

Article

Bibliometric Study on the Conceptualisation of Smart City and Education

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Abstract: In recent years, research in the smart city sector has experienced exponential growth, establishing itself as a fundamental and multifaceted field of study. Education is one of the sectors of interest in smart cities. Concurrently, the extensive academic literature on smart cities makes identifying the main areas of interest related to education, leading institutions and authors, potential interconnections between different disciplines, and existing gaps more complicated. This article maps the knowledge domain of education in smart cities through a bibliometric analysis to identify current trends, research networks, and topics of greatest interest. A total of 88 articles, published between 2000 and 2023, were examined using an interdisciplinary approach. The leading countries are mainly located in Europe and North America and include China. Bibliometrics provides an intellectual configuration of knowledge on education in smart cities; a co-word analysis identifies conceptual sub-domains in specific themes. In general, education within smart cities represents a universal challenge that requires a structured and interdisciplinary approach at all levels. Finally, this paper offers some suggestions for future research, adopting a more comprehensive view of the areas of investigation through a holistic analysis of stakeholders.

Keywords: smart city; education; smart education; educational trends; bibliometrics



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1. Introduction

The concept of smart cities in relation to education is an important area of research in many fields and disciplines and has established itself as a contemporary field of study that still needs to be developed and deepened.

The complexity of smart city education is analysed from different perspectives. Smart city solutions are increasingly being used to address the challenges that cities face, such as energy consumption and traffic management. Education is an integral part of smart cities, and research in this area has recently expanded [1].

In this article, we will explore the emerging field of education in the context of smart cities, using a bibliometric approach to identify and classify the key concepts that emerge at this intersection.

Smart cities represent an environment in which technology, urban planning, architecture, engineering, economics, governance, social interactions, and education converge to create an efficient and sustainable urban ecosystem. In this scenario, education plays a critical role in preparing citizens to live and interact effectively in these complex environments [2].

As more and more people move to urban centres—according to a 2017 United Nations report, it is estimated that by 2050, 70% of the world’s population will live in urban areas—smart cities are emerging as innovative solutions to address challenges that arise [3]

and enrich the lives of citizens [4]. As highlighted by Albino [5], the smart city concept has become increasingly prominent in academic debate and global policy initiatives. To fully grasp the concept of a smart city, a brief exploration is necessary. In the literature, various definitions of a smart city can be examined, emphasizing different aspects ranging from socio-economic to technological. Caragliu et al. [6] mention a series of characteristics drawn from Hollands [7], who used an economic approach to identify them. He underscores that smart cities utilise a network of infrastructures to enhance economic and political efficacy and are oriented towards cultural, social, and urban development. Caragliu et al. [6] themselves provide a widely accepted definition of a smart city: “A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with wise management of natural resources, through participatory governance” [6].

In the current context, a smart city continues to be defined as an urban environment that applies technology to enhance the benefits and reduce the deficiencies of urbanization for its citizens [8].

Giffinger [9] have developed six characteristics for the smart city: the smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. These characteristics indicate the areas of urban life in which the concept of a smart city can be utilised to improve existing infrastructures through the use of data and information and communication technologies (ICTs) to provide efficient services to citizens.

In this dynamic context, education emerges as a key sector. Within smart cities, education takes on a new form, often linked to sustainable development, active citizenship, and learning to use technology [10], and others have revitalised their urban economies to foster, attract, and retain innovation capabilities [11].

The importance of education goes far beyond its traditional role, becoming fundamental to understanding, interpreting, and addressing the challenges of modern society [12]. In addition, education is increasingly recognised as a critical element in empowering citizens and enabling them to play more active roles in the initiatives that characterise smart cities [13]. Elements such as the presence of a creative class and high levels of education are proving to be significant factors in the growth of urban intelligence [6]. Consequently, without creativity, education, knowledge, and learning, a city cannot aspire to a true state of intelligence [14].

Some authors talk about creativity and apply this concept as a key driver of smart cities; therefore, people, education, learning, and knowledge are central in smart cities [15]. Education is a fundamental element that contributes to the attractiveness of a city, attracting companies, organizations, and people from different backgrounds thanks to a dynamic learning environment.

The importance of the human element in smart cities is critical. To move towards more advanced and intelligent cities, it is fundamental to start with people and human capital. In this context, education is essential rather than relying solely on technology, which cannot automatically transform and improve cities alone; it is strongly argued that people and their interactions are critical factors for the success of any city [7].

Research on smart cities continues to attract the interest of a wide range of professionals, academics, public officials, managers, politicians, and educators. This field of study is very broad, providing fertile ground for research and an opportunity for complementary investigations [16]. At the same time, the expansion of the academic literature on the subject makes identifying main areas of interest, leading institutions, key authors, possible links between different disciplines, and existing gaps more complex.

In this context, a bibliometric analysis of the academic literature is particularly useful for mapping the domain of knowledge, identifying current trends, research networks [17], and relevant topics, especially in a rapidly evolving field such as smart cities and education. Studies conducted even a few years ago may not be able to capture new streams of thought or emerging collaborations. Although bibliometric analyses are based on quantitative and rigorous approaches, they can enrich the results of a systematic literature review by

analysing in more detail the characteristics of the literature on a given topic and are valuable tools for evaluating the performance of institutions, journals, or individual scholars [18]. Supported by effective textual analyses and data mining, they can also provide new perspectives and insights into the field of smart cities and education.

As interest in smart city research has grown, several literature reviews have emerged which cover different aspects of the sector [19]. However, only a limited number of these publications have focused specifically on the educational aspect within smart cities. For example, Rico-Bautista [20] studied the use of the Internet of Things (IoT) on smart university campuses. Others have compared two different databases, providing an overview of authors contributing to the field and places where their research has been published [21], while others [1] have provided an overview of existing educational initiatives and the challenges faced in smart city research.

This paper examines education in smart cities, taking an interdisciplinary approach and using Scopus as a database. While some researchers have conducted bibliometric analyses on smart cities, focusing on the network of publications that comprise the intellectual structure of this field of research, there is notable fragmentation and a lack of cohesion in the topic of education in smart cities [22]. Others, through bibliometric analyses, highlight the importance of implementing appropriate technologies to address the challenges of sustainable urban education, thus reinforcing the role of smart cities as catalysts for unconventional innovation [23].

