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Computer in education in the 21st century. A scientific mapping of the literature in Web of Science

La computadora en la educación en el siglo XXI. Un mapeo científico de la literatura en Web of Science

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ABSTRACT. Computers have evolved over the course of history through successive generations. The impact of this technology on society has revolutionised the way we communicate, participate in the political life of a country or access education. The potential of the computer in the field of education has been highlighted by last year's global event. The objective of the study is to analyze the literature on the term computer in the field of education (COMPU-EDU) in the Web of Science database. For this, a bibliometric methodology based on a scientific mapping of the publications on the state of the question has been used. It has worked with an analysis unit of 10939 documents. The results indicate that research related to "computer" in education is mainly presented in English and in research articles. In addition, the journal with the most manuscripts on this line of research is Computer & Education. The analysis of the scientific evolution of this line of research shows that studies are mainly focused on teaching and learning processes, as well as on students' attitudes towards computer use. It can be concluded that the COMPU-EDU investigations are currently at an inflection point, given that there is a downward trend, as far as production volume is concerned. The scientific community is beginning to focus its research on other more specific branches of computer, such as augmented reality or robotics. In addition, the scientific production of COMPU-EDU in the 21th century focuses mainly on the attitudes of the members involved in the pedagogical act, on gender differences, on the elements of the teaching and learning processes - pedagogical methods and evaluation - and in the attention of students with special educational needs. Probably in the future the lines of research will begin to focus on self-regulation of learning, computational-thinking and gamification.

RESUMEN. Las computadoras han evolucionado a lo largo de la historia a través de generaciones sucesivas. El impacto de esta tecnología en la sociedad ha revolucionado la forma en que nos comunicamos, participamos en la vida política de un país o accedemos a la educación. El potencial de la computadora en el campo de la educación ha sido destacado por el evento global del año pasado. El objetivo del estudio es analizar la literatura sobre el término informática en el campo de la educación (COMPU-EDU) en la base de datos de Web of Science. Para ello se ha utilizado una metodología bibliométrica basada en un mapeo científico de las publicaciones sobre el estado de la cuestión. Ha trabajado con una unidad de análisis de 10939 documentos. Los resultados indican que la investigación relacionada con la "computadora" en la educación se presenta principalmente en inglés y en artículos de investigación. Además, la revista con más manuscritos en esta línea de investigación es Computer & Education. El análisis de la evolución científica de esta línea de investigación muestra que los estudios se centran principalmente en los procesos de enseñanza y aprendizaje, así como en las actitudes de los estudiantes hacia el uso de la computadora. Se puede concluir que las investigaciones COMPU-EDU se encuentran actualmente en un punto de inflexión, dado que existe una tendencia a la baja, en lo que se refiere al volumen de producción. La comunidad científica empieza a centrar su investigación en otras ramas más específicas de la informática, como la realidad aumentada o la robótica. Además, la producción científica de COMPU-EDU en el siglo XXI se centra principalmente en las actitudes de los integrantes involucrados en el acto pedagógico, en las diferencias de género, en los elementos de los procesos de enseñanza y aprendizaje - métodos pedagógicos y de evaluación - y en la atención de alumnos con necesidades educativas especiales. Probablemente en el futuro las líneas de investigación comiencen a centrarse en la autorregulación del aprendizaje, el pensamiento computacional y la gamificación.

KEYWORDS: 21st century abilities, Architectures for educational technology system, Human-computer interface, Lifelong learning, Distributed learning environments.

PALABRAS CLAVE: Habilidades del siglo XXI, Arquitecturas para el sistema de tecnología educativa, Interfaz persona-computadora, Aprendizaje a lo largo de la vida, Ambientes de aprendizaje distribuidos.

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1. Introduction

Nowadays, the world would not be the same without the presence of computers. This tool, which appeared in the middle of the last century, has revolutionized the way of communicating (Memmi, 2006; Liao et al., 2018; Martínez-López et al., 2021), of acquiring or selling goods (Alontaga, 2018; Pérez-Amaral et al., 2020), of access training (Cairns & Malloch, 2017; Ellery et al., 2007; Moeller et al., 2015; Sweeney et al., 2006), to participate in the political life of a country (Chen & Stoddard, 2020; Figeac et al., 2020; Hu & Kearney, 2020) and even the way of looking for a partner (Zheng et al., 2017). In this 21st century, every action that the human being performs is mediated by a computer or by a computer system that receives and processes the information, being returned to the user for decision-making. Even now, this decision-making is assumed by technology called artificial intelligence (Elliot et al., 2019; Kim, 2020; Loftus et al., 2020). In this sense, the need to use computers for almost all the daily processes that a person performs. This has generated a dependency that has reached its highest point with home confinement due to the COVID-19 pandemic (Bansak & Starr, 2021; Gaudiot & Kasahara, 2020). This pandemic has had and is having direct consequences at the health level but also at the educational level (Carabelli, 2020; Kucirkova et al., 2020; Molwitz et al., 2021). The changes that were promised in the long term for the inclusion of educational models supported by technological systems have been drastically accelerated. The whole of society has had to make a very important effort to adapt to the situation generated that prevented, for example, the social communication so common on a daily basis.

Throughout their history, computers have evolved giving way to successive generations. Currently six generations are identified. The first generation corresponds to the period between 1946 and 1955 (Raffino, 2020). In 1946 the ENIAC (Eletronic Numerical Interpreter and Calculator) was created, known as the world's first digital electronic computer. These early computers were based on vacuum tube and valve electronics. Its applications were eminently military. The second generation of computers (1956-1964) was characterized by replacing the vacuum valves with transistors, which gave them a lower volume and energy consumption. Furthermore, computers of this generation were the first to have a specific language to program them, such as the famous FORTRAN (Trapp & Öchsner, 2018). With the appearance of integrated circuits, the third generation of computers (1965-1971) began. This was characterized by increasing the processing capacity of the machines and lowering production costs. At this stage where the first step was taken for the miniaturization of computers (Raffino, 2020). The fourth generation of computers is developed between 1972 and 1980 and is identified with the invention of the microprocessor. This integrated circuit brings together all the fundamental elements of the machine in a minimum space and is called a chip. Thanks to these chips, computers began to diversify their logical-arithmetic functions, taking another step towards micro-computerization. This invention allowed personal computers to be developed in this period and companies such as Microsoft or Apple were created. The fifth generation of computers is limited to the period between 1981 and 1990. In this period appears the PC-MS / DOS operating system, the incorporation of the optical hard disk, the use of cache memory to assist the microprocessor and VGA cards that could reach up to 256 colors if the monitor supported it. From 1991, with the appearance of the Internet, the spread of computers in all areas of life was exponential. The development of laptops allowed their use not to be confined only to a room, but to be carried from one place to another as another complement in our work briefcases. From this moment to the present, computers have become popular as they are smaller and more portable computers (laptops, PDAs, smartphones, tablets) that include access to wireless networks such as WiFi and Bluetooth, recognition and voice commands or the use of compact memories such as external USB hard drives. There are authors who propose the existence of a sixth, seventh or eighth generation of computers (Marker, 2020). These generations would have in common the incorporation of artificial intelligence, augmented reality, supercomputer network processing or quantum technology.

At the same time that computers have evolved, their involvement in training processes has gone in parallel (Miguel-Revilla, 2020). In the first generations, the educational approach to computers had the objective of understanding technology as an end in itself, not as a means to achieve specific ends from an educational perspective. With the commercialization of computers and their popularization in the 1980s, his reference in

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the educational field was focused on knowing the history of computers and their development as well as learning to program without adapting all this to the educational context (Cennamo et al., 2019). Another element that allowed a more general approach of computers to teachers and students was the appearance of graphic environments with which the user could interact in a much easier way with the computer without the need to know programming. This graphic interface favored the emergence of productivity and office automation applications, including word processors, software for multimedia presentations or databases (Miguel-Revilla, 2020). As Area-Moreira (2008) argues, one of the difficulties that were detected in these early days was the lack of systematic training of teachers in technical and pedagogical aspects, thus limiting the implementation of the digital world in classrooms. In the following years and with the appearance of the Internet, access to information through web browsers allowed us to offer a world of possibilities that had never been seen before.

Technological advances in telecommunications (fiber optics and 4G and 5G networks) (García et al., 2015; Song et al., 2020) and the generalization of portable devices such as smartphones, have facilitated the interconnection between educational institutions, collaborative work, the implementation of educational networks and virtual training supported by virtual learning environments (VLE) (Alencar & Netto, 2020; Foster & Shah, 2021). In this sense, the potential offered by computers in the field of education is a subject sufficiently studied from a double approach. On the one hand, as a teaching support instrument focused on the renewal of teaching methods and, on the other, as a didactic resource for the improvement of the students' learning processes. As support for teachers, studies show that the incorporation of computers in classrooms has made it possible to improve student motivation and participation in classrooms (Portela, 2020). The use of computers has allowed the development of methodologies such as e-learning (Aeiad & Meziane, 2018; Carraher Wolverton et al., 2020; Mudrák et al., 2020; Thongsri et al., 2019), b-learning (Peralta et al.., 20104; Rembach et al., 2019; Valverde-Berrocoso & Balladares Burgos, 2017), m-learning (Malik et al., 2020; Martínez Martínez, 2019; Razzaque, 2020) or flipped learning (Bond, 2020; López Núñez et al., 2020; Tsai et al., 2020).

