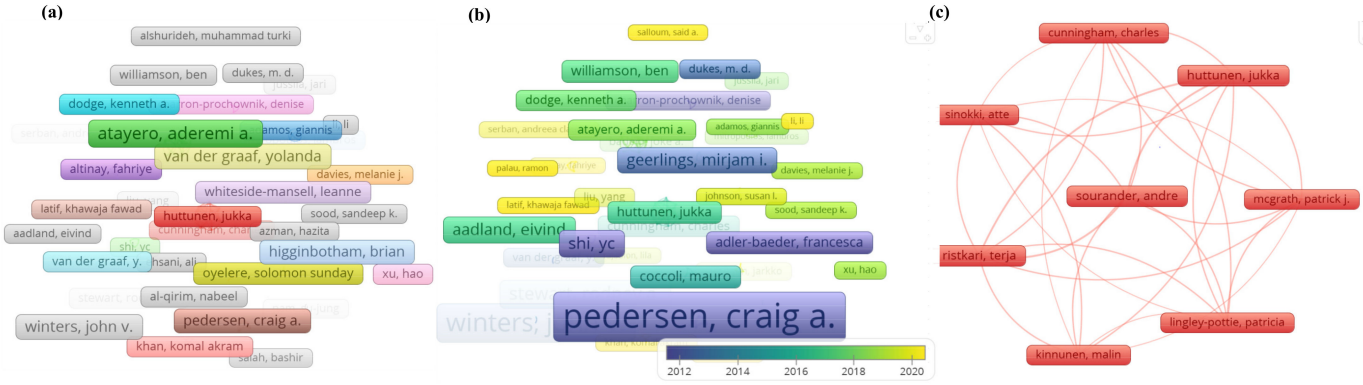

Figure 3. Co-authorship visualization network. (**a**) Network visualization map (document weights). (**b**) Overlay visualization network map (citations weights). (**c**) Visualization network of the largest academic circle (document weights).

Eighty-seven authors met the threshold when the value was set to 3 (1.06%), 33 authors published 4 papers related to smart education (0.4%), and 7 authors published 6 smart education papers. A co-authorship network map was created by setting the value to three. Eighty-seven items appeared in the network (Figure 3a). The overlay visualization network is illustrated in Figure 3b. The largest academic circle in the network consisted of eight authors (Figure 3c). The total strength of the co-authorship links between each of the 87 authors and other authors was calculated.

In Figure 3a, the collaboration clusters appear in different colors. The 87 items were linked by 96 links with 301 total link strengths. The major academic relationships and researchers can be viewed in these clusters. In cooperative networks, the frame size represents the number of papers published by an author. The predominant researchers were Atayero, Aderemi A.; Van Der Graaf, Yolanda; Winters, John V.; Pedersen, Craig A.; Scheckelhoff, Douglas J.; Schneider, Philip J.; Higginbotham, Brian; Badejo, Joke A.; Odukoya, Jonathan A.; and Omole, David O.

In Figure 3b, the author overlay visualization network displays different colors indicating the citations over time. Some authors appeared much more, such as Pedersen, Craig A.; Scheckelhoff, Douglas J.; Schneider, Philip J.; Winters, John V.; Stewart, Rodney A.; Shi, YC; Xie, Wk; Xu, GY; Aadland, Eivind; and Moe, Vegard Fusche. Recently, some authors published some new works about smart education, such as Alshurideh, Muhammad Turki; Salloum, Said A.; Khan, Komal Akram; Qazi, Wasim; and Grencikova, Adriana.

Figure 3c shows the largest academic community composed of eight authors in this field, indicating that scientists' collaborative research could effectively promote the in-depth research of scientific issues and optimize the implementation of smart education. The largest co-author community included 8 authors, each of whom had about 3-4 papers, and the foremost publication year was 2016, with authors such as Huttunen, Jukka; Ristkari, Terja; Sourander, Andre; Cunningham, Charles; Kinnunen, Malin; Lingley-Pottie, Patricia; Mcgrath, Patrick J.; and Sinokki, Atte.

Prolific authors and their cooperating authors have made great contributions to the research field of smart education and jointly promoted this research field. Table 2 lists the top 10 most prolific authors (by VOSviewer).

Table 2. The top 10 most prolific authors.

Rank	Author	Links	TS [a]	Documents	Citations	APY [b]
1	Atayero, Aderemi A.	6	28	9	70	2018
2	Winters, John V.	1	3	9	308	2013
3	Higginbotham, Brian	2	5	6	92	2015
4	Oyelere, Solomon Sunday	2	6	6	12	2020
5	Odukoya, Jonathan A.	6	24	5	51	2018
6	Omole, David O.	6	24	5	51	2018
7	Popoola, Segun I.	5	16	5	23	2018
8	Khan, Komal Akram	2	6	4	18	2021
9	Altinay, Fahriye	2	8	4	1	2020
10	Dagli, Gokmen	2	8	4	1	2020

Note: [a] TS = total link strength; [b] APY = average publication year.

Atayero, Aderemi A. and his co-authors published nine articles related to smart education, with most related to smart campuses. As the first author, Atayero, Aderemi A. published two papers on smart education. Winters, John V. and his co-authors published nine papers related to smart education. As the first author, he published six papers. His paper "Why are smart cities growing? Who moves and who stays" has been cited 154 times [38]. Higginbotham, Brian and his co-authors focused on investigating the Smart Steps program's effects in stepfamily education. Oyelere, Solomon Sunday and his co-authors published six papers related to smart education. Three of those six are on smart learning environmental factors. Odukoya, Jonathan A.; Omole, David O.; and Popoola, Segun I. cooperated closely in publishing on smart education as co-authors. Altinay, Fahriye and Dagli, Gokmen co-authored four publications related to smart universities and society. As can be seen from Table 2, in the past decade, the top 10 prolific authors collaborated closely. To some extent, this shows that the research on smart education is booming.

4.3. Country and Region Cooperation Analysis

The countries and regions, based on the co-authorship network visualization map, were generated by VOSviewer. The "minimum number of documents of a country" was set at 10. Of the 123 countries, 55 met the thresholds and are displayed on the visualization map (Figure 4). The countries with the greatest total link strengths are displayed.

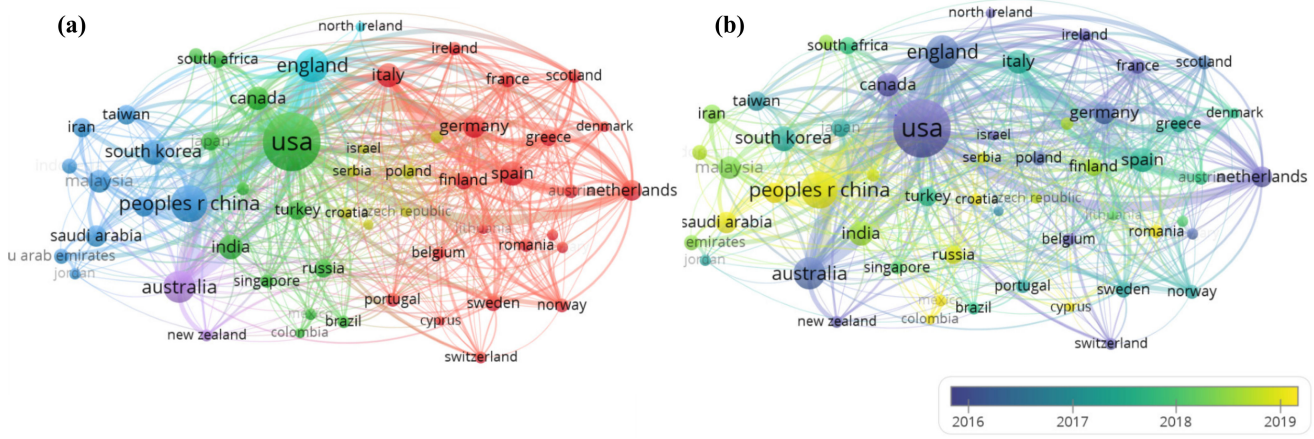

Figure 4. Co-author network maps of countries and regions. (**a**) Network visualization map (document weights). (**b**) Overlay visualization map (document weights).

In Figure 4a, the circle node size portrays the number of articles, and the two are directly proportional. The 55 countries were divided into 6 clusters represented by 6 colors, indicating their close cooperative relationship. In cluster 1, Spain, Italy, Germany, the

Netherlands, and Finland co-authored many works. In cluster 2, the USA, India, Canada, Turkey, Russia, and Japan have a high level of cooperation. In cluster 3, there is much cooperation among countries such as the PRC, South Korea, Malaysia, Saudi Arabia, and Pakistan. In cluster 4, Poland, Ukraine, Croatia, Serbia, and the Czech Republic have moderate cooperation. Other countries also contributed to cluster 5 and cluster 6, such as Australia, New Zealand, and England, Northern Ireland, and Ireland.

A color bar ranging from purple to yellow appears at the bottom of Figure 4b, providing publication dates of the documents by country. The overlay visualization network (Figure 4b) shows that countries (purple nodes) such as Northern Ireland, Belgium, Switzerland, the USA, the Netherlands, Canada, and New Zealand published many documents about smart education before 2016. In 2016, many countries or regions such as Israel, France, Poland, Germany, Australia, Hungary, and England published several works on smart education. In 2017, countries (dark green nodes) such as Norway, Sweden, Japan, Portugal, Jordan, South Korea, Italy, Greece, Spain, Turkey, Denmark, Brazil, and Austria published some articles on smart education. In 2018, many countries or regions (light green nodes) began attending to the research of smart education, such as Singapore, Slovakia, Lithuania, Malaysia, Iran, and the United Arab Emirates. Since 2019, COVID-19 has affected the traditional education mode. Many countries have paid more attention to the development and management of smart education. For example, the countries colored in yellow in Figure 4b are Serbia, the PRC, Saudi Arabia, Romania, Colombia, Croatia, Pakistan, Mexico, and Cyprus. Countries represented by large nodes such as the USA, PRC, UK, Australia, and South Korea cooperated a lot with other countries or regions. They led in collaboration work in the smart education research field.

As listed in Table 3, in the field of smart education research, the USA carried out the earliest relevant research, and it is also the country that has published the most and is cited the most. It is followed by the PRC, UK, Australia, and South Korea. Interestingly, although research on smart education started late in the PRC, the number of papers published is second, indicating that the research on smart education has attracted extensive attention in the PRC. Future research on smart education will attract the attention of more and more countries.

Table 3. Top 10 countries with largest number of documents.