This study aims to fill existing gaps by mapping the knowledge domain and creating new research opportunities, thus providing a clear and updated framework on education in smart cities, considering the growing academic literature on the topic. It highlights the temporal and geographical distribution of research, identifies the most influential authors and journals, and reveals the conceptual structure of education in smart cities through the mapping of the knowledge domain. Furthermore, the analysis illustrates the interdisciplinarity of education in smart cities and highlights some challenges and techniques for effective textual data mining. Finally, while this manuscript makes a significant contribution to the analysis of studies on education in smart cities, it also opens new perspectives for future research in this still partially unexplored field.

The next section of this document defines the conceptual framework; the following sections explain how the data were collected and analysed. The findings are then discussed, and future challenges and gaps are identified. The final section draws some conclusions.

2. Research Questions

This paper provides important insights into education in the context of smart cities and asks three fundamental research questions:

- How is the analysis of education in smart cities evolving?
- What is the intellectual configuration of knowledge on education in smart cities?
- What are the main areas of interest and possible gaps in the literature on education in smart cities?

The first research question aims to determine the volume and geographical distribution of studies on education in smart cities over the years to identify growth trends, reference countries, or journals [24]. The second question focuses on recognizing scholars and articles that have had a significant impact in the field, exploring their nature, relevance and evolution; in practical terms, this means defining their impact on the academic literature through conceptual mapping. The third question focuses on the topics that have received the most attention from scholars and those that have been less explored, with the aim of identifying areas for future investigation.

3. Materials and Methods

A typical bibliometric analysis was applied to the selected data in order to answer the research questions related to education in smart cities, focusing on the evolution, intellectual configuration, trends, and gaps in this field through an interdisciplinary approach.

The choice of a suitable database is a crucial point and is still a matter of debate [25]. In general, large databases such as Scopus, Emerald, Web of Science, ACM, and IEEE [26] are used, but there is no consensus on which is the most appropriate. However, other authors point out that “broad coverage is essential to ensure accurate analysis of the field of study” [27].

In the initial context of this research project, it was planned to use a bibliometric approach that integrated analyses of two major scientific databases, Scopus and Web of Science (WoS). This strategy aimed to ensure comprehensive coverage of the relevant scientific literature. However, a preliminary analysis revealed significant overlap in the content of the two databases, with a high incidence of documents present in WoS that were already present in Scopus. This overlap led to a proliferation of duplicate documents, reducing the effectiveness of the bilateral analytical approach.

A concrete example of this problem was observed during an initial exploratory search using the keywords “smart city” and “education”. The results showed a total of 557 documents in WoS, while in Scopus, the number rose to 1648. The comparative analysis suggested that most of the documents identified in WoS were already present in the Scopus data set.

In light of this finding, it was decided to revise the research methodology and to use Scopus exclusively as the main database for the bibliometric analysis. This decision was based on the finding that Scopus offered a broader and more representative coverage of the corpus of literature relevant to the selected keywords. The decision to focus the analysis on a single database allowed for the optimization of resources and data collection efficiency while ensuring an accurate and comprehensive representation of the field of study under investigation.

Consequently, all disciplines that interact in some way with education in smart cities were examined, so in addition to geography, sociology, and architecture, the study also analysed contributions from fields such as engineering, economics, marketing, and urban planning.

In terms of procedure, this study was based on an initial phase of collection, followed by an analysis aimed at mapping the knowledge domain (MKD), also known as a science mapping analysis [28], using bibliometric techniques.

The collection phase used a systematic review methodology [29] to minimise bias and ensure completeness of information; it also used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to ensure a rigorous and reproducible approach to the collection of articles (SM) [30,31].

From the resulting 1648 documents, different screening criteria were applied according to the study phenomenon (Figure 1). These criteria were in accordance with the statement “Preferred Reporting Items for Systematic Reviews and Meta-Analyses”, better known in the scientific community by its acronym (PRISMA). The PRISMA framework favours a structure and organization that helps authors to better publicise their implemented review process [32].

Firstly, after reviewing the abstracts of the resulting documents, it was realised that the inclusion of the commands in the fields covered (the title, abstract, and keywords) included publications that were not in line with the focus of the study. This led to a partial modification of the search engine so that the command for descriptors related to smart cities and education (“Smart City” AND “Education” OR “Teaching” OR “Learning”) fulfilled the condition of appearing in the title of the publication. This restriction reduced the sample to 1642 documents.

We then excluded from the search results documents that were not articles, proceedings, books, or book chapters. This reduced the sample to 378 documents. On the other hand, we included all documents that were published between 2000 and 2023 according to the previous filter. In order to meet the objective of the study, we excluded those published before the beginning of the millennium and those published after. Thus, after applying the various filters, the final sample consisted of 88 documents (32 articles, 49 communications to

congresses, 7 book chapters, and 0 books). The results were exported as comma-separated values (.csv) for a subsequent analysis of the sample using bibliometric techniques.

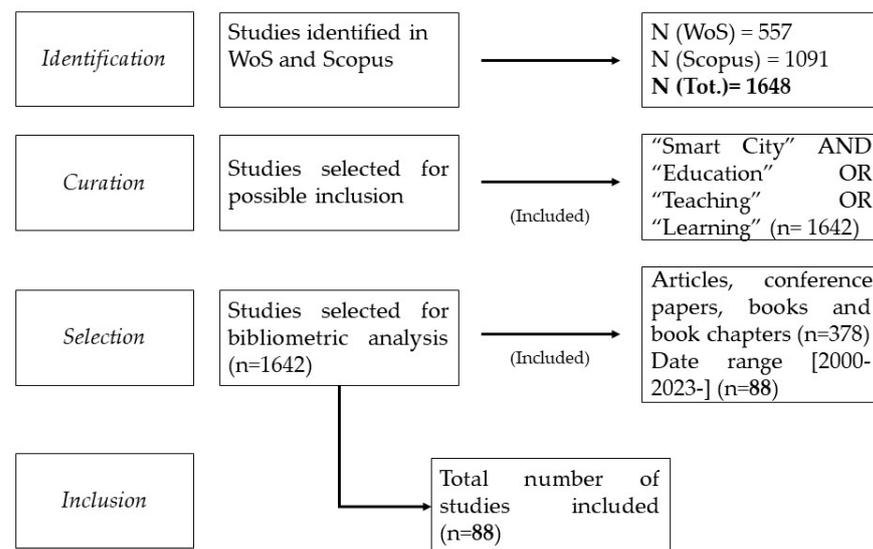


Figure 1. Flowchart of the study selection process based on the PRISMA statement.