As a didactic resource for student learning, computers have made it possible to implement educational software that promotes student inclusion (Eden & Oren, 2020, Gözüküçük & Günbaş, 2020; Israel et al., 2020; Xin et al., 2020; Infante-Moro et al., 2021a, 2021b), the development of values and attitudes for active citizenship (Li et al., 2018; Ryoo et al., 2020), the promotion of a healthy lifestyle (Greer et al., 2016), language learning (Bahari, 2020; Buendgens-Kosten, 2020; Giménez et al., 2020; Jiang et al., 2020; Juniardi et al., 2020; Park & Son, 2020; Yeşilbağ et al., 2020), music learning or other arts (Gorbunova & Pankova, 2020; Gorbunova et al., 2020), the simulation of experiences in virtual environments (Cheng & Beal, 2019; Hirshfield & Koretsky, 2020) or interaction with virtual assistants (Geoffroy et al., 2002; Shoemaker et al., 2014; Todorov et al., 2018).

These studies should serve as an example to assess the potential of the computer in the field of education. The confinement declared worldwide in March 2020 has highlighted the need to accelerate the inclusion of computers in the academic life of educational institutions (Leal Filho et al., 2021). This exceptional circumstance has revealed the need to provide students and teachers with the necessary tools (Pozo-Sánchez et al., 2021) and training to make them technologically competent (Moreno-Guerrero et al., 2021).

In the present work, a study is carried out on the concept "Computer" in the field of education (COMPU-EDU) of the 21st century, from the point of view of bibliometrics (Moreno-Guerrero et al., 2020). To carry out this research, the Web of Science (WoS) database was used. This is considered one of the largest databases worldwide and from which the Journal Citation Reports (JCR) draws. Likewise, it compiles a large documentary volume of scientific texts from the field of education (Zhu and Liu, 2020). For this reason, it has been considered as a relevant database, where to extract an impact literature on the state of the question.

The main novelty reflected in this study focuses on conducting a documentary analysis at a higher level of literary depth. Both the performance of the construct and a scientific mapping of its relevant publications are analyzed. After conducting a review of the existing literature, no study has been reported that analyzes the term COMPU-EDU from this bibliometric perspective. Therefore, this work acquires an exploratory component to establish the knowledge bases on the subject described. To carry out adequate research that contributes to solving this gap found in science, previous studies that have used the aforementioned analytical techniques have been followed as a model (López-Robles et al., 2019; Soler-Costa et al., 2021).

Therefore, the purpose assumed by this research focuses on analyzing the projection of COMPU-EDU in WoS publications, as well as the lines along which the reported studies run and the future trends that will mark this concept. The findings presented will serve to reveal to the scientific community the importance of this concept in the impact literature, helping to establish a point of origin and knowledge for future research by any member of the scientific community. In a more precise way, the objectives of this study are:

-To determine the performance of COMPU-EDU in the WoS scientific literature.
-To establish the evolution of COMPU-EDU in reported WoS publications.
-To reveal the most important topics about COMPU-EDU in documents indexed in WoS.
-To meet the most representative WoS authors who have analyzed the COMPU-EDU concept.

2. Materials and methods

2.1. Research design

To conduct this study a research design based on a bibliometric methodology has been followed (Marín-Marín et al., 2019). This research methodology focuses its potential on the actions of quantification and exhaustive analysis of the scientific literature (Parra-González et al., 2020). Likewise, the proposed research design allows searching, registering, analyzing and predicting the scientific literature on a state of the art (López-Belmonte et al., 2020).

Specifically, in this work a co-word analysis has been carried out (Hirsch, 2005). This is based on studying the keywords extracted from the reported publications. This makes it possible to establish connections between the topics analyzed in the documents. It also manages to make a prediction of the topics that could be potential in the future. Likewise, co-word analysis allows mapping containing nodes to reflect performance, location of conceptual subdomains, and thematic evolution. Furthermore, in this work various bibliometric parameters (h, g, hg and q2 index) have been analyzed (Carmona-Serrano et al., 2021).

2.2. Procedure

To carry out an adequate study free of biases, other impact studies have been taken as a reference (Moral-Muñoz et al., 2020; Sott et al., 2020) and various processes have been carried out: First, WoS was chosen as the basis of data to deploy the documentary analysis. Later, the concept (computer) was delimited to report the scientific literature. Next, the search equation ("computer*") was created. This was applied in the search field allusive to the title of the indexed documents. A total of 247913 publications were reached. The search was limited in the main WoS collection, specifically in the categories Education Educational Research, Education Scientific Disciplines, Psychology educational and Education Special. The following indices were taken: SCI-EXPANDED, SSCI, A & HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED and IC. In addition, the search time interval between 2000 and 2020, inclusive, was refined. Various exclusion criteria were established: 1-Repeated or poorly indexed documents; 2-Documents prior to the year 2000; 3-Documents of the year 2021, for not having finished the year. These actions reported a final analysis unit of 10939 documents.

Likewise, the protocols of the PRISMA declaration were followed, with the purpose of developing a standardized research process at a scientific level and reflected in a flow diagram (figure 1).

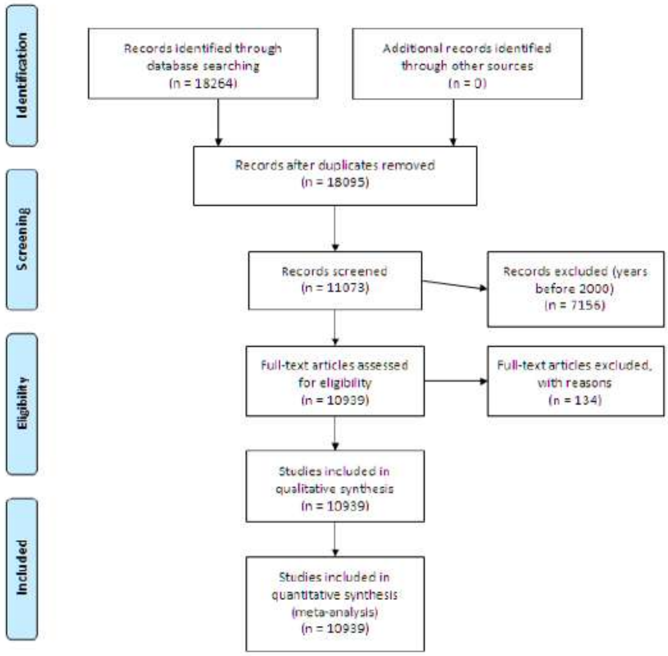

Figure 1. Flowchart according to the PRISMA declaration. Source: Self-made.

2.3. Data analysis

Various programs were used in data analysis. On the one hand, Analyze Results and Creation Citation Report were used to extract and analyze everything related to the year, authorship, country, type of document, institution, language, medium and most frequently cited documents about COMPU-EDU. For this, different inclusion criteria were established that allow the presentation of optimal results. These criteria were: year of publication (all literature comprised between the years 2000-2020); language ($x \geq 100$); knowledge area ($x \geq 500$); type of documents ($x \geq 200$); organizations ($x \geq 95$); authors ($x \geq 19$); sources of origin ($x \geq 165$); countries ($x \geq 500$); the five most cited documents.

Otherwise, if such criteria were not established, the results could not be represented in simply visual tables, since they would cover many cells, making the interpretation and understanding of the study difficult. Therefore, only publications that meet these requirements are reflected in the results tables.

On the other hand, the SciMAT software was used to perform a dynamic and structural development at a longitudinal level of the collected documents. That is, analyze the progression of a keyword converted into a topic in various defined time periods. Various processes were carried out with SciMAT:

-Recognition: In this process, first, the keywords of the reported publications were studied (n = 19,919). Then, maps with co-occurrence nodes were designed. Subsequently, a standardized network of joint words was made and the keywords with the greatest significance were determined (n = 18,642). Through a clustering algorithm, the most outstanding concepts and themes were revealed.
-Reproduction: In this process, strategic diagrams were generated to establish each of the terms according to their significance in the literature. These diagrams were divided (Figure 2a) into four quadrants (Q): top right (Q1) = motor and relevant themes; top left (Q2) = ingrained or isolated issues; bottom left (Q3) = emerging or disappearing issues; bottom right (Q4) = cross-cutting or underdeveloped themes. For its preparation, the principles of density and centrality were taken into account. The density is based on the internal strength of the network. Centrality is based on the level of connection between networks (Cobo et al., 2018). In turn, in this process networks were built with the topics addressed in the publications (Figure 2b). In these networks, the connections of the main topic with other linked terms are displayed.