Rank	Country or Region	Cluster ID	Links	TS [a]	Documents	Citations	APY [b]
1	USA	2	48	273	668	11,021	2015
2	People's Republic of China	3	34	146	230	1743	2019
3	UK	6	50	195	180	2555	2016
4	Australia	5	37	114	163	2729	2016
5	South Korea	3	15	31	95	492	2017
6	Spain	1	34	85	88	773	2017
7	India	2	31	57	88	725	2018
8	Italy	1	40	119	86	1842	2017
9	Canada	2	26	98	79	1642	2016
10	Germany	1	31	113	74	968	2016

ote: [a] TS = total link strength; [b] APY = average publication year.

4.4. Organization Cooperation Analysis

In this section, the cooperation of organizations in smart education was discussed. There were 2966 organizations in all. When the "minimum number of documents of an organization" value was set to 5, there were 160 powerful organizations (5.39%) that met the thresholds. The total link strength of each of the 160 organizations was calculated with the others. The organizations with the greatest total link strengths are displayed in Figure 5.

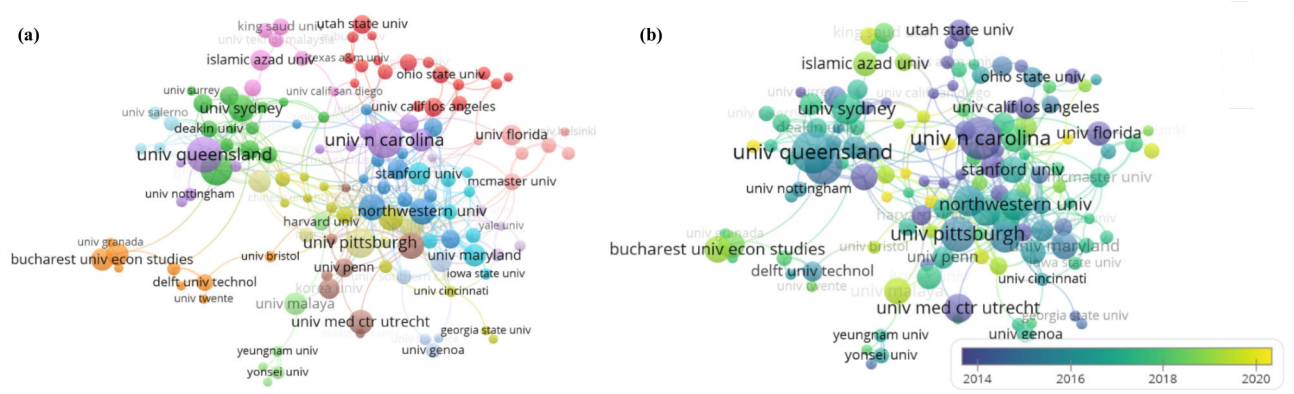

Figure 5. The visualization networks of the organizations. (**a**) Organizational network visualization map (document weights). (**b**) Overlay visualization map (document weights).

One hundred sixty organizations belonged to 15 clusters and had 338 links with 408 total links strengths (Figure 5a). The node size is the organization's number of publications. The line linking nodes indicates a close academic relationship between the two organizations. The shorter the line between the two organizations, the closer the connection. Many institutions have made significant contributions to the research of smart education. The top 10 most productive organizations were as follows: the University of North Carolina System, the University of Queensland, Griffith University, the University of Pittsburgh, Columbia University, Northwestern University, the University of California San Francisco, the University of Sydney, the University of Hong Kong, and the University of Illinois. There were many clusters of institutions, indicating that most of the institutions were exploring this topic.

Many organizations (purple) began to explore the topic of smart education (Figure 6b), such as the University of Southern California, the University of Oklahoma, the University of New Mexico, the University of North Carolina System, and Auburn University. After 2019, there was a greater demand for smart education, and many research institutions began to explore how to do a good job in smart education to achieve better educational purposes, such as these countries displayed in yellow: the University of Malaya, Northern University of Malaysia, Shanghai Jiao Tong University, the University of Eastern Finland, the University of Oxford, the University of South Carolina, the University of Science and Technology of China, Oregon State University, the Hong Kong Polytechnic University, Xi'an Jiao Tong University, and the University of Sharjah.

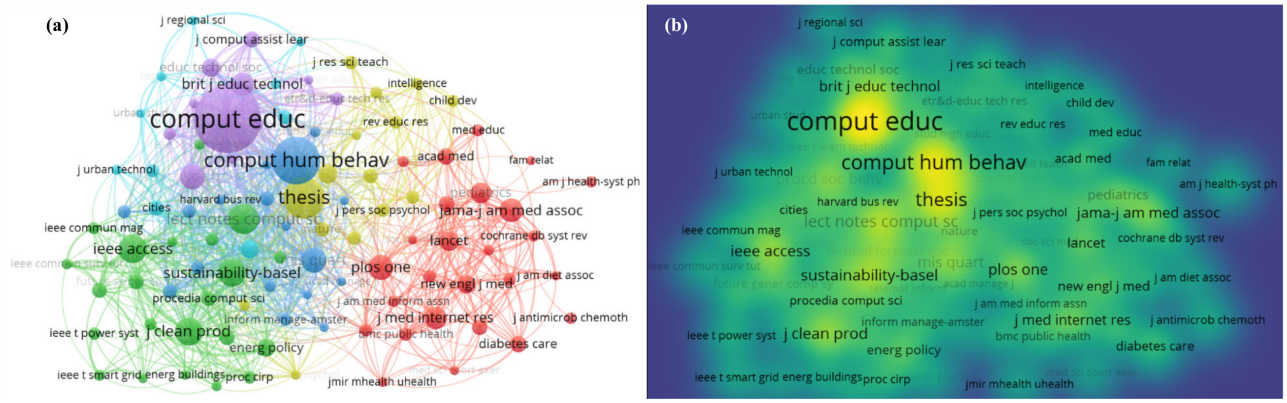

Figure 6. Journal co-citation network. (**a**) Journal network visualization map. (**b**) Journal density map.

Since 2019, more PRC institutions have studied smart education. Perhaps this is because smart education, as a product of the deep integration of information technology and education, has attracted the attention of many scholars and universities. Smart educa-

tion research institutions were geographically dispersed. The top 10 high-yield research institutions were in universities around the world. Smart education research institutions have not yet formed regional research bases with leading roles. The construction of smart education regional research bases is important to the optimal allocation of resources and the formation of discipline groups. Research institutions should strengthen regional cooperation based on their characteristics so as to form a regional research base with smart education characteristics.

4.5. Co-Citation Journal Analysis

Co-citation analysis occurs when two articles appear in the bibliography of a third article, making the two articles have a co-citation relationship. Mining a co-citation relationship of a document dataset is the co-citation analysis of texts [39].

One hundred one of the 40,121 journals met a threshold of 73 "minimum number of citations of a source". Figure 6 shows the co-citation network of journals.

Figure 6 depicts the journals cited the most in smart education research. The node size was determined by the publication quantity of a journal. There were six clusters. *Computers & Education* was the most cited journal, followed by *Computers in Human Behavior*, *Thesis*, *Lecture Notes in Computer Science*, *IEEE Access*, the *Journal of Cleaner Production*, and *Sustainability Basel*. The top 10 journals cited the most in smart education research appear in Table 4.

Table 4. Top 10 journals cited the most in smart education research.

Journals	Cluster ID	Links	TS [a]	Citations
Computers & Education	5	90	9466	809
Computers in Human Behavior	3	94	8091	535
Thesis	4	97	2531	448
Lecture Notes in Computer Science	2	90	2336	309
IEEE Access	2	75	3407	289
Journal of Cleaner Production	2	74	2963	282
Sustainability-Basel	2	84	2918	274
MIS Quarterly	3	89	4488	247
Plos One	1	88	1850	247
Procd Soc Behv	5	84	3066	244

Note: [a] TS = total link strength.

4.6. Cited Reference Analysis

Burst detection analysis detects emerging or important information. Figure 7 shows the six strongest references as detected by CiteSpace. The settings were as follows: years per slice: 1; node type: reference; pruning: pathfinder + pruning sliced networks; top N: 50; and top N%: 10.0%. Six references had citation bursts. The blue line is the period of publication. The red line is the period during which the article was cited the strongest.

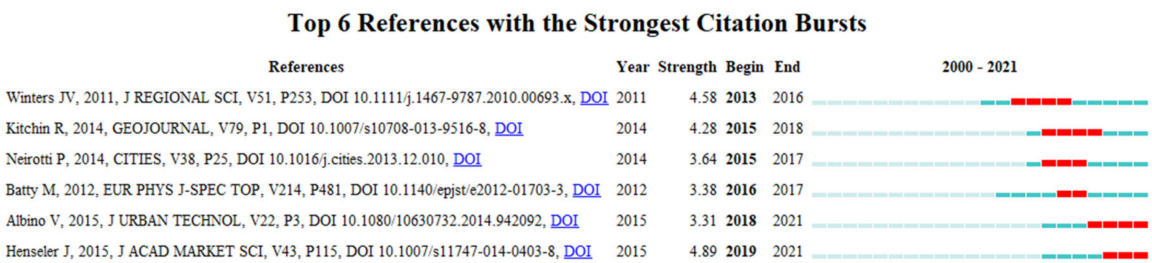

Figure 7. Top six references with the strongest citation bursts.

The longest citation period of the reference was 3 years, and the shortest was 1 year. The texts were published before 2015, when currently published papers were often underestimated by citation analysis [20]. Of the six references, five with the strongest citation

bursts related to the "smart city" keyword [38,40–43]. The sixth reference related to the structural equation modeling method. "Smart city construction" is a new stage of urban construction. Education is an important smart city public service. How to evaluate the educational application of a smart city is not only a problem to be solved but also a hot research topic.

4.7. Co-Keyword and Keyword Citation Burst Analysis

Keywords are important indicators of information measurement research. They are used to accurately summarize the entire text. Frequent keywords reflect the focus of the topic and can be used to determine the research hotspot and development trends in a research field [44]. Keywords are chosen from the title, abstract, and body of the publications and summarize the article [37]. Co-word analysis is similar to counting the frequency at which a cluster of words appears in the same literature. It assesses the affinity by the frequencies of co-occurrence. The bibliometric data showed 9840 keywords. A co-occurrence of the keyword network map was created by VOSviewer to identify research hotspots in the smart education research field. When the minimum number of keyword occurrences was set at 10, 246 items appeared in the visualization map. Figure 8 shows the co-keyword network visualization of smart education research.