Several bibliometric analysis techniques were used for the analysis:

- Scientific production in order to study the evolution of this production as a function of the variables identified.
- Bibliographic coupling to determine the degree of influence of an article in the scientific field based on its similarity (common references) with other related publications.
- Co-authorship, using countries as the unit of analysis in this study. The aim was to examine existing co-operations in relation to the topic under study.
- Co-citation to know the frequency with which different articles are cited together.
- Co-occurrence for the identification of the most frequently used keywords in the study articles.

An accurate data collection phase is essential for the quality of data and subsequent analyses. As highlighted by several authors [32], the correct selection of keywords for the search query is a crucial step for the accurate analysis of the chosen topic. This aspect is often overlooked in various systematic reviews and bibliometric analyses despite its importance for more rigorous research [33].

In this research, data were selected and then exported in RIS format for use with Zotero (v 1.0), a bibliographic management software. They were then integrated into SciMat (v.1.1) [32], a software specialised for bibliometric analyses. This process allowed for the extraction of specific data required for a bibliometric analysis.

A study of the relational nodes formed between the articles in the sample was carried out using VOSviewer (v.1.6.20), a free but not open-source software that allows for the construction and visualisation of bibliometric networks. It displays relational maps generated at the levels of bibliographic coupling, co-authorship, co-citation, and co-occurrence [28].

For the analysis of scientific production, the following variables were defined: year, in order to study the evolution of the articles over time; field of knowledge, in order to know in which thematic areas the articles are indexed; journals, in order to identify the most productive publications with respect to the object of interest of this study; country, in order to know in which countries the most research on the phenomenon under study is carried out; affiliation, in order to study the institutions with the greatest production; and publications with greatest impact, in order to know which were the most relevant articles in the field of study at the time this research was carried out. Not all results were considered.

However, exclusion criteria were established according to the variables considered, which are listed below (Table 1).

Table 1. Study variables and exclusion criteria.

Variables	Exclusion Criteria
Year	All publications outside the data range 2000–2023
Area of knowledge	All areas with fewer than 10 publications
Journals	All journals with fewer than 3 articles
Country	All countries with less than 4 publications
Affiliation	All institutions with less than 4 publications
Publications with more impact	All publications with less than 20 citations

Source: authors' own elaboration.

4. Results

In order to carry out an analysis on the subject of this study, the results were organised according to the different bibliometric techniques applied. In this way, the research questions were answered. The analyses of bibliographic coupling, co-authorship, co-citation, and co-occurrence began with an analysis of scientific production.

4.1. Scientific Production Analysis

The analysis was conducted on all 88 publications that constituted the study's corpus.

4.1.1. Year

Considering that the publications were included in the data range 2000–2023 (Figure 2), both included, a discontinuous evolution is observed, with continuous increases and decreases. This generates a range of 17 publications between the most productive year (17 in 2019) and the year with the lowest number of documents (0 in 2000). In any case, there is an increase in production in the last period (2013–2023) compared to the first period studied (2000–2012).

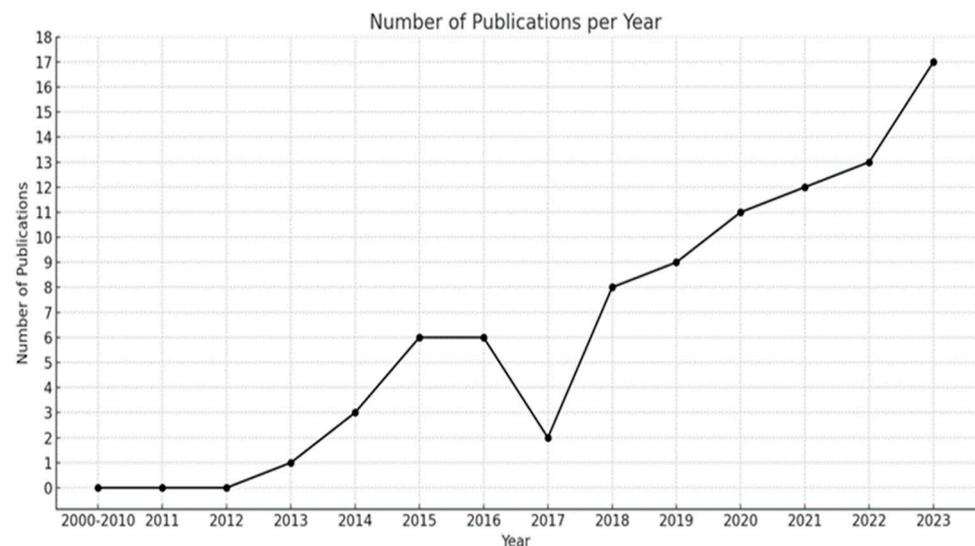


Figure 2. Number of papers per year.

Analysing the data on the annual production of articles in the period between 2000 and 2023, a significant picture emerges in relation to the topic of education in smart cities. Looking at the graph, we can see that before 2013, there is no scientific publication specifically dedicated to this topic.

However, from that year onwards, there is a gradual increase in the number of studies, with a slight upward trend consolidating around 2015. This phenomenon can be attributed

to the increased attention of the scientific community to the concepts of smart cities and the Sustainable Development Goals outlined in the United Nations 2030 Agenda [34].

Interestingly, despite this positive trend, a significant decline is observed in 2017, a year in which only two publications are counted. This decline could be due to several factors, such as changes in research priorities.

This was followed by a resurgence of interest and a consequent increase in scientific production in recent years. This growth can be interpreted as a response to the increasing relevance of issues related to sustainability and technological innovation in the field of smart city education.