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-Determination: In this process, various time periods were configured to articulate the reported publications and analyze the evolution of the nodes over time. Specifically, four periods were established (P1 = 2000-2004; P2 = 2005-2009; P3 = 2010-2014; P4 = 2015-2020). These time periods were configured taking the criterion of documentary similarity. To analyze the authors, only a single period was established that occupies the entire temporal space of the study (PX = 2000-2020). The strength of association between time periods was found by the number of keywords or themes in common.

-Performance: In this process, various production indicators were taken with their corresponding inclusion criteria (table 1). In addition, the significance and progression of the topics in the configured periods was analyzed (Figure 2c).

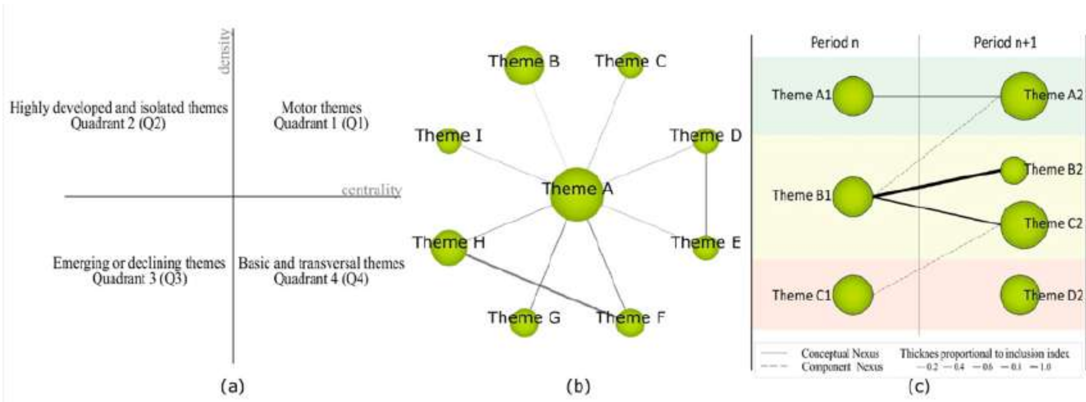

Figure 2. Strategic diagram (a). Thematic network (b). Thematic evolution (c). Source: (Herrera-Viedma et al., 2020).

Configuration	Values
Analysis unit	Keywords authors, keywords Web of Science (WoS)
Frequency threshold	Keywords: P_1 = (3), P_2 = (5), P_3 = (7), P_4 = (9)
	Authors: P_X = (6)
Network type	Co-occurrence
Co-occurrence union value threshold	Keywords: P_1 = (2), P_2 = (3), P_3 = (4), P_4 = (5)
	Authors: P_X = (3)
Normalization measure	Equivalence index: eij = cij2/Root (ci – cj)
Clustering algorithm	Maximum size: 9; Minimum size: 3
Evolutionary measure	Jaccard index
Overlapping measure	Inclusion rate

Table 1. Production indicators and inclusion criteria. Source: Self-made.

3. Results

3.1. Scientific output and production

The total volume of scientific production for the term "computer" in WoS is 247913 manuscripts. If the search term is narrowed down to the field of education, the scientific output is reduced to 18264 manuscripts. That is, 7.37% of the total. In this case, it can be seen that the educational line of this term is not currently exploited. Focusing the COMPU-EDU study on the 21st century, the total number of manuscripts in the last two decades is 11108. In comparison with the total production of the term "computer" in the field of education in the 21st century, this represents 60.82%. In other words, the largest volume of scientific production on COMPU-EDU has been produced in the last 20 years. If we analyse its evolution year after year, we can see that there has been a constant and upward evolution from 2004 to 2018. From 2018 onwards, scientific production begins to fall considerably. In 2020, the production of manuscripts is at levels similar to those of 2004. Interestingly, this decline in research on the term "computer" occurs both in education and in other fields (Figure 3).

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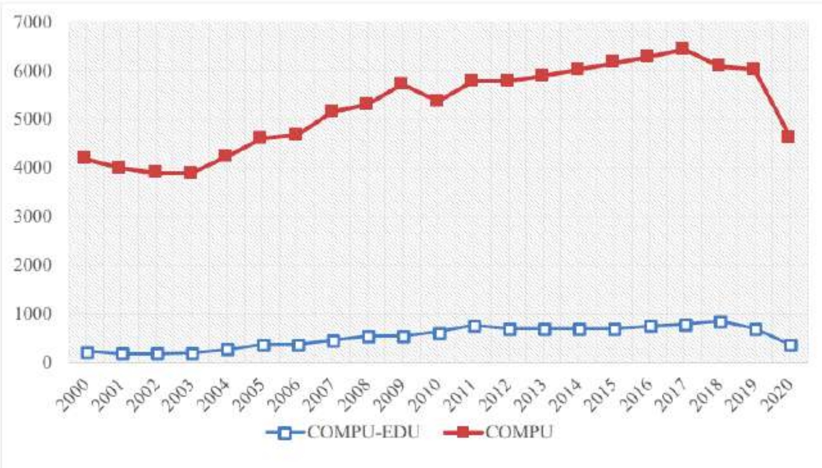


Figure 3. Evolution of scientific production. Source: Self-made.

Documents containing studies on the COMPU-EDU are written in English, accounting for more than 90% of the total output. Other languages show residual production volumes compared to English (Table 2).

Languages	n
English	10376
Spanish	197
Russian	151
Chinese	136

Table 2. Scientific language used. Source: Self-made.

The studies on the COMPU-EDU are mainly collected in the field of Education Educational Research, followed, at a considerable distance, by the field of Education Scientific Disciplines. Both areas focus their research on the field of education. Although, as can be seen in table 3, there are other areas whose volume of production is considerable, especially in the field of computing and engineering.

Denomination	n
Education Educational Research	7981
Education Scientific disciplines	3528
Computer Science Interdisicplinary Applications	1608
Computer Science Theory Methods	751
Engineering Multidisciplinary	627
Engineering Electrical Electronic	595
Psychology Educational	550

Table 3. Areas of knowledge. Source: Self-made.

Two types of documents are distinguished when presenting scientific results in COMPU-EDU studies. These are articles and proceedings papers. Articles have a slightly higher production volume than proceedings papers (table 4).

Denomination	n
Article	5773
Proceedings Paper	4723
Book Chapter	407
Editorial Material	212

Table 4. Type of document. Source: Self-made.

US institutions are leading the field in COMPU-EDU research. Three of them stand out in particular: State University System of Florida, University of California System and University System of Georgia (table 5).

Denomination	n
State University System of Florida	150
University of California System	131
University System of Georgia	128
University of Texas System	99

Table 5. Institutions. Source: Self-made.

In the field of COMPU-EDU research, there are about 5 authors with a production volume of more than 20 manuscripts. Among them, Milosz, M. stands out, who a total of 28 documents has listed in WoS (Table 6).

Authors	n
Milosz, M.	28
Fischer, F.	24
Goode, J.	22
Hwang, G.J.	20
Soh, L.K.	20

Table 6. Most prolific authors. Source: Self-made.

With regard to the source of publication, there is an equal production between conference papers and research articles. Of the publications at conferences, Frontiers in Education Conference stands out. Of the publications in scientific journals, Computers & Education stands out (table 7).

Source titles	n
Frontiers in Education Conference	362
Computers & Education	353
EDULEARN Proceedings	290
Procedia Social and Behavioral Science	278
INTED Proceedings	239
Computer Applications in Engineering Education	170

Table 7. Source of origin. Source: Self-made.

Of the countries with the highest volume of COMPU-EDU production, the United States stands out above the rest. It is followed by China, with a scientific output of over a thousand (table 8).

Countries	n
USA	3071
China	1289
Spain	587
England	542
Turkey	515

Table 8. Countries. Source: Self-made.

In the field of COMPU-EDU, there are several manuscripts with high citation levels. Among them, the manuscript by Connolly et al. (2012) stands out considerably, with over a thousand citations. This study focuses on a systematic review of computer games and serious games. Among the results obtained, they highlight that computer games have an impact on students, especially in the perceptual, cognitive, affective and emotional domains (table 9).

References	Citations
Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T., & Boyle, J.M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*, 661-686. https://doi.org/10.1016/j.compedu.2012.03.004	1020
Stahl, G., Koschmann, T., & Suthers, D.D. (2006). Computer-Supported Collaborative Learning. Cambridge Handbook of the Learning Science, 409-425. Cambridge Handbooks in Psychology.	685
Papastergiou, M. (2009). Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*, 1-12. https://doi.org/10.1016/j.compedu.2008.06.004	666
Mazer, J., Murphy, R., & Simonds, C. (2007). I'll See You On "Facebook": The Effects of Computer-Mediated Teacher Self-Disclosure on Student Motivation, Affective Learning, and Classroom Climate. *Communication Education*, *56*, 1-17. https://doi.org/10.1080/03634520601009710	476
Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education*, *46*, 71-95. https://doi.org/10.1016/j.compedu.2005.04.003	389

Table 9. Most cited articles. Source: Self-made.