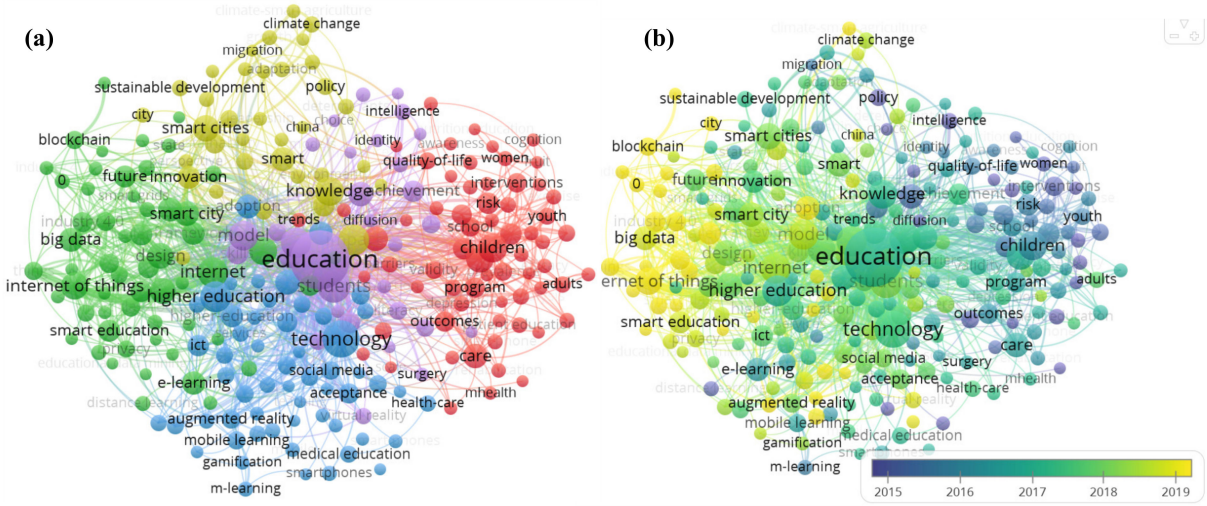

Figure 8. Keyword network visualization. (**a**) Co-keyword visualization map (occurrence weight). (**b**) Co-keyword overlay visualization map (occurrence weight).

In Figure 8a, the node size indicates the keyword frequency. The larger the node, the more times there is co-occurrence. The two largest nodes were for "education" and "technology", which were the strongest. The same nodes were clustered, and they displayed similar themes, being the most closely related. The keywords in Figure 8a consist of five clusters in five colors. Each cluster was a subfield of the smart education research field. By analyzing the five primary cluster nodes, a primary cluster could be assigned an appropriate label.

Sixty-six items were in cluster 1, which is red. The large node keywords were children, health, behavior, care, intervention, adolescents, risk, outcomes, prevention, program, school, interventions, prevalence, validity, physical activity, participation, quality of life, youth, and adults, which were associated with a "smart learning environment". Researchers should pay attention to how a new generation of new technology can effectively act on the smart education environment and improve the construction of a smart education ecosystem through creative integration and application.

In cluster 2 (green), there were 56 items. The keywords with large nodes in cluster 2 were as follows: Internet, management, IoT, system, design, smart city, big data, systems, e-learning, framework, smart education, future, challenges, artificial intelligence, and

engineering education, which relate to "science technology". Research should attend to how a new generation of new technologies can act in a smart education environment and improve the construction of a smart education ecosystem through creative integration and application.

There were 55 items in cluster 3 (blue). The large nodes in cluster 3 were technology, higher education, information, adoption, perceptions, higher education, ICT, teachers, acceptance, augmented reality, mobile learning, social media, communication, self-efficacy, user acceptance, and classroom, which focused on the main topic "smart technical support". Developing science and technology is the premise and foundation for effective implementation of smart education. Currently (2021), developing smart information technologies such as "Internet plus", big data, the IoT, and cloud computing are immature. Many technologies are only at the theoretical level, but their application remains. Developing smart education supporting technology is needed to strengthen information technology integration. This should result in "from point to line, from line to surface, and from surface to body" breakthrough key technology integration.

There were 35 items in cluster 4. The large node cluster 4 keywords were follows, impact, knowledge, smart cities, smart, innovation, quality, sustainability, cities, policy, universities, sustainable development, trust, climate change, adaptation, determinants, energy, and environment, and they were concerned with the topic "theoretical research".

There were 30 items in cluster 5 (purple). The keywords with large nodes in cluster 5 were education, students, performance, model, attitudes, science, achievement, skills, motivation, gender, engagement, curriculum, literacy, simulation, intelligence, and virtual reality, which concentrated on "practical application". At present, there are few practical studies on smart education. Therefore, the future development of smart education research not only needs to strengthen the construction of theoretical methods and systems but also pay attention to and increase the intensity and breadth of the application of theory in smart education practice. Only when the theory is fully applied in practice can it effectively promote the sustainable development of smart education practices.

In Figure 8b, different colors represent the keyword occurrence over time from 2015 (dark purple) to 2019 (yellow). The overlay visualization of keywords shows that nutrition, intelligence, predictors, pedagogy, smart phones, patient education, efficacy, disabilities, parents, diffusion, and distance learning occurred earlier than the other keywords, and these keywords were in purple. The hot keywords, such as smart campus, technology acceptance, IoT, adoption, security, things, online, smart university, smart manufacturing, digitalization, climate-smart agriculture, PLS-SEM, Industry 4.0, intention, machine learning, beliefs, smart contract, deep learning, block chain, and COVID-19 were in in yellow. Since 2019, those keywords related to smart education have been of wide concern. With the spread of COVID-19, the biggest challenge for universities and communities is to enable teachers and students to participate in online teaching and online learning in online school environments [18]. Specific information of the links and total link strength of the top 10 occurrence keywords is displayed in Table 5.

Table 5. The top 10 occurrence keywords.

Rank	Keywords	Cluster ID	Links	TS [a]	Occurrences	APY [b]
1	education	5	235	1234	409	2017
2	technology	3	180	474	134	2017
3	students	5	152	355	99	2018
4	higher education	3	125	256	86	2017
5	impact	4	157	337	86	2017
6	performance	5	142	319	84	2018
7	internet	2	133	336	83	2018
8	model	5	137	331	80	2019
9	knowledge	4	126	284	75	2017
10	children	1	112	270	74	2016

Note: [a] TS = total link strength; [b] APY = average publication year.

Links and total link strength are both standard weight attributes [45]. According to the VOSviewer manual, "A link is a connection or a relation between two items" [45]. The total link strength represents "the total strength of the links of an item with other items" [45]. For instance, concerning co-occurrence links between keywords, "links" means the number of co-occurrence links of a keyword with other keywords. The total link strength of keywords means the total strength of the co-occurrence links among keywords. Specifically, the higher the value, the stronger the link. Table 6 shows that the new research hotspots mainly focus on education, technology, students, higher education, impact, performance, and Internet. The future direction of education will pay more attention to the use of science and technology to achieve the educational purpose of being "student-centered".

Table 6. Key labels of the smart education research topics.

Cluster ID	Labels	Size	Silhouette	Mean (Year)	Top Terms (Log Likelihood Ratio)
0	smart campus	92	0.709	2016	smart campus (790.96); Fog Computing (714.56); Nigerian university (637.11); learning analytics (478.28); English language teaching (446.91)
1	clinical trial	81	0.798	2008	clinical trial (425.9); snowboard school (379.07); early childhood service program (347.86); bringing reality (347.86); parent participation (347.86)
2	UAE University	66	0.716	2015	UAE university (539.96); social media (437.08); web-based cross-sectional survey study (361.13); deploying mask (361.13); my health (361.13)
3	mobile health application	60	0.756	2013	mobile health application (411.38); controlled trial (401.74); cross-sectional study (396.57); study protocol (319.44); newborn unit (318.31)
4	children's belief	54	0.848	2010	children's belief (367.94); predicting academic success (362.6); masculinity capital (357.25); adolescent boys science aspiration (357.25); gender ethnicity leadership (351.91)
5	blockchain technology	50	0.794	2016	blockchain technology (764.26); knowledge worker satisfaction (593.16); smart city (546.26); sustainable smart cities (487.22); fuzzy set qualitative comparative analysis (361)
6	parental attitude	47	0.908	2008	parental attitude (292.83); white matter lesion (288.65); young femininities (286.25); reducing case ascertainment cost (283.04); population studies (283.04)
7	early care	45	0.856	2007	early care (387.71); single-program solution (387.71); education system (251.54); African-American churches (240.86); cancer risk (240.86)
8	human capital externalities	38	0.77	2014	human capital externalities (426.66); knowledge triangle (401.36); task-technology fit model (388.05); smart system model (353.43); public education institute (353.43)
9	smart classroom	38	0.864	2011	smart classroom (306.93); school perspective (262.39); pressure ulcer prevention (257.354); Indonesian province (254.92); digital resource (254.92)
10	online prepayment	23	0.916	2003	online prepayment (210.83); electronic ticket (210.83); institutional context (190.1); multilevel approach (190.1); 4-year college (190.1)
11	parental coaching programme	6	0.99	2010	parental coaching programme (20.37); smart cognitive training (20.37); medulloblastoma (20.37); children (20.37); smart classroom (0.06, 1.0)

Keyword citation bursts refer to those keywords with a sharp increase in citations. Burst detection is a useful analytical method which is used to find keywords that have attracted special attention from relevant scientific fields for a period of time [31]. Keyword bursts are one of the important indicators for identifying emerging or dying research

trends [46]. Therefore, several interesting topics can be discovered through keyword analysis. In order to investigate the dynamics of smart education research and explore in-depth research directions, CiteSpace was used to detect burst keywords. There were 29 keywords with strongest citation bursts detected by CiteSpace (Figure 9) (parameter settings of years per piece: 1; node type: keyword; top N of each slice: 50; and top N %: 10%). The keywords with the strongest citation burst were divided into two stages according to the beginning year of the burst: the first stage (in yellow) and the second stage (in orange).