4.1.2. Area of knowledge

For this variable, the exclusion criterion was not to reach 10 publications. It should also be noted that the publications were subject to a multi-classification criterion with regard to their inclusion in the fields of knowledge, with the result that the same publication can be included in one or more fields of knowledge, depending on the subject it deals with. This means that the sum of all the fields in which the publications are included (Table 2) is greater than the 88 documents that make up the final sample.

Table 2. Documents by subject area of knowledge.

Area	Number of Publications
Computer Science	56
Social Sciences	43
Engineering	40
Energy	19
Business, Management and Accounting	13
Environmental Science	12

Source: authors' own elaboration.

The field of computer science registered the highest production (56), somewhat more than social sciences, which is in second place with 43 publications. The plurality in the fields is striking, distinguishing two areas: fields of knowledge, more rooted in the content of smart cities, and the educational field, with the variable ICT and educational technology as tools/instruments conveyed to the educational process.

In the context of research on education in smart cities, an analysis of the extract-ed data reveals a multidisciplinary panorama, highlighting how different fields of knowledge contribute to this emerging theme.

As can be seen, the field of computer science stands out as the most productive, reflecting the crucial importance of information and communication technologies (ICTs) in contemporary research. The dominance of computer science shows that ICT is not only a field of study in its own right but also a catalyst for progress in other fields and an indispensable tool for innovation and understanding urban dynamics in smart cities.

The area of social sciences shows a strong interest in the study of social behaviour, structures, and human interactions and plays a central role in understanding social phenomena in smart cities.

The focus on engineering shows an interest in technological innovation and the practical application of science in the urban context.

4.1.3. Journals

The journal *Sustainability* ranks first based on the exclusion criterion of less than three publications on the topic of analysis (Table 3). An analysis of the data in the table shows that the journal *Sustainability* stands out as the main source of publications on the topic of education in smart cities, with a total of five articles. This fact highlights the relevance of *Sustainability* as a reference point in the scientific debate on sustainability issues applied to the educational context of smart cities.

Table 3. Top eight journals indexed with the greatest numbers of publications.

Journal Name	Number of Publications
<i>Sustainability</i> (Switzerland)	6
<i>Advances in Intelligent Systems and Computing</i>	2
<i>Security and Communication Network</i>	2
<i>Internet design and Architecture(s)</i>	2
<i>Journal of Higher Education Theory and Practice</i>	2

Source: authors' own elaboration.

Next is a group of journals, each with two publications, which also contribute to the literature in this field, although to a lesser extent compared to *Sustainability*. This secondary group shows a more varied distribution of research, suggesting that despite the predominant concentration in a single journal, there is widespread interest across different editorial platforms.

Finally, it can be observed that many other articles were published in journals that only dealt with the topic once. This aspect reflects a dispersion of the scientific discourse on this topic across a wide range of publications. Such a dispersion can be interpreted both as a sign of the nascent and still consolidating nature of this field of study and as an indication of a growing interest that cuts across different disciplines and academic contexts.

4.1.4. Country

Having less than four publications on the topic under study (Table 4) was the exclusion criterion for the country variable.

Table 4. Top ten countries with the most indexed publications.

Country	Documents by Country
United State	10
China	9
Spain	9
Saudi Arabia	6
United Arab Emirates	6
United Kingdom	6
Italy	5
Austria	4
Indonesia	4
Mexico	4

Source: authors' own elaboration.

A geographical analysis was carried out in order to identify the leading countries in the field of science and the evolution of these nations over the years. The data on the geographical distribution of scientific production, presented in Table 4, show a clear predominance of publications from European and North American countries and the People's Republic of China (PRC). Specifically, the top three countries in terms of the volume of publications are the United States, the PRC, and Spain.

Given that contributions on the topic of smart cities can span various research areas, we delved deeper into trends in scientific contributions from the United States, China, and Europe. The United States shows a marked inclination towards social sciences, accounting for 30.4% of contributions, followed by computer sciences at 21.7% and business management at 17%. This profile suggests a strong interest in understanding and managing the social and entrepreneurial dynamics associated with smart cities, as well as in technological solutions.

In contrast, China demonstrates a predominance of technological and mathematical research, with a significant 36% of contributions in computer science, followed by engineering at 23% and mathematics at 23.5%. This reflects the country's significant focus on technological and innovative development in the context of smart cities.

An analysis of European publications, focusing on the top three countries, namely Spain, Italy, and Austria, reveals a more balanced distribution of research areas: computer science accounts for 35%, social sciences for 25%, engineering for 20%, and environmental sciences for 12%. This suggests a European trend towards a holistic approach in smart city research, integrating technology, social aspects, engineering, and environmental issues.

These regional differences in research focus reflect both the specific priorities and competencies of individual countries as well as the varied cultural, economic, and political approaches towards the development and integration of smart cities.

In order to obtain a more detailed and comprehensive analysis, it was later considered necessary to complement the study of the number of publications per country with other bibliometric metrics, such as a citation analysis and co-authorship and network visualisations.

A VOSviewer graph was generated from a total of 44 countries with at least two publications, of which 21 countries met this criterion (Figure 3). The results of this visual analysis show well-defined clusters, many of which are not connected to each other.

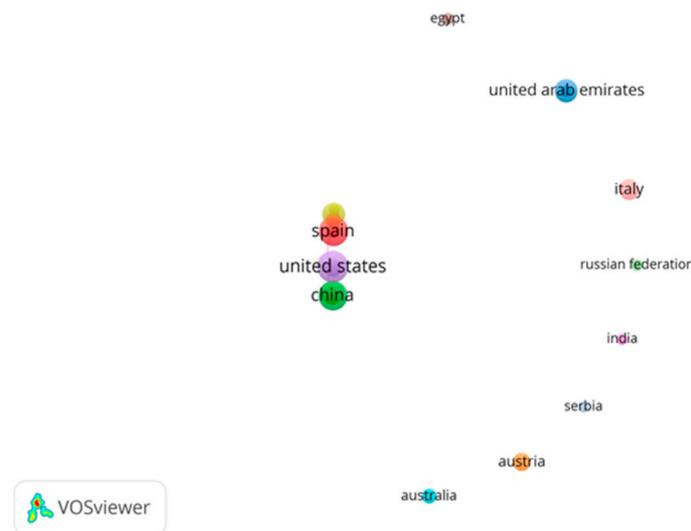


Figure 3. Co-authorship for countries. Purple: United States, Mexico. Green: China, Indonesia, South Korea, United Kingdom. Red: Spain, Brazil, Greece, Lithuania. Yellow: Saudi Arabia, Pakistan. Blue: United Arab Emirates, Canada. Pink: Italy. Brown: Egypt. Orange: Austria. Light green: Russia. Sky blue: Australia. Lilac: Serbia.