3.2. Structural and thematic development

The keyword development indicates several aspects: a) it shows the total number of keywords used by authors in a given time period, represented by the number inside the circle; b) keywords that stop being used in the subsequent time period, represented by an upward arrow; c) new keywords in a time period, represented by a downward date; d) and overlapping keywords between time periods, represented by a horizontal date. The data shown in figure 4 show several aspects that need to be mentioned. On the one hand, the number of keywords used by the authors in the manuscripts is increasing. This indicates that the indexing of manuscripts is becoming more and more specific and concrete, with a view to their visibility in the scientific community. On the other hand, the percentage of coincidence between periods is shown. It can be seen that this percentage of coincidence is gradually decreasing. At first, between the 2000-2004 and 2005-2009 time periods, the percentage of coincidence of keywords is 42%. In contrast, between the 2010-2014 and 2015-2020 time periods, the keyword match rate is 32%. What do these data indicate? That the research trends on the subject analysed in this article are changing, given that new lines and trends in research are being generated.

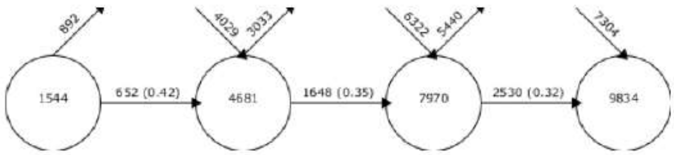
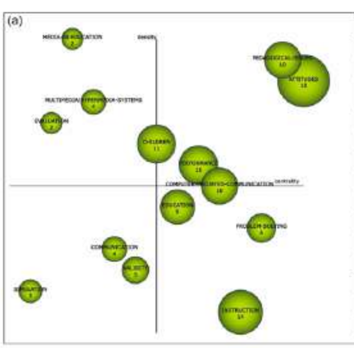


Figure 4. Keyword continuity between contiguous intervals. Source: Self-made.

In the following, both the interval diagram and the academic performance of the themes resulting from the co-word analysis will be analysed. In this case, the interval diagram shows the level of importance of the themes generated. This degree of importance is given by Callon's index, which generates a clustering process based on centrality and density. Centrality is based on the strength of the relationship between the external links of each of the themes with other themes. Density is based on the strength of the relationship between the external links existing in each of the themes. Academic performance provides the bibliometric value of the various themes generated in the analysis. These bibliometric values are based on various indicators, such as h-index, g-index, hg-index and q^2-index. In addition, this study analyses the average number of citations per document.

In the first period analysed, corresponding to the time interval between 2000 and 2004, the "attitudes" theme shows the highest academic performance, with higher bibliometric indicators than the rest of the themes. It should also be noted that this subject is also considered to be one of the driving themes. In this case, it can be considered as a fundamental axis in the research carried out in this period. Going into a little more depth on this theme, it can be seen that its research focus was directly related to experiences, students, gender differences, secondary school students, achievements and technology. With respect to the rest of the themes, it is worth highlighting the themes "problem-solving", "pedagogical-issues" and "validity", which show, in relation to academic performance, a higher document average citations than the rest of the themes. It should be noted that "pedagogical-issues" is considered, together with "performance", to be a driving theme. The "pedagogical-issues" theme focuses its line of research on the improvement of classroom teaching, gender differences in computer use, pedagogical techniques focused on collaborative learning, the use of various applications in different subjects, the use and application of learning environments, the evaluation of training processes developed with computers, post-secondary education and teaching and learning strategies. The "validity" theme, on the other hand, focuses on the validation and reliability of instruments for analysing the use of computers in education (figure 5).



Theme	Cuadrant	Documents	Citation	Document average citations	h-index	g-index	Hg-index	q²-index
Attitudes	Q1	24	904	37.66	16	22	18.9	24.74
Pedagogical-issues	Q1	12	594	49.5	10	12	10.95	20
Children	Q1-Q2	12	550	45.83	11	12	11.49	20.88
Problem-solving	Q4	8	470	58.75	6	8	6.93	14.28
Education	Q4	16	232	14.5	9	15	11.62	11.22
Performance	Q1	13	349	26.84	11	13	11.96	15.01
Instruction	Q4	17	671	39.47	14	17	15.43	21.82
Computer-mediated-comunication	Q1-Q4	14	686	49	10	12	10.95	19.24
Communication	Q3	4	29	7.25	4	4	4	6
Validity	Q3	5	248	49.6	5	5	5	14.14
Evaluation	Q2	4	31	7.75	2	2	2	6.63
Median-in-education	Q2	3	20	6.66	2	3	2.45	4.24
Multimedia/hipermedia-systems	Q2	4	34	8.5	4	4	4	6.63
Simulation	Q3	3	31	10.3	3	3	3	6.24

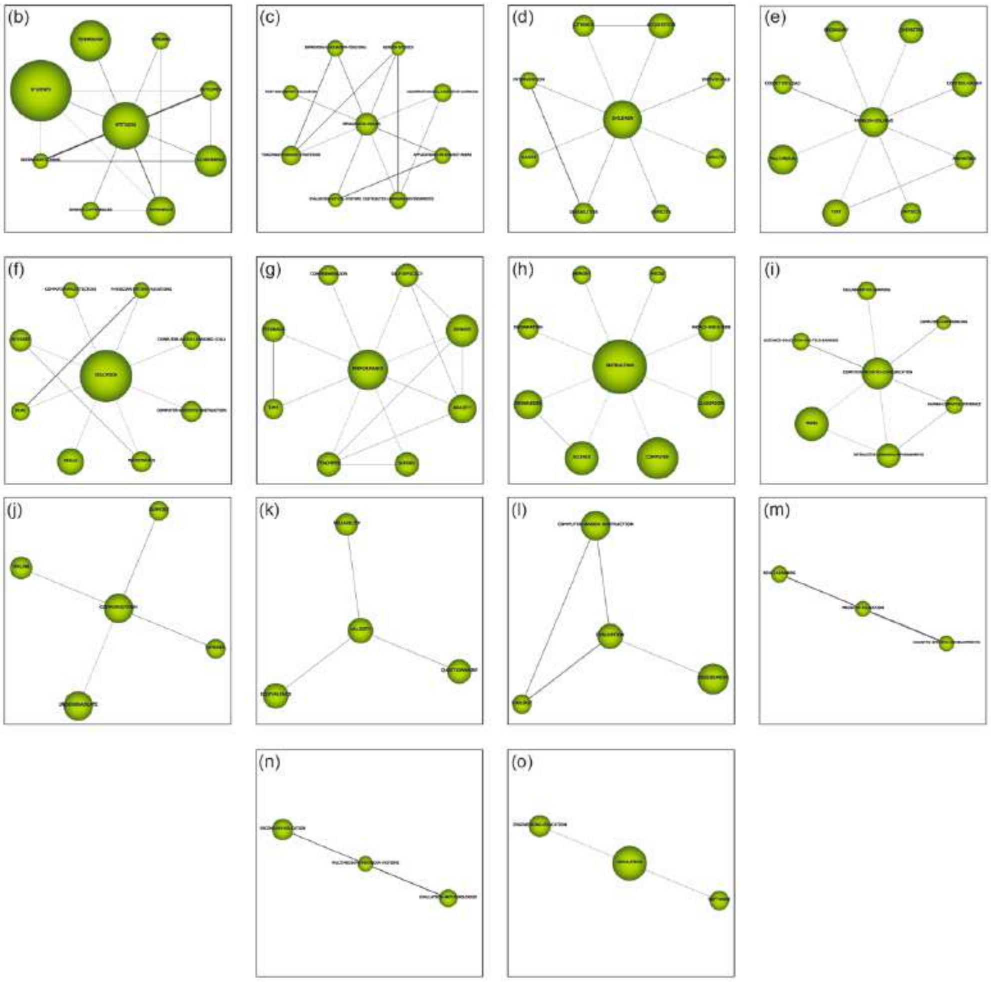
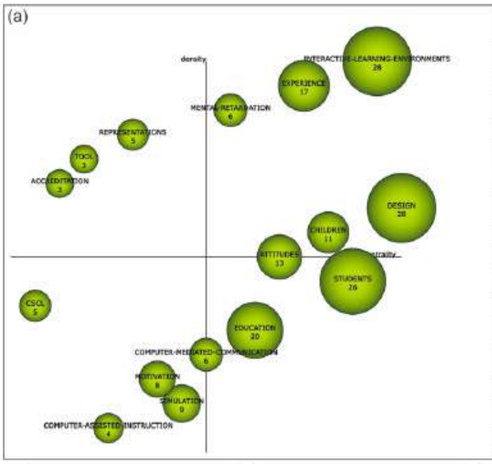


Figure 5. (a) Strategic diagram (h-index) and performance from 2000 to 2004. (b) "attitudes" theme. (c) "pedagogical-issues" theme. (d) "children" theme. (e) "problem-solving" theme. (f) "education" theme. (g) "performance" theme. (h) "instruction" theme. (i) "computer-mediated-communication" theme. (j) "communication" theme. (k) "validity" theme. (l) "evaluation" theme. (m) "media-in-education" theme. (n) "multimedia/hypermedia-systems" theme. (o) "simulation" theme. Source: Self-made.