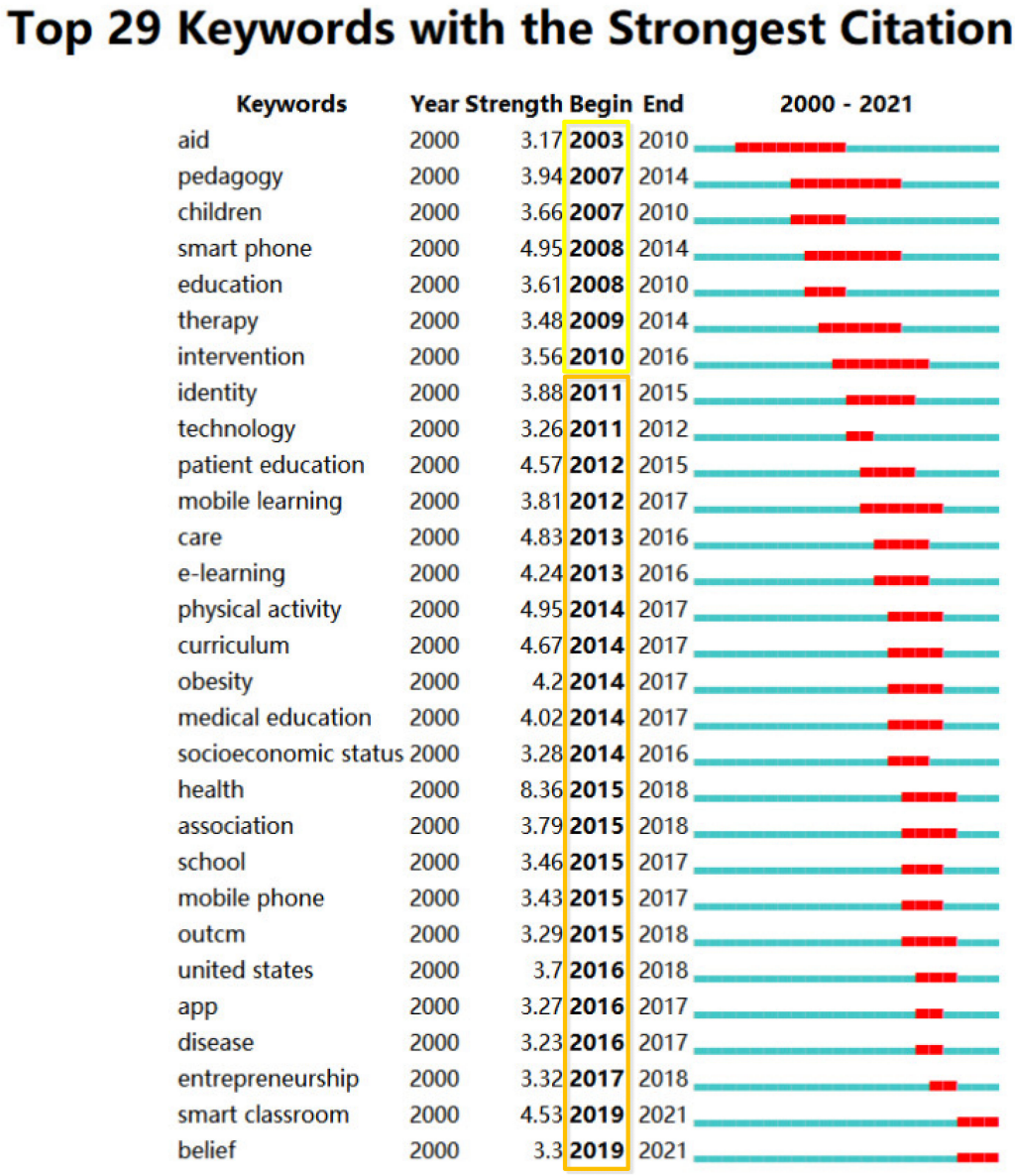

Figure 9. Top 29 keywords with the strongest citation bursts, sorted by the beginning year of the burst.

In smart education, several hot research topics have attracted considerable attention. Keywords with the strongest citation bursts mean that some words have changed significantly in a short time, reflecting the emerging research theme and cutting-edge direction. Keywords with citation bursts in the field of smart education were sorted according to the starting year, as shown in Figure 9. The research frontier of smart education was mainly theoretical discussion in the initial stage. Some papers mainly discussed the necessity of smart education. For example, the keywords were as follows in the first decade: aid (2003), pedagogy (2007), children (2007), smart phone (2008), education (2008), therapy

(2009), and intervention (2010). In recent years, the support technologies of smart education such as technology (2011), mobile learning (2012), e-learning (2013), curriculum (2014), medical education (2014), mobile phone (2015), APP (2016), and smart classroom (2019) have become the new research topics.

4.8. Emerging Trends

The hot spots are not enough to reflect the research trend in an academic field because "the timeliness of different literature" are not considered [20]. In order to overcome this weakness, CiteSpace was used to conduct a cluster analysis on the keywords to obtain emerging trends and cutting-edge keywords in the field of smart education. The major function of cluster analysis is tantamount to detect the overall situation of this field from different angles [20]. The settings in CiteSpace were set as node types: keyword; top N: 10%; top N: 50; and years per slice: 1. Then, a keyword cluster network map was displayed (Figure 10), where modularity $Q = 0.5414 > 0.3$ and the weighted mean silhouette $S = 0.7973 > 0.5$. These important values suggest that the clusters were very good and the outline was clear. The log likelihood ratio (LLR) function was utilized to name the clusters. Twelve clusters were generated by CiteSpace. Some terms between various clusters may have overlapped.

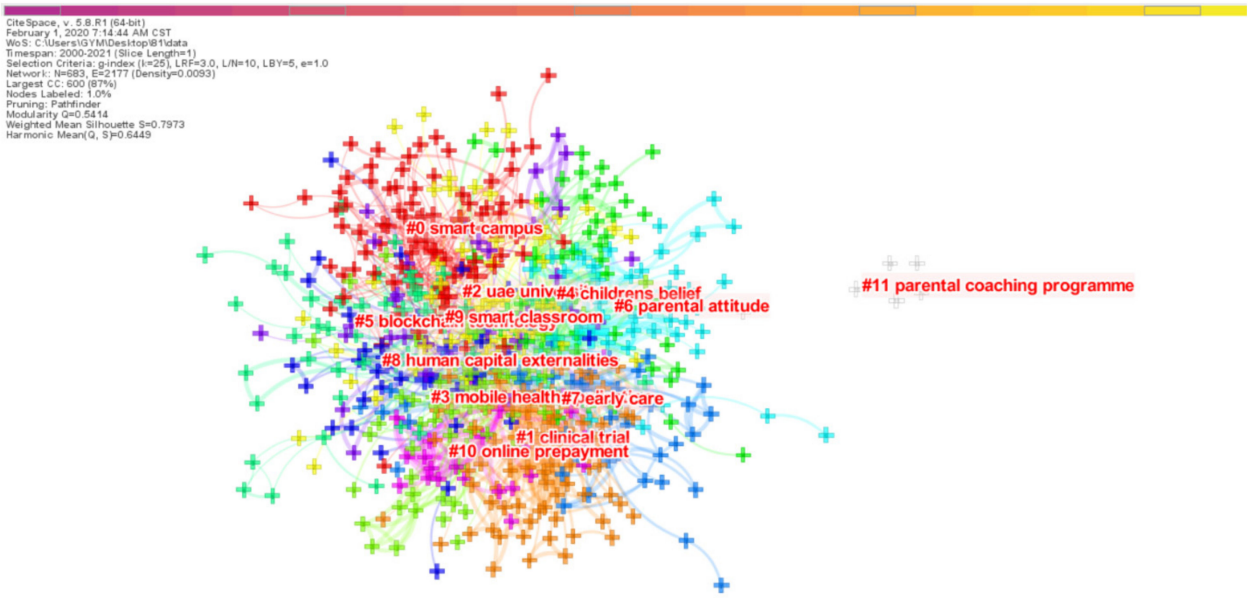

Figure 10. Clusters of smart education keywords.

There were 11 clusters in all, including smart campus, clinical trial, UAE University, and mobile health application (Figure 10). They are represented in different colors. The specific information of the clusters of keywords is listed in Table 6.

Cluster 0 was labeled as smart campus. Cluster 0 was one of the mainstream research frontiers and trends, focusing on the construction of the basic theoretical system of smart education. As an educational concept in the new era, the theoretical system of smart education is constantly improving with time. At present, the research on the basic theory of smart education mainly focuses on hot topics such as smart campus, digital campus, smart class, smart classroom and smart education system. Digital campus and smart campus are the concepts put forward in the early development of smart education. Smart campus is the high-end form of the digital campus [47]. With the development of smart campus, the concepts of smart class and smart classroom were put forward. The concept of smart class and smart classroom are mainly reflected in the information environment, shared resources, visual content, interactive feedback, and virtual perception. In recent years, how

to construct the theoretical system of smart education has become one of the important hot spots in this field.

The label of cluster 1 was clinical trial. The rapid development of information technology provides unlimited possibilities for human learning, pushes the educational concept and model to a new height, and promotes the upgrading and development of smart education. Some educators of medical universities realize that there were some problems in clinical teaching for medical students, such as low utilization of network resources, a single teaching mode, and weak autonomous learning ability. They hope to make the teaching resources, teaching process, and teaching evaluation more efficient, convenient, and intelligent to develop the practical operation ability of each student. Some researchers put forward the idea of introducing smart education into clinical trial teaching [48]. Compared with the traditional classroom teaching mode, the smart education mode realizes the combination of theory and practice, virtual and reality, and online and offline, which is conducive to enable the medical students to establish clinical thinking as soon as possible and improve their learning interest so as to promote the improvement of the medical level.

Cluster 2 (UAE University), cluster 3 (mobile health application), and cluster 4 (children belief) show that smart education is being gradually implemented at some levels, such as the university and science aspiration levels. Some researchers analyzed and discussed the application examples of smart education technology in several universities in the United Arab Emirates (UAEU) [49,50]. The goal of the United Arab Emirates (UAE) is to promote its education system to be student-centered by developing and using world-class teaching science and the latest technology. Whether in or out of class, learners are encouraged to actively participate in an interactive and favorable learning environment to improve their creativity, innovation, and analysis ability [7].

Cluster 5 was blockchain technology. In the modern era, information technology has greatly promoted the upgrading of smart education. Many researchers proposed using blockchain technology, the IoT, and Fog Computing to better realize smart education [51,52]. Cluster 6 (parental attitude) and cluster 7 (early care) suggest that in the process of promoting the practice of smart education, it is necessary that researchers fully consider the children's beliefs and parents' attitudes and pay attention to children's development and early care. The label of cluster 8 was human capital externalities, which suggests that the construction of smart education can share resources, optimize the allocation of resources, and save human costs.

Cluster 9 (smart classroom) is a hot topic. The smart characteristics of smart classroom are mainly reflected in the information environment, shared resources, visual content, interactive feedback, and virtual perception, where "high definition", "deep experience", and "strong interaction" are its three typical characteristics. Recently, how to establish an interactive smart classroom has also been a hot topic in this field.