4.1.5. Affiliation

As in the case of the country variable, in order to take into account institutions of affiliation, it was established that a minimum of two publications should be registered (Table 5).

Table 5. Top ten institutions of affiliation with the most indexed publications.

Institution	Documents by Institution
Tecnológico de Monterrey	2
Pharos University in Alexandria	2
Fachhochschule Technikum Wien	2
Universidad de Jaén	2
Universidad de Granada	2
Universidade Estadual de Campinas	2
Universidade Estadual de Londrina	2
Matematički Institut SANU	2
Universitas Islam Negeri Maulana Malik Ibrahim Malang	2
Pharos University	2

Source: authors’ own elaboration.

When analysing the table of publications on the topic of interest, a significant data point emerges concerning the institutions that have contributed in terms of the volume of documents. It can be seen that the top 10 institutions listed have each produced two publications relevant to the topic studied.

In this context, it is particularly relevant to note the geographical composition of these institutions. Two Spanish universities stand out, the University of Granada and the University of Jaén, confirming the country's active role in research on this topic. Moreover, the presence of an Austrian university underlines the important contribution of European institutions to the scientific literature in this field.

However, most of the institutions listed in the top 10 are located outside the European context. This geographical distribution indicates a global and diversified participation in research in the specific field, with a notable contribution from institutions located in different parts of the world.

4.1.6. Publications with the Highest Impact

In terms of the most relevant publications, based on the number of citations, published papers with a total of less than 20 citations were excluded (Table 6).

The table below looks at publications with at least 20 citations. At the top of the list is a French study with 93 citations. This paper explores how the smart city concept, which encompasses aspects such as the environment, mobility, and everyday life, influences "digital native" students. It highlights the potential of smart home technologies to enrich the educational and everyday experiences of these students [35]. Others focus on the role of ICT in higher education, highlighting how technology-enhanced learning (TEL) can be a key factor for sustainable socio-economic development, and raising questions about the conditions necessary for its effectiveness [36].

We see how others analyse the development of "smart classrooms" in universities, providing an overview of their potential and the ethical dilemmas they raise. This study highlights how advanced technologies can transform the educational environment but require careful regulation [37].

Finally, another line of research focuses on the importance of education as a universal human right and proposes a model based on computational intelligence to personalise education. This approach is in line with the concept of smart education, which uses data mining techniques to improve the learning experience of students [38].

Table 6. The top five publications with the highest scientific impact.

Authors	Year	Title	Journal	Cited by	Average Number of Appointments per Year
Baudier, P., Ammi, C., and Deboeuf-Rouchon, M. [35]	2020	Smart home: Highly-educated students' acceptance	<i>Technological Forecasting and Social Change</i>	93	23.3
Daniela, L., Visvizi, A., Gutiérrez-Braojos, C., and Lytras, M.D. [37]	2018	Sustainable higher education and Technology-Enhanced Learning (TEL)	<i>Sustainability (Switzerland)</i>	86	14.3
Kwet, M. and Prinsloo, P. [36]	2020	The 'smart' classroom: a new frontier in the age of the smart university	<i>Teaching in Higher Education</i>	78	19.5
Gomede, E., Gaffo, F.H., Brigano, G.U., de Barros, R.M., and Mendes, L.S. [38]	2018	Application of computational intelligence to improve education in smart cities	<i>Sensors (Switzerland)</i>	45	7.5
Musa, S. [39]	2018	Smart cities—a road map for development	<i>IEEE Potentials</i>	38	6.3
Mircea, M., Stoica, M., Ghilic-Micu, B. [40]	2021	Investigating the Impact of the Internet of Things in Higher Education Environment	Mircea, M., Stoica, M., and Ghilic-Micu, B.	35	11.7
Ahmed, V., Alnaaj, K.A., and Saboor, S. [41]	2020	An investigation into stakeholders' perception of smart campus criteria: The American University of Sharjah as a case study	Ahmed, V., Alnaaj, K.A., and Saboor, S.	35	8.8
Williamson, B. [42]	2015	Educating the smart city: Schooling smart citizens through computational urbanism	Williamson, B.	35	3.9

Table 6. Cont.

Authors	Year	Title	Journal	Cited by	Average Number of Appointments per Year
Bracco, S., Delfino, F., Laiolo, P., and Morini, A. [43]	2018	Planning & open-air demonstrating smart city sustainable districts	<i>Sustainability</i> (Switzerland)	32	5.3
Molnar, A. [1]	2021	Smart cities education: An insight into existing drawbacks	<i>Telematics and Informatics</i>	22	7.3
Nuseir, M.T., Basheer, M.F., and Aljumah, A. [44]	2020	Antecedents of entrepreneurial intentions in smart city of Neom Saudi Arabia: Does the entrepreneurial education on artificial intelligence matter?	Nuseir, M.T., Basheer, M.F., and Aljumah, A.	20	5.0

Source: authors' own elaboration.

4.2. Bibliographic Linking

From the application of this bibliometric methodology, we can derive some key information about the structure of research and collaboration between authors in the field of education in smart cities. The image of the graph generated by VOSviewer shows a bibliometric coupling based on authors who have produced at least one document and who have received at least 20 citations each. In total, 251 authors were considered, of which only 30 met the established criteria for inclusion in this study and were further grouped into eight different clusters.

The clusters, represented by different colours, indicate groups of authors who are more closely linked by mutual citations, suggesting common areas of research. The fragmented nature of these clusters, with only a few authors per cluster, suggests that education in the context of smart cities is not only a large field but also highly specialised and fragmented. This fragmentation may be the result of different sub-fields of research developing independently.