In the second period analysed, from 2005 to 2009 inclusive, two themes stand out. These are "interactive-learning-environments" and "design". These themes have the highest bibliometric values. In addition, it is worth highlighting the theme "students", which shows slightly lower bibliometric values than the aforementioned themes. The remaining themes offer lower values than these three themes. In addition, it should be noted that the themes "interactive-learning-environments" and "motivation" show high values in relation to document average citations. On the other hand, both the themes "interactive-learning-environments" and "design" are also positioned as driving themes. This shows the high value of both themes in this period. Also noteworthy are the themes "mental-retardation", "experience" and "children", which are positioned as driving themes. If we analyse in more depth the themes considered as driving themes, we can see that "interactive-learning-environment" focuses its research on different educational stages, especially in primary and secondary education, on the application of active pedagogical methods, such as collaborative learning, on the use of applications for the teaching of different subjects, on the structures necessary for the development of educational technology, on training processes with the use of computers, on the use of multimedia systems and on the improvement of the pedagogical act in the classroom; "design" focuses its research on the information presented, on the attention of the subjects, on models generated, on the instruction of the participants, on science, on the use of words, on cognitive load and on academic performance; "mental-retardation" focuses on multiple disabilities, adults and intellectual disabilities; "experience" focuses on self-efficacy, reliability, gender differences, anxiety, teachers, meta-analysis studies and the impact of computer use on learning processes; and "children" focuses on autism, dyslexia, student tracking, adolescents, disabilities, pedagogical intervention, content acquisition and individual development (figure 6).



Theme	Cuadrant	Documents	Citation	Document average citations	h-index	g-index	Hg-index	q²-index
Interactive-learning-environments	Q1	47	3380	71.91	28	47	36.28	45.13
Children	Q1	23	404	17.56	11	20	14.83	17.86
Experience	Q1	28	1229	43.89	17	28	21.82	28.27
Attitudes	Q1-Q4	24	986	41.08	13	23	17.29	26.74
Design	Q1	49	2133	43.53	28	46	35.89	42
Students	Q4	47	2527	53.76	26	44	33.82	38.83
Education	Q4	50	1827	36.54	20	42	28.98	32.86
Simulation	Q3	13	617	47.46	9	12	10.39	19.67
Representations	Q2	9	139	15.44	5	8	6.32	10.49
Motivation	Q3	11	778	70.72	8	11	9.38	23.32
Mental-retardation	Q1	6	143	23.83	6	6	6	13.19
Computer-mediated-communication	Q3-Q4	10	331	33.1	6	8	6.93	13.86
Tool	Q2	4	150	37.5	3	4	3.46	13.3
Accreditation	Q2	6	44	7.33	3	4	3.46	4.24
CSCL	Q3	6	180	30	5	5	5	10.25
Computer-assited-instruction	Q3	5	114	22.8	4	5	4.47	12

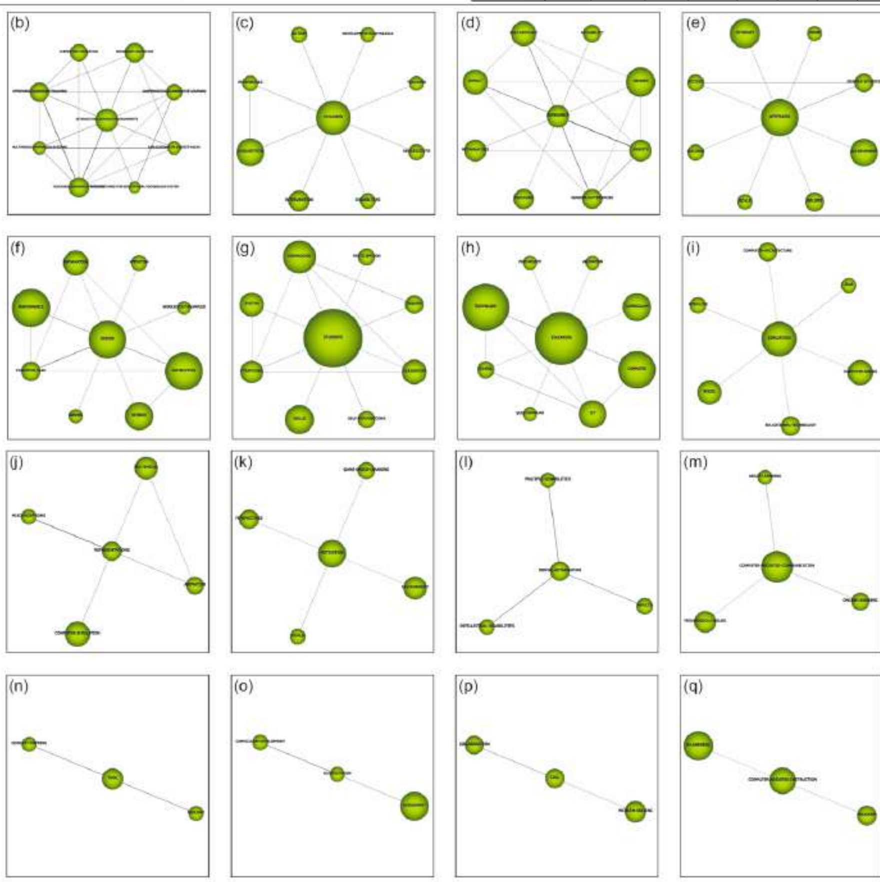
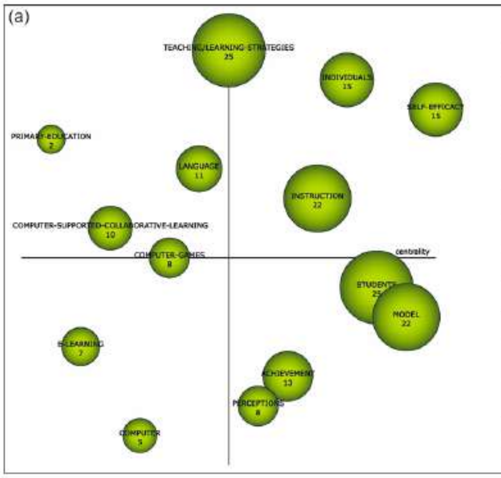


Figure 6. (a) Strategic diagram (h-index) and performance from 2005 to 2009. (b) "interactive-learning-environments" theme. (c) "children" theme. (d) "experience" theme. (e) "attitudes" theme. (f) "design" theme. (g) "students" theme. (h) "education" theme. (i) "simulation" theme. (j) "representations" theme. (k) "motivation" theme. (l) "mental-retardation" theme. (m) "computer-mediated-communication" theme. (n) "tool" theme. (o) "acreditation" theme. (p) "CSCL" theme. (q) "computer-assited-instruction" theme. Source: Self-made.

In the third period, from 2010 to 2014 inclusive, four themes stand out. The topics "teaching/learning strategies" and "students" are those with the highest bibliometric values. They are closely followed by "instruction" and "model". The remaining topics have much lower bibliometric values. In addition, the subject "computer-games", which shows high values in document average citations, should also be taken into account. It should also be noted that the subject "instruction" appears in this period as a driving theme, together with "individuals" and "instruction". Analysing each of them in more depth, it can be seen that the theme "instruction" is related to meta-analysis studies, knowledge acquisition, anatomy, animation, disabilities, pedagogical intervention, subject skills and didactic strategies used by teachers; the theme "individuals" is related to people related to the educational field, multiple disabilities, children, developmental disabilities, intellectual disabilities, educational technology and knowledge acquisition; and the thematic "self-efficacy" relates to anxiety generated by the use of computer devices, the acceptance of technology by those involved in the teaching and learning process, the attitudes of those involved in the pedagogical act, in the experience of the agents of the didactic act and in the validation of the instruments (figure 7).