The label of cluster 10 was online prepayment. The improvement of the smart education environment and technology makes online education flourish and has good economic benefits. The label of cluster 11 was parental coaching programme. This is also an interesting research direction. The keyword cluster analysis can have an insight into the research hotspots and trends in this field, from research on the construction of the basic theoretical system of smart education to research on promoting the upgrading of smart education under the background of advanced information technology in the new era. The latest research hotspots are closely related to the application and promotion of advanced science and technology, such as "IoT", "big data", "cloud computing", "block chain technology", and "Internet Plus".

4.9. Knowledge Structure for Smart Education

Following the method of constructing a knowledge map in the previous publications [53,54], the knowledge base (keywords related to research topics), knowledge domain (key research focus), and knowledge evolution (keywords with citation bursts) generated

by the bibliometric method were integrated to construct a knowledge structure map for smart education (Figure 11).

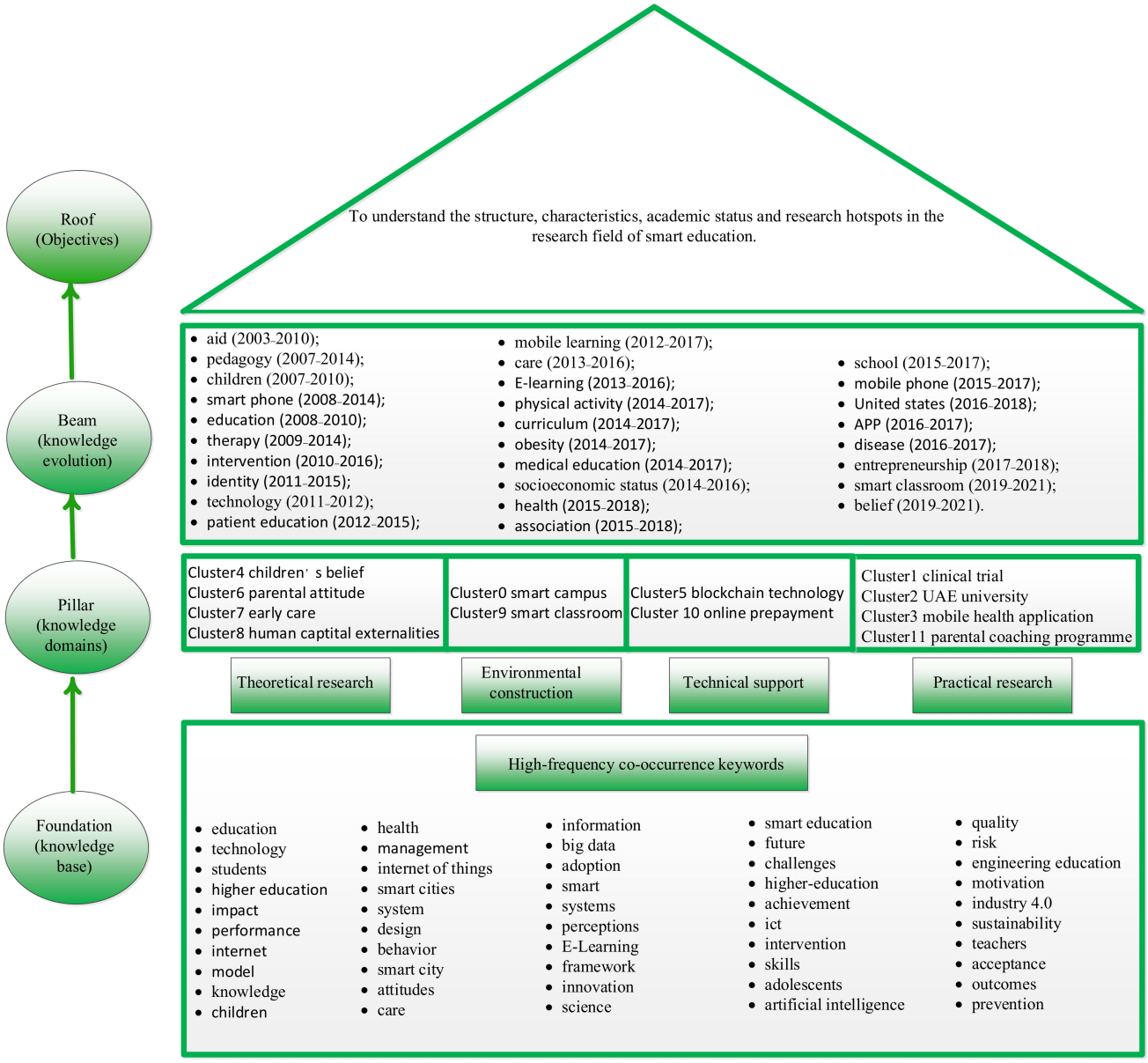

Figure 11. Smart education integrated knowledge structure map.

The smart education knowledge base was constructed by keywords identified by the co-occurrence network. The smart education domain was identified by analyzing the key research focus, including theoretical research, environmental construction, technical support, and practical research. These four aspects are active pillars for the implementation of smart education. The knowledge evolution consists of cluster analysis and citation burst analysis. The knowledge evolution process of smart education is described below. The main concern of early research on smart education was theoretical research, such as aid (2003–2010), pedagogy (2007–2014), children (2007–2010), and education (2008–2010). With the rapid development of information technology, technical support has become the research hotspot, namely for smart phone (2008–2014), technology (2011–2012), mobile learning (2012–2017), e-learning (2013–2016), mobile phone (2015–2017), and APP (2016–2017). In addition, the construction of a smart environment has also attracted the attention of scholars, such as for school (2015–2017) and smart classroom (2019–2021). The most critical issue is to apply the

theory of smart education to practice. The practical research on smart education is very important and is the hot spot and frontier of research, such as for therapy (2009–2014), patient education (2012–2015), medical education (2014–2017), and disease (2016–2017).

By analyzing the integrated knowledge map of smart education, it will be helpful for understanding the knowledge framework structure and development process of smart education. With the rapid development of information technology, smart education will be updated rapidly, so the knowledge base, knowledge field, and knowledge evolution structure will also change in the future. Future research should focus on taking theoretical research, environmental construction, technical support, and practical research as a whole, as well as the development of more "smart" education, as the goal.

5. Definition and Theoretical Framework of Smart Education

Based on the analysis of the literature, this section describes the detailed overview of the definition of smart education and constructs a conceptual framework of smart education.

5.1. Definition of Smart Education

The most common and basic question in smart educational theory is "what is smart education?" There are various answers for this question. The following describes such an issue in order to lay the foundation for building the theoretical framework of smart education. So far, there are many versions of the definition of smart education, and experts have different views. Table 7 summarizes the definitions of smart education in some of the important literature.

Table 7. Definitions of smart education in some of the literature.

	Definition	References
•	"smart education is a unique learning concept that entitles and facilitates the overall learning process and credentials in the digital age"	[5]
•	"An educational paradigm in which students acquire knowledge and skills during which the following overarching factors are considered: (a) career relevance and development, (b) societal relevance and potential impact, (c) sound pedagogy, and (d) classrooms equipped with appropriate technologies and devices that enable good instruction and facilitate the ease of rapid acquisition and synthesis of knowledge."	[55]
•	"Education in a smarten environment supported by smart technologies, making use of smart tools and smart devices, can be considered smart education. Smart education is just the upper layer, and other aspects must be considered such as: communication, social interaction, transport, management (administration and courses), wellness (safety and health), governance, energy management, data storage and delivery, knowledge sharing, it infrastructure, environment"	[56]
•	"Smart education is the conception to describe the brand new learning process in the information era"	[57]
•	"The essence of smart education is to create intelligent environments by using smart technologies, so that smart pedagogies can be facilitated as to provide personalized learning services and empower learners, and thus talents of wisdom who have better value orientation, higher thinking quality, and stronger conduct ability could be fostered."	[58]
•	"Smart education is about providing personalized learning, anywhere and anytime."	[4]

Although many articles have put forward different versions of the definition and theoretical framework of smart education, there is no unified understanding of these issues. In recent years, with the application and promotion of new-generation information technologies such as the IoT, cloud computing, big data, and ubiquitous networks, smart education is endowed with a new connotation and characteristics. Researchers in the field of educational technology have expounded the concept of smart education from the perspective of informatization. Smart education should not only be smart "implements",

but also smart "education" and "learning". Education itself is far more important than technical tools. Therefore, in the future, in the process of practice, it is necessary to eliminate the misunderstanding of smart environment construction; that is, smart education cannot be realized by simply enriching hardware, as it also needs reform of the smart teaching mode and education system.

From the perspective of education discipline and referring to the definition of education, this study believes that the basic elements of smart education include smart educators, smart learners, and smart intermediary factors. The relationship between the three is dynamic, and the focus is different in different stages.

From the perspective of pedagogy, this study believes that smart education is a form of education in which educators build a smart education environment by relying on the new generation of information technologies such as the IoT, cloud computing, and wireless communication and use the smart teaching method to design the teaching content and promote the learners to carry out smart learning. The overall goal of smart education is to cultivate people with high intelligence and creativity and promote their wisdom cultivation and sustainable development. Smart education aims to improve the intelligence level of the existing digital education system and realize the deep integration of information technology and mainstream education factors, such as smart teaching, smart management, smart evaluation, smart scientific research, and smart service.

Smart educator refers to the subject of smart educational practice who has a smart educational influence on the learners' knowledge, skills, ideology, and morality, such as schoolteachers, managers, part-time teachers, tutors, and parents. Among them, schoolteachers are the main body and are representative of educators. The range of educators is wider. In school education, educators mainly refer to teachers and other educational staff in schools. Smart educators are the implementers of smart educational activities and the main influences and guides of students. As an intentional activity, smart education is inseparable from smart educators. Smart educators are a basic element of smart educational activities [57].

Smart learner refers to the object of smart educational practice. It refers to people engaged in learning in various smart educational activities, including children and teenagers studying in schools as well as students in various forms of adult education. The smart learners are the object of smart education, the subject of learning, and the basic element of educational activities. Without this element, smart educational activities cannot be formed. In the context of Education 4.0, the smart learners should have the following four basic abilities: "(1) basic knowledge and core skills, (2) comprehensive abilities, (3) personalized expertise, and (4) collective intelligence" [7].

The smart educational intermediary factor refers to the sum of all things that smart educators and smart learners rely on in smart educational activities. Smart educational intermediary factors are intermediary factors that influence the achievement of a smart educational purpose, including the material intermediary factors and non-material intermediary factors.