The red cluster, represented by Bracco's publication, has a total link strength of 157. The green cluster has a total link strength of 192, the dark blue cluster has a total link strength of 210, and the brown cluster represented has a link strength of 80. The violet cluster has a link strength of 127. Finally, the orange and blue clusters appear to form an interconnected core, indicating that the authors in these groups are often cited together and suggesting a strong thematic correlation.

4.3. Co-Authorship Analysis

The use of VOSviewer to visualise citation networks by country provides an immediately interpretable representation of the main national clusters. As shown in Figure 4, each nation is represented by a circle whose size and label are proportional to its weight in the field of study. The lines connecting the different circles indicate the citation relationships between different nations, while the spatial distance between two circles provides a visual measure of their thematic and citation correlation.

In order to understand the existing collaborative networks between countries in the scientific production under study, a co-authorship analysis was applied (see Figure 5). Countries with at least two co-authored publications with at least 20 citations were included. In total, 11 countries met this criterion. A further restriction was applied to the graph as only seven countries had a co-authorship relationship, as reflected in the graph generated using VOSviewer.

Therefore, three clusters were formed: a red cluster consisting of Saudi Arabia, Lithuania, and Greece, a green colour marking the collaboration cluster between Spain and Brazil, and finally, a blue cluster representing the close collaboration between the United States and the United Kingdom. It is clear that Spain plays an important role as it is the only country that has links with all the countries studied.

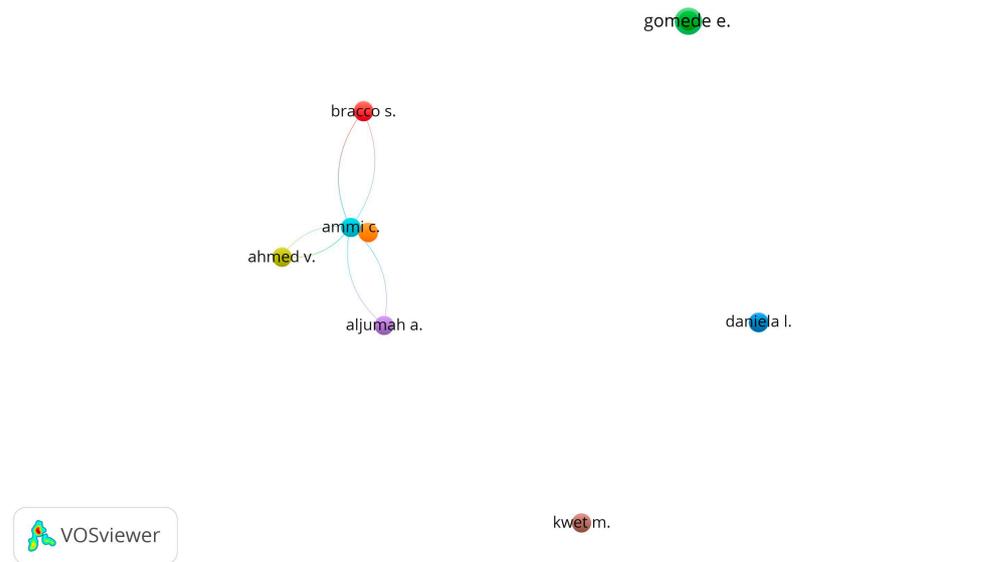


Figure 4. Co-authorship with “countries” as the unit of analysis. Purple: Ahmed V.; Yellow: Aljumah A.; Sky Blue: Ammi C.; Orange: Ghilic-Micu B.; Red: Bracco S.; Brown: Kwet M. Pink: Musa S.; Green: Gomed E.; Dark Blue: Daniela.

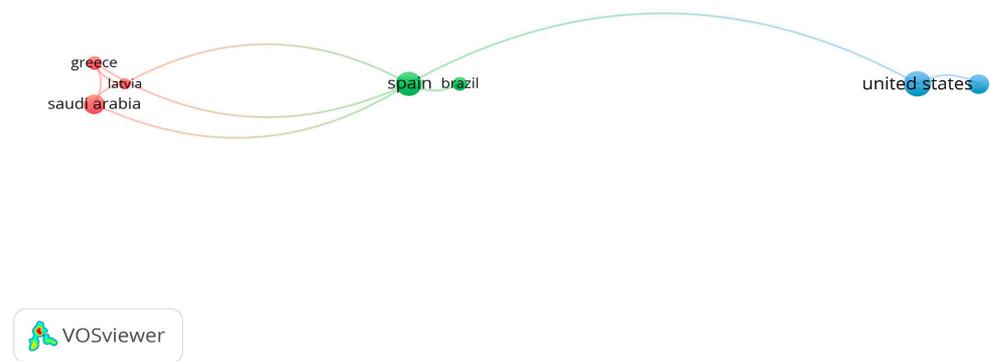


Figure 5. Network visualisation of citations by country. Red: Saudi Arabia, Greece, Lithuania. Green: Spain, Brazil. Blue: United Kingdom, United States.

4.4. Analyzing Co-Citation and Co-Occurrence

In order to investigate the main trends and developments in the field of smart city education, two bibliometric techniques were used: co-citation analysis and keyword co-occurrence analysis. These techniques allowed us to trace connections and emerging themes in this area of study.

In the co-citation analysis, we used a criterion that required a minimum of five citations for each paper, a requirement that was met by 91 publications (see Figure 6). This approach identified seven main groups of co-citations, based on publications that were frequently cited together. This highlighted the importance of certain key authors in the context of education in smart cities; in particular, the works of Nam. This bibliometric review aims to document and synthesise research trends in the field of education in smart cities over the last 25 years.

Through a bibliographic analysis of 2877 Scopus-indexed documents, this review found that this is a very recent topic in the literature, with over 80% of relevant documents published since 2010. It is a global subject in the literature, with significant contributions from both economically developed and developing societies. A citation analysis identified the key authors and documents that have shaped the development of this literature. Author co-citation analysis, used to identify the intellectual structure of the SCOP knowledge base, revealed four “schools of thought” or dominant lines of inquiry. In order of size

and importance, these were alternative materials for sustainable construction, sustainable construction management, recycling and waste reduction, and social sustainability in construction management. The results of the keyword co-occurrence analysis confirmed these findings regarding the conceptual structure of the SCON knowledge base, including the conclusions that “social sustainability” represents the “weakest” dimension and “alternative materials” the leading edge of the sustainability literature. Container title Journal of Cleaner Production [29] (total link strength 359), Pardo (total link strength 234), Gil-Garcia (total link strength 245), Chourabi (total link strength 226), Molina (total link strength 279), and Yigitcanlar (total link strength 261) showed a high frequency of co-citation. This suggests that their works have become fundamental references in the field of smart cities and, consequently, education in smart cities, contributing significantly to the understanding of the different applications and facets of education in these advanced urban environments.