Theme	Cuadrant	Documents	Citation	Document average citations	h-index	g-index	Hg-index	q²-index
Teaching/learning-strategies	Q1-Q2	53	2111	39.83	25	45	33.54	32.79
Self-efficacy	Q1	46	718	15.60	15	26	19.75	21.21
Instruction	Q1	62	1676	27.03	22	38	29.29	30.03
Individuals	Q1	38	700	18.42	15	25	19.36	21.21
Computer-games	Q2-Q3	27	1220	45.18	8	15	10.95	13.56
Students	Q4	92	2231	24.25	25	45	33.54	31.62
Model	Q4	47	1648	35.06	22	40	29.66	33.17
Achievement	Q4	32	954	29.81	13	30	19.75	22.52
Language	Q2	16	414	25.87	11	15	12.85	18.17
Perceptions	Q4	20	358	17.9	8	18	12	16.97
Computer-supported-collaborative-learning	Q2	16	383	23.93	10	12	10.95	13.78
E-learning	Q3	23	185	8.04	7	13	9.54	12.12
Computer	Q3	13	102	7.84	5	9	6.71	10.49
Primary-education	Q2	6	22	3.66	2	4	2.83	5.1

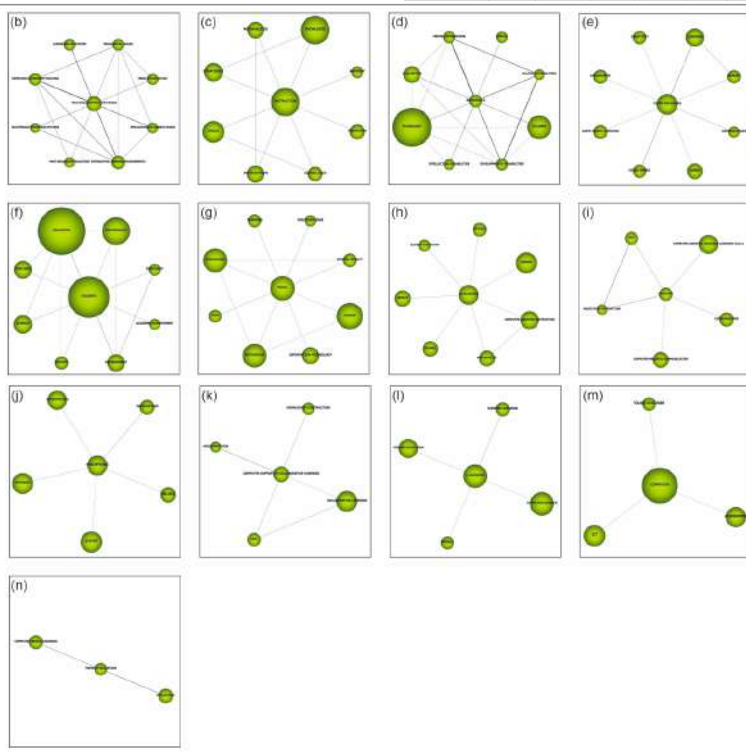
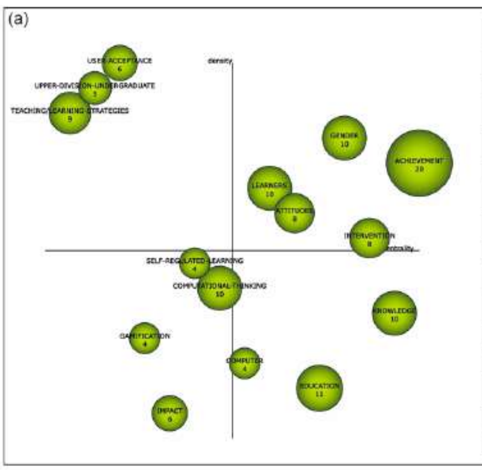
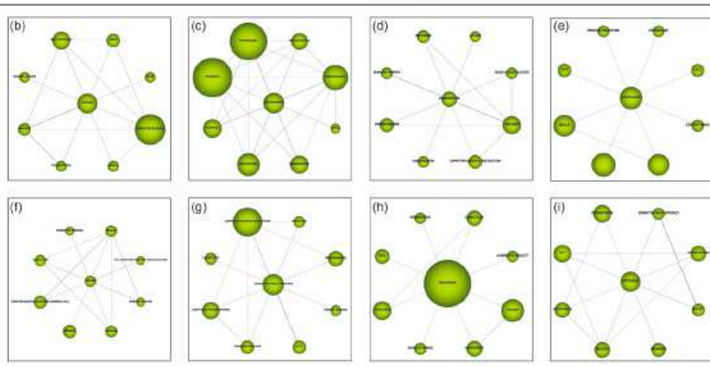


Figure 7. (a) Strategic diagram (h-index) and performance from 2010 to 2014. (b) “teaching/learning-strategies” theme. (c) “self-efficacy” theme. (d) “instruction” theme. (e) “individuals” theme. (f) “computer-games” theme. (g) “students” theme. (h) “model” theme. (i) “achievement” theme. (j) “language” theme. (k) “perceptions” theme. (l) “computer-supported-collaborative-learning” theme. (m) “e-learning” theme. (n) “computer” theme. (o) “primary-education” theme. Source: Self-made.

In the fourth and final period, from 2015 to 2020 inclusive, only one subject stands out in terms of bibliometric indices. This is the case of "achievement". The rest of the topics have lower bibliometric values. It should also be noted that this theme appears as a driving theme in this period, together with other themes such as "learners", "attitudes", "gender" and "intervention". A more in-depth analysis of each of these themes shows that "achievement" is related to the use of educational technology, in meta-analysis studies, student achievement, learning process goals, mathematics, student motivation, science subjects and students; "learners" to English language learning, computer-mediated communication, foreign language acquisition, language acquisition, feedback, computer-assisted language learning and content acquisition; and "attitudes" to perceptions of the use of technology in education, to the use of technology in education, to the use of technology in education, to student achievement, to the objectives set in the learning process, to the subject of mathematics, to student motivation, to science subjects and to students; "attitudes" with learner perceptions, computer self-efficacy, information acquisition, anxiety, subject behaviour, beliefs of those involved in learning processes, in educational experiences and in the use of information and communication technologies; "gender" with students' own learning self-efficacy, STEM, stereotypes and differences established between people of different gender and race in the use of computers in education; and "intervention" with autism, students' outcomes, computer-assisted instruction, children, infant learners, concept understanding and working memory. Furthermore, the themes "self-regulated-learning", "computational-thinking", "gamification" and "impact" have to be taken into account. This is due to their location in the diagram, given that in the coming years they may be the new trend in the field of computer research in education (figure 8).



Theme	Cuadrant	Documents	Citation	Document average citations	h-index	g-index	Hg-index	q²-index
Gender	Q1	74	415	5.60	10	18	13.42	14.83
Achievement	Q1	232	1777	7.65	20	32	25.3	26.08
Intervention	Q1	45	231	5.13	8	11	9.38	3.98
Knowledge	Q4	61	305	5	10	14	11.83	13.04
Learners	Q1	57	334	5.86	10	15	12.25	12.65
Computational-thinking	Q3	76	374	7.92	10	17	13.04	14.14
Education	Q4	88	351	3.98	11	14	12.41	12.41
Attitudes	Q1	60	303	5.05	8	14	10.58	11.31
User-acceptance	Q2	21	154	7.33	6	12	8.49	11.22
Teaching/learning-strategies	Q2	26	210	8.07	9	13	10.82	12
Computer	Q4	28	193	6.89	4	13	7.21	6.93
Upper-division-undergraduate	Q2	19	53	2.78	5	6	5.48	5.48
Gamification	Q3	15	103	6.86	4	10	6.32	12.17
Impact	Q3	16	120	7.5	6	10	7.75	11.22
Self-regulated-learning	Q3	8	40	5	4	6	4.9	6.32



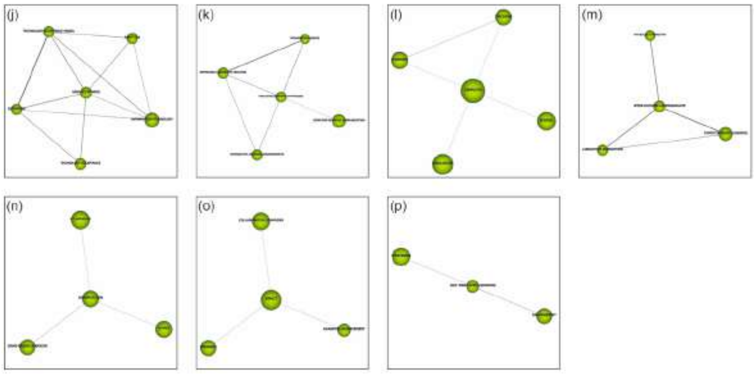


Figure 8. (a) Strategic diagram (h-index) and performance from 2015 to 2020. (b) "gender" theme. (c) "achievement" theme. (d) "intervention" theme. (e) "knowledge" theme. (f) "learners" theme. (g) "computational-thinking" theme. (h) "education" theme. (i) "attitudes" theme. (j) "user-acceptance" theme. (k) "teaching/learning-strategies" theme. (l) "computer" theme. (m) "upper-division-undergraduate" theme. (n) "gamification" theme. (o) "impact" theme. (p) "self-regulated-learning" theme. Source: Self-made.