5.2. Theoretical Framework of Smart Education

A theoretical framework for smart education using the concepts of smart education described above appears in Figure 12. Smart education is a system of smart educators, smart students, and smart educational intermediary factors. The relationship between the three main factors is independent and interrelated. Smart educators organize and lead smart educational activities. Smart educators grasp the educational purposes and adopt appropriate educational contents and smart means. They create the necessary smart educational environment and regulate the smart learners and the entire smart educational process. This is performed to make the expected changes in the learner's mind and realize the educational purpose. Smart education is always built around the smart learners. A smart environment based on artificial intelligence and other technologies can meet learners' needs for personalized education. Teachers control and regulate the student by

mastering, controlling, and regulating intermediary links. Students develop themselves and react to instruction by using, absorbing, and inheriting intermediary links as media. As the subject and object, teachers and students are connected and interact with each other via the transmission, connection, harmony, regulation, and extradition of smart intermediary factors.

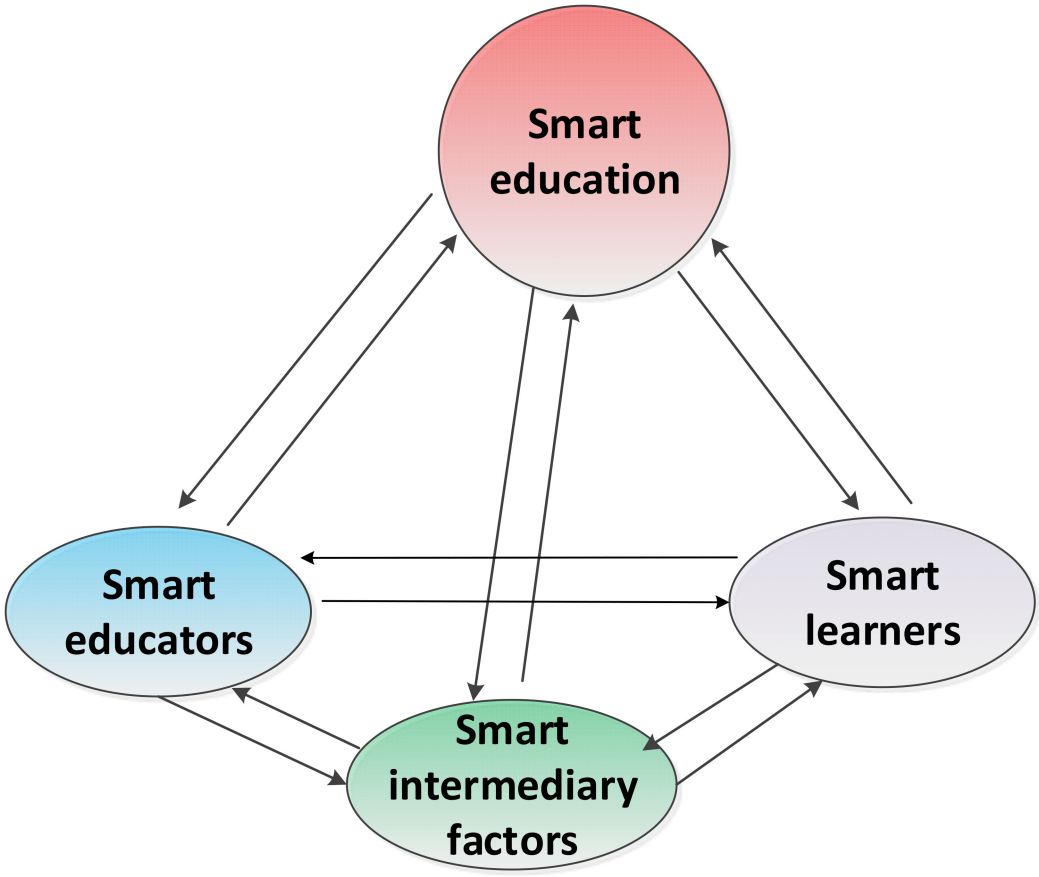

Figure 12. Smart education theoretical framework.

The smart intermediary factors are very complex, which includes both material and non-material intermediary factors. Table 8 illustrates the smart intermediary factors.

Table 8. Smart intermediary factors: an illustration.

Intermediary Factors	Educational Classification	Content Examples
Material intermediary factors	Equipment	Computers, projectors, and recorder
	Location	Classrooms, schools, science and technology museums, and lab
	Medium	Books, newspapers, magazines, and teaching materials
	Environmental resources	Sculpture, art painting, garden, school buildings, playgrounds, laboratories, school run factories, and farms
Non-material intermediary factors	Content	Knowledge, skills, emotion, attitude, values
	Activities	teaching activities, extracurricular activities, and practical activities
	Purpose	Cognitive objectives, motor skill objectives, and emotional objectives
	Method	Teaching and learning methods
	Behavior	Personal behavior, manners, and ways of dealing with people
	Management	Practical teaching management, laboratory opening, laboratory management, laboratory team, instrument and equipment management
	Technology	IoT, cloud computing, and big data
	Evaluation	Evaluation of students' academic achievements, evaluation of teachers' teaching quality, and curriculum evaluation

Smart intermediary factors are the material and non-material factors providing a bridge between the student and educator (Table 8). A smart educational material intermediary refers to the venue or vehicle used, such as the equipment, location, medium, and environmental resources. There are many non-material intermediary factors, such as content, activities, evaluation, purpose, method, behavior, management, technology, and evaluation.

Educational content is the primary intermediary for educational activity. Books, newspapers, and magazines carry or are the vehicle for this content. They are the material presentation of the ideology. Books are the material intermediary, where the content they carry is the ideology and the non-material intermediary for educational activities. Some social cultures, customs, and local customs appear in books and belong to the non-material intermediary of educational activities.

Educational purpose, method, and means are also non-material intermediaries of smart educational activities. Non-material intermediaries for educational activities change as human society evolves. There are different smart learning methods, such as differentiated learning, personalized learning, collaborative learning, group intelligence learning, inbound learning, ubiquitous learning, cloud learning, and seamless learning.

Educator personal behavior, speech, approaches to dealing with the world, and attitude toward student fairness are all behavior intermediaries of educational activities. Some have subtle or imperceptible impacts on students and directly affect a student's personality and personality formation. Smart assessment can promote learning by evaluation.

6. Discussion

The main disadvantage of reviewing research topics according to traditional methods is that an author's subjectivity in selecting the literature may come into play. The results may produce some deviations and defects due to the author's personal and intentional selection of limited publications [59,60]. Another disadvantage is that the traditional literature review is difficult to reveal the core literature and the main paths of the key literature [61]. The bibliometric analysis method avoids the possible factors of subjective selection of papers in the traditional review and avoids the omission of key documents by searching and selecting all the relevant literature in a certain period of time. This method is utilized to quantitatively explore the knowledge structure, research hotspots, and new emerging trends in some scientific fields [62,63]. In order to provide more objective findings for further research, the bibliometric analysis was used to analyze 2358 papers by using CiteSpace and VOSviewer.

With Q1, researchers aimed at exploring the current situation and development trend of smart education research. In terms of the number of publications, few articles on smart education were published before 2003. From 2000 to 2010, articles on smart education were published sporadically. Until 2013, less than 100 articles on smart education were published every year. After 2014, the research in this field began to increase year by year and soared after 2019. With the advance of science and technology and the urgent need to change learning methods, people are more and more interested in the research of smart education. At the beginning of 2020, many countries were forced to choose online education due to COVID-19's influence. However, there is still a large number of students unable to receive education. The fact that the closure of schools has damaged the basic fairness of students' access to education has exposed the vulnerability of the education system to some extent. It has become the best choice to help colleges and universities continue to carry out teaching and management under this circumstance. As a high-end form of educational informatization, smart education, based on the deep integration of information technology and education, not only breaks through the time and space constraints of teaching and learning but also realizes the seamless integration of global educational resources. Smart education can solve these problems and will attract much attention in the future.

With Q2, researchers aimed at detecting the most active frontier discipline in the research of smart education. Smart education research involves a wide range of disci-

plines. Researchers tend to study smart education by interdisciplinary methods, such as education educational research, computer science information systems, engineering electrical electronic, education scientific disciplines, and public environmental occupational health. Different disciplines have made different interpretations and contributions to smart education based on their own research paradigms. At present, the active research group of smart education is mainly scholars in the field of educational technology. Based on the perspective of educational informatization, they put forward that smart education is a new realm of educational informatization and the promotion of new smart technology.

With Q3, this research aimed at helping researchers to quickly identify international and potential collaborators in smart education research from the perspective of spatial distribution. According to the analysis of countries and regions and organizations cooperating, the USA carried out the earliest relevant research, and it is also the country with the largest number of publications and citations on the topic of smart education, followed by the PRC, UK, Australia, and South Korea. Numerous institutions have made significant contributions to the research of smart education, such as the University of North Carolina System, the University of Queensland, Griffith University, the University of Pittsburgh, Columbia University, Northwestern University, the University of California San Francisco, the University of Sydney, the University of Hong Kong, and the University of Illinois.

Most countries began to focus on the theoretical and practical research of smart education. In addition, countries and international institutions have noted the need to strengthen academic cooperation and academic exchanges. In November 2008, the then president of IBM put forward the concept of "smart earth". IBM officially put forward the vision of a "smart city" in 2011, in which smart education is an important part of the smart city and has gradually been paid attention to. The U.S. government and some American scholars have long paid attention to smart education, believing that it can solve the unsustainable development of education faced by American urban education and the cultivation of students' knowledge and skills, which cannot meet the needs of economic and social development.

According to the analysis of co-authors, 5.84% (n = 481/8235) of the authors were credited in 2 publications on smart education research. This shows that more and more scholars began to focus on the topic of smart education. The main prolific authors were Atayero, Aderemi A.; Van Der Graaf, Yolanda; Winters, John V.; Pedersen, Craig A.; Scheckelhoff, Douglas J.; Schneider, Philip J.; Higginbotham, Brian; Badejo, Joke A.; Odukoya, Jonathan A.; and Omole, David O. Some authors were cited a lot, such as Pedersen, Craig A.; Scheckelhoff, Douglas J.; Schneider, Philip J.; Winters, John V.; Stewart, Rodney A.; Shi, YC; Xie, Wk; Xu, GY; Aadland, Eivind; and Moe, Vegard Fusche. Recently, some authors published some of the latest works about smart education, such as Alshurideh, Muhammad Turki; Salloum, Said A.; Khan, Komal Akram; Qazi, Wasim; and Grencikova, Adriana. It can be seen that prolific authors or authors with the more cited literature have contributed a lot to the research field of smart education, and their efforts have jointly promoted the development of this research field. The academic background of most experts and scholars is education theory and education management. Many experts specialize in information technology, computer software, and computer applications. They explore various aspects of education informatization under the background of Internet Plus, thus changing smart education. Some authors are relatively scattered in the network and need to strengthen their cooperation.