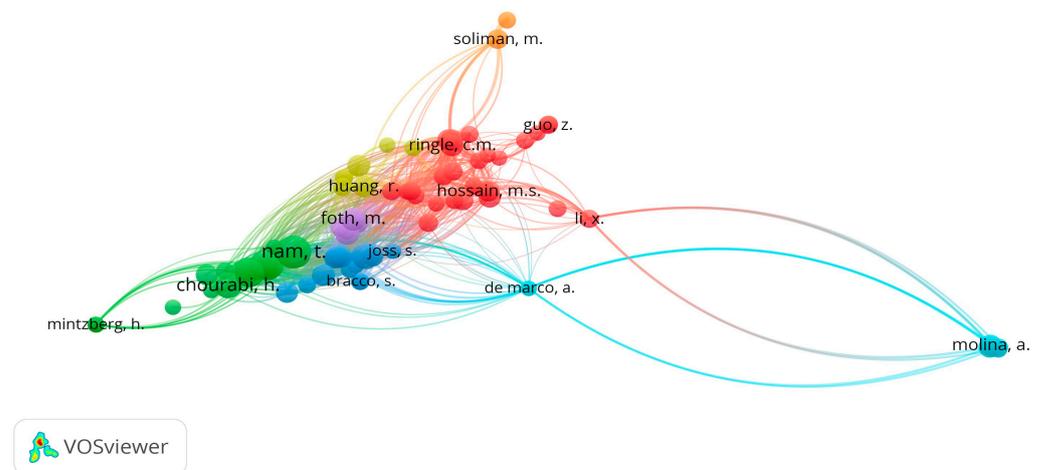


Figure 6. Co-citation of cited authors. Red: Guo Z., Hossain M. S., Li X.; Green: Nam T., Chourabi H., Scott, L.; Blue: Albino V., Giffinger R., Bibri S. E., Caragliu A.; Yellow: Huang R., Lee K., Williamson B.; Violet: Visvizi A., Molnar A., Daniela L.; Sky blue: de Marco, Molina. Orange: Soliman M., Guetl C.

When analysing the co-occurrence of keywords in the 88 publications selected for our sample (see Figure 7), we identified 313 keywords proposed by the authors. In addition, the documents were indexed with 578 different keywords, making a total of 783. Among these, 20 keywords appeared at least five times, as highlighted in Figure 6. We then grouped these keywords into four clusters based on the descriptors that most frequently co-occurred. The dominant keyword is “smart city”, which emerges as the central node, the most representative and significant concept within the analysed dataset. Other recurring keywords representing different clusters include terms such as “education”, “students”, and “sustainable development”. Within the green cluster, the term “educational computing” stands out due to its higher frequency.

The keyword analysis allows us to identify the most relevant research areas. For example, if we look at the green cluster, we can see that it is an area related to computer science, highlighted by specific terms from this field. The blue cluster, on the other hand, focuses more on the school context, including words such as curricula, students, teaching, and e-learning, suggesting a strong correlation with educational methodologies and teaching technologies. Finally, the red cluster focuses on issues of sustainability and sustainable development, including terms related to environmental education, reflecting an interest in research on environmental awareness and sustainable practices.

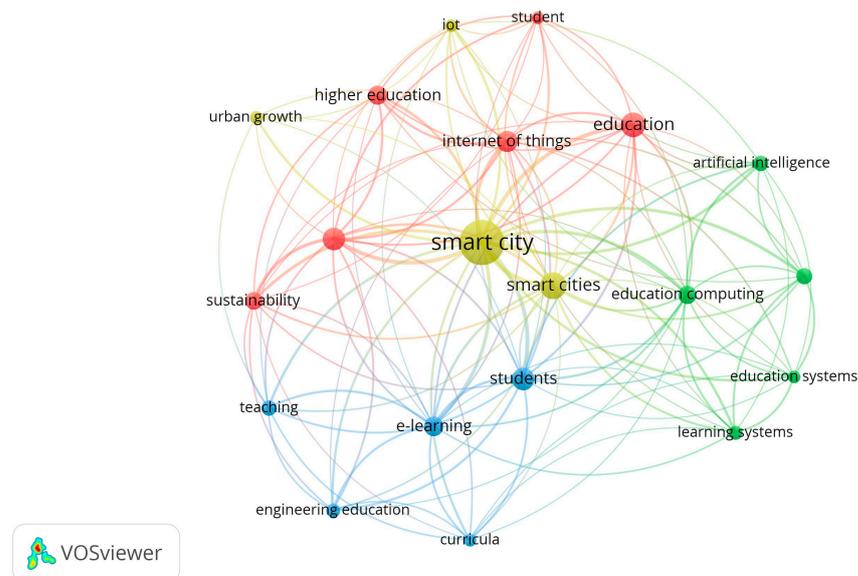


Figure 7. Concurrence of keywords in scientific production. Yellow: smart city, smart cities; Blue: Students, e-learning, teaching; Red: Education, sustainability, internet of things; Green: AI, Education computing, education system.

5. Discussion

Using bibliometric and text mining techniques, this article examines education in the context of smart cities. In this section, we interpret the overall findings, analyse the implications, provide suggestions for future research, and highlight the limitations of this study. The bibliometric analysis is based on a literature review with a final corpus of 88 publications.

The bibliometric work has revealed that the scientific production on education in smart cities is not yet fully developed, leaving ample room for future growth, dissemination, and the creation of collaborative networks. As can be seen, the field of study shows a discontinuous evolution in terms of the proliferation of publications, with the first works analysed dating back to 2013. There is an increase in interest after 2015, indicating greater attention to environmental issues, sustainable development, and the application of information and communication technologies in urban centres.