The location of the various themes presented in figures 5, 6, 7 and 8 is shown in table 10. The data show that no one theme is present in all periods. This means that there is a conceptual gap in the COMPU-EDU field of study. Of all the themes resulting from the co-word analysis, there are two that are repeated in three of the four periods. These are the cases of "attitudes" and "education". In the case of "attitudes", its position in the diagram has always been relevant. In the case of "education" it has not. This indicates that the attitudes of those involved in the teaching and learning process have been of great relevance to the scientific community.

	P1(2000-2004)	P2(2005-2009)	P3(2010-2014)	P4 (2015-2020)
Attitudes	Q1(28.12/19.5)	Q1-Q4(11.74/3.85)		Q1(6.8/3.65)
Pedagogical-issues	Q1(25.08/19.94)			
Children	Q1-Q2(9.65/9.45)	Q1(13.56/4.59)		
Problem-solving	Q4(21.17/5.98)			
Education	Q4(12.95/6)	Q4(11.27/3.13)		Q4(7.19/1.03)
Performance	Q1(14.49/6.88)			
Instruction	Q4(20.77/2.58)		Q1(10.57/3.19)	
Computer-mediated-communication	Q1-Q4(17.68/6.29)	Q3-Q4(5.59/2.54)		
Communication	Q3(7.63/5.51)			
Validity	Q3(7.76/5.43)			
Evaluation	Q2(1.21/12.61)			
Media-in-education	Q2(5.83/25.93)			
Multimedia/hypermedia-systems	Q2(6.48/17.78)			
Simulation	Q3(0.89/2.69)	Q3(3.25/1.44)		
Interactive-learning-environments		Q1(19.57/13.91)		
Experience		Q1(12.01/9.62)		
Design		Q1(21.14/5)		
Students		Q4(17.6/3.82)	Q4(14.3/2.28)	
Representations		Q2(1.41/7.28)		
Motivation		Q3(3.14/2.17)		
Mental-retardation		Q1(8.81/8.51)		
Tool		Q2(0.97/7.06)		
Accreditation		Q2(0.12/6.02)		
CSCL		Q3(0/3.59)	Q2(0.68/3.04)	
Computer-assisted-instruction		Q3(1.05/1.14)		
Teaching/learning-strategies			Q1-Q2(5.31/19.26)	Q2(0.75/14.98)
Self-efficacy			Q1(16.63/7.96)	
Individuals			Q1(10.91/17.6)	
Computer-games			Q2-Q3(3.42/2.45)	
Model			Q4(14.31/1.37)	
Achievement			Q4(8.63/1.02)	Q1(23.03/5.4)
Language			Q2(3.67/4.07)	
Perception			Q4(5.87/0.96)	
E-learning			Q3(0.56/1.15)	
Computer			Q3(1.41/0.5)	Q4(2.45/1.11)
Primary-education			Q2(0.1/4.42)	
Gender				Q1(8.58//5.55)
Intervention				Q1(9.39/3.24)
Knowledge				Q4(12.61/1.32)
Learners				Q1(4.31/3.7)
Computational-thinking				Q3(2.36/2.38)
User-acceptance				Q2(0.83/26.17)
Upper-division-undergraduate				Q2(0.78/21.32)
Gamificacion				Q3(1.16/1.28)
Impact				Q3(1.36/0.91)
Self-regulated-learning				Q3(1.51/2.76)

Note: (X/Y), X=centrality; Y=density.

Table 10. Principal research themes related to COMPU-EDU from 2006 to 2019. Source: Self-made.

Moreno-Guerrero, A. J.; Marín-Marín, J. A.; Parra-González, M. E.; López-Belmonte, J. (2022). Computer in education in the 21st century. A scientific mapping of the literature in Web of Science. *Campus Virtuales*, 11(1), 201-223. https://doi.org/10.54988/cv.2022.1.1019

The thematic development of studies related to the COMPU-EDU is established on the basis of Jaccard's index. The relationship between themes is established if they share keywords or themes. Depending on the relationship, the connection is represented in different ways. In this case, connections established by keywords are represented by dashed lines. It is also called a non-conceptual connection. Connections established by themes are represented by continuous lines. It is also called conceptual connection. Depending on the number of coincidences between themes in contiguous periods, the thickness of the line increases or decreases. The greater the thickness, the greater the number of coinciding themes or keywords. In this case, following the data provided by figure 9, one line of research stands out from the rest. This is the case of "multimedia/hypermedia-systems_interactive-learning-environment_teaching/learning-strategies_teaching/learning-strategies". This indicates that the scientific community has attached great importance to interactive environments in teaching and learning processes. There are two other lines of research, but with less strength than the previous one. This is the case of "attitudes-experience-self_efficacy-attitudes" and "attitudes-experience-self_efficacy-user_acceptance". In other words, these lines of research show the importance given by the scientific community to students' attitudes in the development of training processes based on the use of computers, as well as taking into account their acceptance. Other lines of research can be seen, but they are not as relevant as those indicated above. Another aspect to note is that there are a number of non-conceptual connections. This indicates that there is not a strong relationship between the lines of research developed by the scientific community.

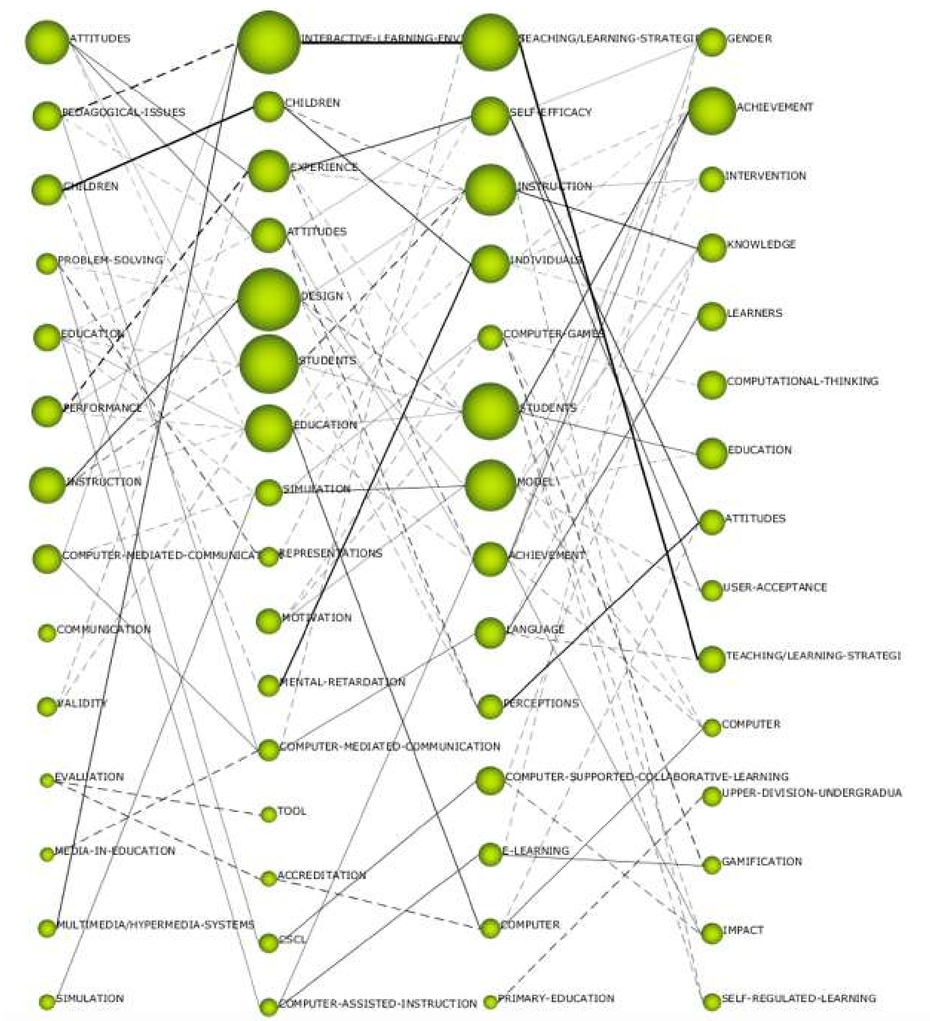


Figure 9. Thematic development by h-index. Source: Self-made.

3.3. Authors with the highest relevance index

In relation to the authors, there are three authors who can be considered as driving forces in this field of study. These are the cases of Davies, D.K., Redondo, J.L., and Palfrey, J. In addition, the authors Fischer, F., Falkner, N., and Milosz, M., should be borne in mind, given that their location in the diagram places them as authors who may be, in the not too distant future, authors of great relevance in the field of study of COMPU-EDU (figure 10).