With Q4, this research aimed at helping researchers identify influential and productive journals and important references. Co-citation journals analysis showed that *Computers & Education* was the most cited journal, followed by *Computers in Human Behavior*, *Thesis*, *Lecture Notes in Computer Science*, *IEEE Access*, the *Journal of Cleaner Production*, and *Sustainability Basel*. Most journals are related to the disciplines of computer science and engineering, which has attracted researchers with particularly strong theory and practice in the world to study the theme of smart education. The literature source not only reflects that the research content of smart education is closely linked to educational theory, edu-

cational technology, distance education, open education, and adult education, but it also shows that smart education is a lifelong education under the modern computer science and engineering system.

Generally speaking, the much-cited literature can be regarded as the literature that plays a key role in a certain research field. Cited reference analysis showed that most documents with the strongest citation bursts were related to the theme of a "smart city". Education is an important public service of the smart city. How to build an excellent smart education system is an important research hotspot. In general, the key literature in the field of smart education involves the micro level and macro level of smart education. It is valuable for future research in four aspects: theoretical connotation, technical support, environmental construction, and practical research.

With Q5, this research aimed at helping researchers have an insight into the research hotspots and development trends in this field. Co-keyword analysis showed that the new research hotspots mainly focused on education, technology, students, higher education, impact, performance, and Internet. More attention will be paid to the application of science and technology in education to achieve the educational purpose of being "student-centered". Keyword citation burst analysis showed that the research frontier of smart education was mainly theoretical discussion in the early stage. Some papers mainly discussed the necessity of smart education. The keywords with citation bursts in the first decade were as follows: aid (2003), pedagogy (2007), children (2007), smart phone (2008), education (2008), therapy (2009), and intervention (2010). Recently, the support technologies of smart education such as the technology (2011), mobile learning (2012), e-learning (2013), curriculum (2014), medical education (2014), mobile phone (2015), APP (2016), and smart classroom (2019) have become the new research topics. An in-depth understanding of the theoretical knowledge and hot academic themes related to smart education is a promising solution to implement the practical application of smart education. The emerging trends and research directions identified by CiteSpace provide a novel, interesting, and systematic perspective on how to deeply understand the academic topic of smart education in the future. Some possible directions for further research in this field are suggested, such as the smart campus, digital campus, smart class, smart classroom, smart education system, and blockchain technology. The research hotspots of smart education are divided into the following categories: (1) smart learning environment; (2) smart technical support; (3) theoretical research; and (4) practical application. Future research may focus more on these research directions, which may be a promising academic field of smart education.

To sum up, the current research orientation of smart education relatively ignores the value of education. Through the analysis of the concept of smart education and its related research, the current educational technology academic circles regard smart education more as a concept and future educational paradigm of "optimizing the teaching process and promoting learners' smart development through man–machine cooperation". The ultimate goal of smart education should be to cultivate smart talents with a high knowledge level, strong professional ability, good technical quality, and noble morality.

In the practice of smart education, in the era of "Internet Plus", it was used by enterprises and other professionals and criticized in some aspects. For example, in the Internet field, more and more enterprises participate in the strategic advocacy and promotion of education and various smart media. In terms of publicity, any technology product is called "smart". In this case, terms such as smart education, smart teaching, smart learning, smart technology, smart teaching environment, smart classroom, and smart campus are quoted and even abused.

7. Conclusions and Recommendations

This study used bibliometric analysis and systematically analyzed and summarized the emerging systematic literature in the smart education field. It was intended to provide reference ideas for the research and development of smart education. This study, based

upon a literature review, propounded a concept of smart education and constructed a smart education research framework. The author intends to perform some specific practical cases studies to verify this framework in the future. The present study used CiteSpace and VOSviewer to provide a thorough understanding of the smart education research field and create a smart education knowledge structure map. Based on its bibliometric research findings, this study suggests some topics for future smart education research to provide direction and guidance to researchers on related topics. Its practical implications and recommendations can be summarized as follows.

First, presently (2021), smart education research is mainly in the conceptual discussion stage. Many scholars have explored the connotations, characteristics, and framework of smart education. A systematic and universally recognized theoretical system has not yet been developed. Smart education development and progress lies in a deepening of theoretical research. Smart education theoretical research should also be closely tied to teaching practice.

Second, some of the literature propounds practical measures such as building smart campuses, smart classes, smart classrooms, and other new teaching equipment and methods. However, overall, these remain theoretical and rarely include the analyses of successful cases or evaluations of specific application practices. Many countries and regions are implementing smart education practices. Currently there is an emphasis on hardware over software, reconstructing design over application, and ownership over sharing. Smart education should not only be the intelligence of "implementation" but the intelligence of "education", "teaching", and "learning". It is suggested that in future practice, researchers should eliminate any misunderstandings of smart learning environment construction. Better hardware by itself will not realize smart education. Reform of smart teaching modalities and educational systems is required. The first step would be to strengthen the smart education pilot programs. This should be followed by the comprehensive promotion of effective practical application modalities.

Third, research on smart educational technology is decentralized and fragmented. A complete supporting technology system is required. There is much research on teaching practices using single key technologies such as the Internet, cloud computing, big data, and artificial intelligence. There is little research on the interaction and coupling applications of multiple technologies. A smart education system is not easily achieved by reliance on a single piece of technology. With Education 4.0 as a background, technical research of smart education requires the cooperation and efforts of scholars in many disciplines such as education and computer science.

Fourth, many contemporary studies neglect to investigate the "people" participating in smart education. Cultivating smart teachers is critical. An information society needs talent training, and smart teachers need to establish the concept of smart education. They need to master smart teaching methods and continually learn advanced smart technology. Teachers should be given special training to cultivate and improve their ability to apply smart education and information technology abilities in a smart education system. Teachers should be encouraged to actively promote innovative teaching mode practices, such as micro class, flip class, and live broadcast classes. In an era of Education 4.0, smart learners also need to have certain concentration, autonomous learning, self-management, and information technology abilities so that smart education can achieve the results desired.

Fifth, substantial reconstruction of the smart education ecosystem is a must. The emergence of the new generation of information technology, such as Internet Plus and "big data", has changed the people culture of many fields, particularly in education. Recent "Internet Plus education" approaches and developing smart education should not be patchy upgrades but a substantive reform. Through the integration of multilateral subjects such as "government planning and supervision, school core creation, and active participation of enterprises", a new smart education ecosystem including smart teaching, smart big data, smart security, and smart service will be jointly built.

Currently, smart technology development has impacted the foundations of the traditional education system and teaching modalities. Smart education is a breakthrough and provides an opportunity by triggering comprehensive reform. All national governments attach great importance to developing smart education. The wave of research and implementation of smart education is growing and developing. In smart education research, there remain many key problems which provide the future research directions proposed here, and they include the following: (1) formulating standardized smart education industry standards and guides for the standardized development of a smart education industry; (2) creating a smart education environment which realizes a smart process transformation and performance improvement of mainstream education businesses such as teaching, management, and evaluations; and (3) building a smart team of teachers by innovating teacher training modes and content and improving a teacher's ability to implement smart teaching in a smart environment.

Many challenges in this field remain even after this study, as there were limitations. First, data collection was restricted to the WoS core collection. Only English language text documents were studied. Other global databases, such as PubMed or Scopus, should be included. Second, despite these limitations, this study identified the main research hotspots and frontiers, but attention should be paid to the more in-depth information of each research topic.

Finally, the bibliometric software used has limitations. With this in mind, when describing bibliometric analysis, it is suggested to conduct more in-depth content analysis for further research.

Author Contributions: Conceptualization, data curation, formal analysis, funding acquisition, project administration, methodology, writing—original draft, writing—review & editing, X.-R.G.; methodology, supervision, writing—review & editing, Y.-M.G.; software, validation, visualization, X.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Shanghai Philosophy and Social Science Planning Education Youth Project, 2019, grant number B19005.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: https://webofscience.com/WOS (accessed on 31 July 2021).

Acknowledgments: The authors thank Stephen Laudig's efforts to have this paper be in Standard Academic English.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. NESCO Education for Sustainable Development Goals: Learning Objectives. 2017. Available online: https://www.iau-hesd.net/sites/default/files/documents/247444e.pdf (accessed on 22 November 2021).
2. Krishna, V.R.; Shashidhar, R.; Smitha, D. Sustainable development and thresholds of education: Education for sustainable development. *Soc. Sci. Electron. Publ.* **2016**, *9*, 35–42.
3. Kang, S.C.; Dossick, C.S. Smart education method, technology and environment. *Int. J. Autom. Smart Technol.* **2015**, *5*, 113–114.
4. Bajaj, R.; Sharma, V. Smart Education with artificial intelligence based determination of learning styles. *Procedia Comput. Sci.* **2018**, *132*, 834–842. [CrossRef]
5. Iqbal, H.M.N.; Parra-Saldivar, R.; Zavala-Yoe, R.; Ramirez-Mendoza, R.A. Smart educational tools and learning management systems: Supportive framework. *Int. J. Interact. Des. Manuf.* **2020**, *14*, 1179–1193. [CrossRef]
6. Singh, H.S.J. Smart Education Literature: A Theoretical Analysis. *Educ. Inf. Technol.* **2020**, *25*, 3299–3328. [CrossRef]
7. Zhu, Z.T.; Yu, M.H.; Riezebos, P. A research framework of smart education. *Smart Learn. Environ.* **2016**, *3*, 4. [CrossRef]
8. Abdel-Basset, M.; Manogaran, G.; Mai, M.; Rushdy, E. Internet of things in smart education environment: Supportive framework in the decision-making process. *Concurr. Comput. Pract. Exp.* **2018**, *31*, e4515. [CrossRef]
9. Spector, J.M.; Merrill, M.D. Special issue: Effective, efficient and engaging (E3) learning in the digital age. *Distance Educ.* **2008**, *29*, 123–126. [CrossRef]
10. Merrill, M.D. *First Principles of Instruction: Identifying and Designing Effective, Efficient, and Engaging Instruction*; Pfeiffer: Hoboken, NJ, USA, 2013.