The geographical analysis of the literature corpus shows that the topic of education in smart cities is of global interest. In addition to a broad sample of studies from various European and North American countries, there is a significant expansion of the literature in other regions of the world. China in particular stands out as one of the leading countries in smart city research, with a significant impact on the education sector.

Overall, these examples show that the correct interpretation of results requires a combined analysis of articles, authors, and keywords to identify the main strands of a research area. In this sense, scientific mapping offers a unique opportunity to visualise the conceptual structure of a topic [29].

The analysis of the bibliographic sources of the articles shows a marked prevalence of publications in the journal *Sustainability*, which deals with issues related to environmental, cultural, economic, and social sustainability. There are also numerous journals in the field of engineering and technology, such as *Sensors* or *IEEE Access*, a multidisciplinary journal, and the *Journal of Higher Education Theory and Practice*. It is also worth noting that about 36% of the articles examined were communications presented at conferences. This indicates that the topic of education in smart cities is not only highly topical but also in a dynamic phase of development.

The collaborative networks between different countries in the field of education in smart cities show some interesting trends. It can be observed that most of the collaborations take place between researchers affiliated with institutions in the United States. However,

collaborations between researchers from the United Kingdom and the United States are particularly productive. Spain stands out in this context, with significant collaborations with Brazil. Co-operation between Saudi Arabia, Greece, and Lithuania also stands out.

With regard to the main lines of research, the multidisciplinary character of smart cities and education is clearly evident. On one hand, some publications include environmental sciences as well as computer sciences, engineering, and social sciences [45]. On the other hand, there are various articles on engineering and computer science, while Bracco focuses on environmental sciences and engineering [46]. This diversity reflects the complex and multifaceted nature of the smart cities field.

This bibliometric analysis has some limitations. First, the selected literature is exclusively in English, which means that the final corpus may not fully represent all existing research networks and current trends. For example, some geographical areas have significant production in languages such as Spanish or Arabic, so a correct geographical or authorial analysis should also include these publications.

Furthermore, the decision to use only the Scopus database does not guarantee full coverage of all academic production available in English. Future research could therefore benefit from including articles in other languages from other databases to avoid missing potentially important documents.

Although the search query was carefully formulated and includes a wide range of keywords, there is always a risk that some relevant terms will be missed, especially given the extensive academic production on smart cities. Furthermore, this study does not evaluate the quality of the selected articles, as such an evaluation would require specific criteria that may not be applicable to all the disciplines involved. Given that the aim of this manuscript is a holistic analysis of the topic, the inclusion and exclusion criteria adopted are considered adequate for the selection of the final literary corpus.

As highlighted by some authors, “bibliometrics as a method has the advantage of reducing elements of judgement and producing quantitative results that tend to be the sum of many small judgments and assessments made by many people” [45].

6. Considerations

The findings of this study may have significant implications for the practical development of education in smart cities. The identified trends and research networks provide a foundation to inform educational policies and urban development strategies.

The convergence of educational technologies, smart city management, urban infrastructure, e-learning, and sustainable urban development, as highlighted in this study, suggests an integrated and multidisciplinary approach to addressing the challenges of contemporary education. In particular, educational institutions can leverage this information to design curricula that integrate digital literacy and environmental awareness, preparing students to become active and informed citizens in smart cities. The integration with cutting-edge technologies such as artificial intelligence (AI), big data, cloud computing, blockchain, and nanotechnology can catalyse an educational revolution characterised by the development of dynamic teaching management systems, interactive learning environments, and innovative pedagogical approaches.

Concurrently, urban administrators can collaborate with academic institutions to develop urban infrastructures that support a connected and interactive learning environment, promoting universal access to education and encouraging the use of environmental IoT technologies for more efficient resource monitoring and management. This interdisciplinary collaboration is crucial to holistically addressing the complexities of smart cities and ensuring that the evolution of smart cities is driven by an inclusive and sustainable educational vision.

For instance, the city of Turin in Italy undertakes innovative initiatives in the field of smart cities, establishing a consolidated collaboration with the Polytechnic University of Turin, leveraging academic expertise to promote intelligent and sustainable urbanization. The Polytechnic University of Turin, through various projects and partnerships, significantly

contributes to transforming Turin into a smart city, focusing efforts on key aspects such as sustainable mobility, energy, building design, and the quality of life of its citizens, with a focus on reducing carbon dioxide emissions. An example of this collaboration is the “Torino City Lab”, an initiative aimed at creating economic development policies based on innovation and new technologies, offering new opportunities to the city through citizen participation.

This not only indicates a growing interest in the field but also creates new opportunities for future studies that can translate theoretical knowledge into innovative practices, tangibly contributing to the development of smart cities that are equally attentive to the educational dimension and the training of citizens. In the European context, the implementation of school programs aimed at education for active citizenship demonstrates the potential of this educational approach and lays the groundwork for future educational investigative initiatives.

7. Conclusions

This article analyses academic production on education and smart cities through a bibliometric approach; it provides a clear and updated framework of the knowledge structure in this specific sector, demonstrating its relevance and the contemporaneity of the topic treated, highlighting that it is an expanding and evolving subject. Indeed, this document makes a substantial contribution to the literature on education and smart cities, identifying trends and gaps and suggesting directions for future research. In particular, it identifies thematic areas such as educational technologies, smart city management, urban infrastructures, e-learning, and sustainable urban development. It also highlights a little explored but timely line of inquiry, providing a valuable and up-to-date overview of the literature on education and smart cities. As such, it is useful for scholars approaching the fields of education and smart cities for the first time. Indeed, while highlighting some of the limitations of existing research, it also proposes several suggestions for future studies, such as a more comprehensive analysis of education that integrates the perspectives of students and teachers or the potential of environmental IoT technologies and smart city management. Further analysis is needed to increase citizens’ awareness of their role in sustainable urban development.

This leads to the need for further research at an interdisciplinary level, taking into account the need to improve education and urban management at all levels and to make citizens more involved in sustainable development and aware of their environmental impact. In this respect, the creation of interdisciplinary research teams would be very beneficial for future research on these topics and would favour the integration of different theoretical approaches from different disciplines.

Finally, given that this article highlights the growth trajectory of the literature on education and smart cities, a significant increase in academic production is predicted for the coming years.

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