11. Kinshuk, P. *Designing Adaptive and Personalized Learning Environments*; Routledge: London, UK, 2016.
12. Koper, R. Conditions for effective smart learning environments. *Smart Learn. Environ.* **2014**, *1*, 1–17. [CrossRef]
13. Hwang, G.J. Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective. *Smart Learn. Environ.* **2014**, *1*, 4. [CrossRef]
14. Puncreobutr, V. Education 4.0: New Challenge of Learning. *St. J. Humanit. Soc. Sci.* **2016**, *2*, 92–97.
15. Anggraeni, C.W. Education 4.0 in English for Survival Class: What, why, and how is to promote it? In Proceedings of the English Language and Literature International Conference (ELLiC) Proceedings, Semarang, Indonesia, 27 April 2019.
16. Miranda, J.; Lopez, C.S.; Navarro, S.; Bustamante, M.R.; Molina, J.M.; Molina, A. Open Innovation Laboratories as Enabling Resources to Reach the Vision of Education 4.0. In Proceedings of the 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), Valbonne, Sophia-Antipolis, France, 17–19 June 2019.
17. Wilson, J.; Kandege, P.; Edjoukou, A.; Teklu, M.T. Unpacking smart education's soft smartness variables: Leadership and human resources capacities as key participatory actors. *Educ. Inf. Technol.* **2021**, *26*, 6267–6298. [CrossRef] [PubMed]
18. Yavuz, M.; Kayal, B.; Tutal, Ö. Trend of distance education research in the covid-19 period: A bibliometric and content analysis. *J. Educ. Technol. Online Learn.* **2021**, *4*, 256–279. [CrossRef]
19. Mka, B.; Huk, A.; Wn, A.; Mf, A.; Sur, A. Blockchain and internet of things: A bibliometric study. *Comput. Electr. Eng.* **2020**, *81*, 106525.
20. Guo, Y.M.; Huang, Z.L.; Guo, J.; Guo, X.R.; Nkeli, M.J. A bibliometric analysis and visualization of blockchain. *Futur. Gener. Comput. Syst.* **2021**, *116*, 316–332. [CrossRef]
21. Merigó, J.M.; Pedrycz, W.; Weber, R.; de la Sotta, C. Sotta Fifty years of Information Sciences: A bibliometric overview. *Inf. Sci. An. Int. J.* **2018**, *432*, 245–268.
22. Broadus, R.N. Toward a definition of "bibliometrics". *Scientometrics* **1987**, *12*, 373–379. [CrossRef]
23. Pritchard, J. Statistical-Bibliography or Bibliometrics? *J. Doc.* **1969**, *25*, 348–349.
24. Xue, J.; Reniers, G.; Li, J.; Yang, M.; van Gelder, P.H.A.J.M. A Bibliometric and Visualized Overview for the Evolution of Process Safety and Environmental Protection. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5985. [CrossRef]
25. Bindra, S.; Parameswar, N.; Dhir, S. Strategic management: The evolution of the field. *Strateg. Chang.* **2019**, *28*, 469–478. [CrossRef]
26. Singh, S.; Dhir, S.; Das, V.M.; Sharma, A. Bibliometric overview of the Technological Forecasting and Social Change journal: Analysis from 1970 to 2018. *Technol. Forecast. Soc. Chang.* **2020**, *154*. Available online: https://www.sciencedirect.com/science/article/pii/S0040162519305220 (accessed on 22 November 2021). [CrossRef]
27. Wang, H.B.; Chen, Q.; Hong, A.; Wang, X.; Cheng, L. The hotspots of smart education in China: Base on the bibliometric analysis and knowledge mapping. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *806*, 12016. [CrossRef]
28. Zhao, L.; Tang, Z.Y.; Zou, X. Mapping the knowledge domain of smart-city research: A bibliometric and scientometric analysis. *Sustainability* **2019**, *11*, 6648. [CrossRef]
29. Small, H. Update on science mapping: Creating large document spaces. *Scientometrics* **1997**, *38*, 275–293. [CrossRef]
30. Lu, Y.; de Vries, W.T. A bibliometric and visual analysis of rural development research. *Sustainability* **2021**, *13*, 6136. [CrossRef]
31. Chen, C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J. Am. Soc. Inf. Sci. Technol.* **2006**, *57*, 359–377. [CrossRef]
32. Van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef] [PubMed]
33. Van Nunen, K.; Li, J.; Reniers, G.; Ponnet, K. Bibliometric analysis of safety culture research. *Saf. Sci.* **2018**, *108*, 248–258. [CrossRef]
34. Ping, Z.; Zhong, Y.; Yu, M. A bibliometric investigation on China–UK collaboration in food and agriculture. *Scientometrics* **2013**, *97*, 267–285.
35. Katz, J.S.; Martin, B.R. What is research collaboration? *Res. Policy* **1997**, *26*, 1–18. [CrossRef]
36. Zhou, W.; Kou, A.; Chen, J.; Ding, B. A retrospective analysis with bibliometric of energy security in 2000–2017. *Energy Rep.* **2018**, *4*, 724–732. [CrossRef]
37. Guo, Y.-M.; Huang, Z.-L.; Guo, J.; Li, H.; Guo, X.-R.; Nkeli, M.J. Bibliometric analysis on smart cities research. *Sustainability* **2019**, *11*, 3606. [CrossRef]
38. Winters, J.V. Why are smart cities growing? Who moves and who stays. *J. Reg. Sci.* **2011**, *51*, 253–270. [CrossRef]
39. Small, H. Co-citation in the scientific literature: A new measure of the relationship between two documents. *J. Assoc. Inf. Sci. Technol.* **2010**, *24*, 265–269. [CrossRef]
40. Kitchin, R. The real-time city? Big data and smart urbanism. *GeoJournal* **2014**, *79*, 1–14. [CrossRef]
41. Neirotti, P.; De Marco, A.; Cagliano, A.C.; Mangano, G.; Scorrano, F. Current trends in smart city initiatives: Some stylised facts. *Cities* **2014**, *38*, 25–36. [CrossRef]
42. Batty, M.; Axhausen, K.W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y. Smart cities of the future. *Eur. Phys. J. Spec. Top.* **2012**, *214*, 481–518. [CrossRef]
43. Albino, V.; Berardi, U.; Dangelico, R.M. Smart cities: Definitions, dimensions, and performance Vito Albino Umberto Berardi Rosa Maria Dangelico. *J. Urban. Technol.* **2013**, 1723–1738.
44. Su, H.N.; Lee, P.C. Mapping knowledge structure by keyword co-occurrence: A first look at journal papers in Technology Foresight. *Scientometrics* **2010**, *85*, 65–79. [CrossRef]
45. Eck, N.; Waltman, L. VOSviewer Manual. 2021. Available online: https://www.vosviewer.com/download (accessed on 22 November 2021).

46. Kenekayoro, P. Author and keyword bursts as indicators for the identification of emerging or dying research trends. *J. Scientometr. Res.* **2020**, *9*, 120–126. [CrossRef]
47. Huang, R.; Zhang, J.; Amp, H.Y.; Yang, J. Smart campus: The developing trends of digital campus. *Open Educ. Res.* **2012**, *4*, 12–17. (In Chinese)
48. Saposnik, G.; Teasell, R.; Mamdani, M.; Hall, J.; Mcilroy, W.; Cheung, D.; Thorpe, K.E.; Cohen, L.G.; Bayley, M. Effectiveness of Virtual Reality Using Wii Gaming Technology in Stroke Rehabilitation. *Stroke* **2010**, *41*, 1477–1484. [CrossRef]
49. Al-Qirim, N. An empirical investigation of smart board innovations in teaching in UAE University. *Educ. Inf. Technol.* **2016**, *21*, 1895–1911. [CrossRef]
50. Al-Qirim, N. Smart board technology success in tertiary institutions: The case of the UAE University. *Educ. Inf. Technol.* **2016**, *21*, 265–281. [CrossRef]
51. Sathya, A.R.; Panda, S.K.; Hanumanthakari, S. Enabling smart education system using blockchain technology. In *Blockchain Technology: Applications and Challenges*; Springer: Cham, Switzerland, 2021.
52. Chaiyarak, S.; Koednet, A.; Nilsook, P. Blockchain, IoT and Fog computing for smart education management. *Int. J. Educ. Inf. Technol.* **2020**, *14*, 52–61. [CrossRef]
53. Li, X.; Wu, P.; Shen, G.Q.; Wang, X.; Teng, Y. Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach. *Autom. Constr.* **2017**, *84*, 195–206. [CrossRef]
54. Shi, Y.; Liu, X. Research on the literature of green building based on the web of science: A scientometric analysis in citespace (2002–2018). *Sustainability* **2019**, *11*, 3716. [CrossRef]
55. Sykes, E.R. New Methods of Mobile Computing: From Smartphones to Smart Education. *Techtrends* **2014**, *58*, 26–37. [CrossRef]
56. Maresca, P.; Coccoli, M.; Guercio, A.; Stanganelli, L. Smarter universities: A vision for the fast changing digital era. *J. Vis. Lang. Comput.* **2014**, *25*, 1003–1011.
57. Lin, J.; Pu, H.; Li, Y.; Lian, J. Intelligent recommendation system for course selection in smart education. *Procedia Comput. Sci.* **2018**, *129*, 449–453. [CrossRef]
58. Zhu, Z.T.; He, B. Smart Education: New frontier of educational informatization. *E-Educ. Res.* **2012**, *12*, 1–13.
59. Li, Y.; Fang, R.; Liu, Z.; Jiang, L.; Zhang, J.; Li, H.; Liu, C.; Li, F. The association between toxic pesticide environmental exposure and Alzheimer's disease: A scientometric and visualization analysis. *Chemosphere* **2021**, *263*, 128238. [CrossRef]
60. Zhu, Q.; Yang, Y.; Zhong, Y.; Lao, Z.; O'Neill, P.; Hong, D.; Zhang, K.; Zhao, S. Synthesis, insecticidal activity, resistance, photodegradation and toxicity of pyrethroids (A review). *Chemosphere* **2020**, *254*, 126779. [CrossRef]
61. Liu, J.S.; Lu, L.Y.Y. An integrated approach for main path analysis: Development of the Hirsch index as an example. *J. Am. Soc. Inf. Sci. Technol.* **2014**, *63*, 528–542. [CrossRef]
62. Yang, W.; Zhang, J.; Ma, R. The Prediction of Infectious Diseases: A Bibliometric Analysis. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6218. [CrossRef]
63. Zhang, J.; Jiang, L.; Liu, Z.; Li, Y.; Li, F. A Bibliometric and Visual Analysis of Indoor Occupation Environmental Health Risks: Development, Hotspots and Trend Directions. *J. Clean. Prod.* **2021**, *300*, 126824. [CrossRef]