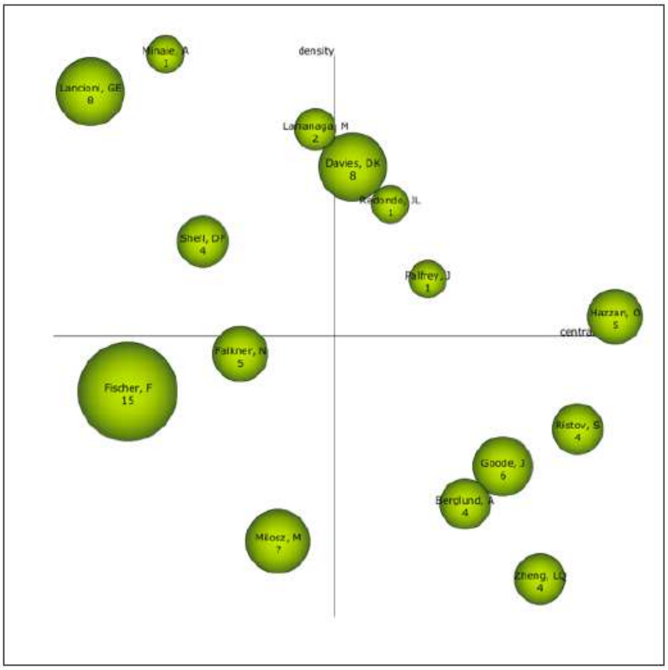


Figure 10. Strategic author diagram of all scientific output. Source: Self-made.

4. Discussion

As it has been shown, the appearance and proliferation of the use of computers has revolutionized the way we communicate (Liao et al., 2018), carry out actions that were considered buying and selling as face-to-face relationships (Pérez-Amaral et al., 2020), or even with regard to training (Cairns & Malloch, 2017; Moeller et al., 2015).

As different tools associated with the use of computers have evolved and different applications have been developed and their usefulness seen. In education, this has meant a breakthrough and revolution, since different benefits have been obtained, such as the creation of collaboration and communication networks between educational institutions, the implementation of educational networks and virtual training supported by virtual learning environments (Alencar & Netto, 2020; Foster & Shah, 2021).

As has been observed in the results, the term COMPU-EDU, if WoS is taken into account, has accounted for 7.37% of the total scientific production. If this data is analyzed in the whole of the scientific production of computer in the 21th century, it may seem scarce. But if the rest of the disciplines are analyzed, it can be seen that COMPU-EDU is the fourth most studied category in WoS. It only has categories like electrical engineering or computer science ahead. That is to say, the scientific production of computers in the educational field is high.

In this 21th century, the volume of scientific production of the term COMPU-EDU has evolved, in a similar way to the studies on the term computer in general. In this case, in the educational field, it can be observed that from 2010 to 2018, it is the moment when scientific production has been most prolific. It should be noted, both in the research lines of the term computer in general, and in the educational field, there is a significant decrease, in terms of scientific production. Could we be facing a change in trends in research? This fact is possible, above all because research may be focusing on other more specific elements in the computational field, such as robotics (López-Belmonte, et al., 2021) or augmented reality (Arici, Yildirim, Caliklar, Yilmaz, 2019). In these cases, the trend in recent years has been upward.

Analyzing the academic performance of the scientific production on the term COMPU-EDU, it is observed that the language used mainly by the scientific community to present their findings is English. This is normal in the WoS database, since it is a database that collects more focused studies from the Anglo-Saxon field. In addition, since it is the universal language, it makes sense to think that the way to reach the largest number of scientists in the world is English.

The areas of knowledge that collect the most manuscripts on this line of research are, obviously, education educational research and education scientific disciplines, although they are not the only ones. Other areas of knowledge, such as computer science or engineering, also present a high number of researches in this field of study. This is due to the fact that in these other areas the computer is used as the main work tool in the teaching and learning processes.

The main type of manuscript used is the articles closely followed by the proceedings paper. This can have two interpretations. On the one hand, the fact of using research articles in a field of knowledge is due to the fact that there is a base of studies established over time. But on the other hand, presenting the findings in proceedings paper is because new lines of research are being presented. This fact is evident in this study, where the evolution of scientific production has evolved over time, generating new trends in studies on the term COMPU-EDU. This is reflected in the sources of presentation of the data. Examples of this are Frontiers in Education Conference, which compiles proceedings paper; and Computer & Education, which compiles research articles.

The United States stands as the largest production of scientific literature on the term COMPU-EDU. This is reflected in the main institutions that generate manuscripts in these lines. All of them from that country. The institutions of the State University System of Florida, the University of California System and the University System of Georgia stand out above the rest.

There is no author who stands out above the rest, as far as production volume is concerned. Among all those analyzed, Milosz, M. stands out in this regard, which slightly exceeds the rest of the scientists who analyze the term COMPU-EDU. But the fact of being the one with the most production in the scientific community does not mean that it is the most relevant. In this case, this privilege falls to three authors: Davies, DK, Redondo, JL, and Palfrey, J. In addition, it should be noted that there are authors, who probably, in the not too distant future, may be relevant in this field of study. This is the case of three other authors Fischer, F., Falkner, N., and Milosz, M. As can be seen, Milosz, M. presents the highest production value and is positioned as an emerging author. Be that as it may, all the authors presented here should be considered for those who want to analyze or start studies in COMPU-EDU.

In relation to the most cited manuscripts, it can be indicated that the volume of citation of this field of study is high, when compared with other studies such as, in this case, robotics (López-Belmonte, et al., 2021) or augmented reality (Arici, Yildirim, Caliklar, Yilmaz, 2019). Of all the manuscripts, the one that stands out the most, with a number of citations greater than a thousand, is the manuscript by Connoly et al. (2012). This manuscript, coincidentally, follows a line of research similar to this study, since it is a systematic review. In it, computer games and serious games are analyzed. The rest of the works that follow, such as that of Stahl et al. (2006) or that of Papastergiou et al. (2009), exceed half a thousand citations.

Now focusing the analysis on the structural and thematic development of the term COMPU-EDU, several aspects are observed that are worthy of mention. In the first place, as has been observed in the type of manuscripts used by the scientific community to present their findings, there is a change in trend. That is to say, it goes from a 42% coincidence of keywords between the periods 2000-2004 and 2005-2009, to a 32% coincidence between the periods 2010-2014 and 2015-2020. These data confirm that although there is a base line of research established over time, there is a change in trends.

This fact is also reflected in the academic performance and the positions of the various themes resulting from the analysis. In this case, in the first period (2000-2004), the topic "attitudes" can be considered the most relevant and of greatest interest to the scientific community. In other words, the research focused in this first period, mainly, on the attitudes of the members of the educational community in the use of the computer in the educational environment. In addition, in this period other trends are observed in this field of study, such as existing gender differences in the use of the computer. Or aspects related to teaching and learning processes, as is the case with pedagogical methods. Or the evaluation systems when using the computer. Or the validations of evaluation instruments, necessary in this case to be able to present valid and reliable findings.

This line marked in that first period is broken in the second period (2005-2009), given that the research topics move from the attitudes of the students to interactive learning environments and towards the designs of techno-pedagogical applications. In addition, although to a lesser extent, in this period attention to students with special educational needs begins to gain strength, mainly those with intellectual disabilities or autism. It also focuses the study on the students themselves, of various ages, putting more interest in the learning and content achieved by the students themselves.

This trend is broken again, in part, in the third period (2010-2014), since the main focus of the educational community is mainly focused on the teaching and learning strategies necessary to apply the use of the computer. Although it also continues to focus on the students themselves, but from another perspective. That is, it focuses on students, but on their individual development and the self-efficacy generated in them when they use the computer in education. In addition, during this period, students with special educational needs continue to be analyzed.

Finally, in the last period (2015-2020), the trend breaks again. In this period, the focuses are on student academic achievement, but also on learning, attitudes, gender of the students, and intervention. In other words, during this period, other lines of research started in previous periods were taken up again, with more relevance.

Looking ahead to the coming years, it can be seen that topics such as "self-regulated-learning", "computational-thinking", "gamification" and "impact" may be positioned as relevant research topics of great interest to the scientific community.

If all the periods are analyzed as a whole, observing the thematic evolution of the term COMPU-EDU, the changes in trends in the scientific field are confirmed. In addition, other noteworthy aspects are displayed. On the one hand, although there are trend changes in the periods analyzed individually, it is observed, in the set of periods, that there are three lines of research worth mentioning, such as the cases of "multimedia / hypermedia-systems_interactive-learning- environment_teaching / learning-strategies_teaching / learning-strategies", "attitudes-experience-self_efficacy-attitudes" and "attitudes-experience-self_efficacy-user_acceptance". In other words, the baseline of research established over time in the COMPU-EDU study focuses on the teaching and learning processes, and on the attitudes of students in the use of the computer. On the other hand, there are no great connections between the various lines of research generated by the scientific community, which shows the diversity of lines and the different trends in this field of study.

5. Conclusions

It can be concluded that the COMPU-EDU investigations are currently at an inflection point, given that there is a downward trend, as far as production volume is concerned. The scientific community is beginning to focus its research on other more specific branches of computer, such as augmented reality or robotics. In

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addition, the scientific production of COMPU-EDU in the 21th century focuses mainly on the attitudes of the members involved in the pedagogical act, on gender differences, on the elements of the teaching and learning processes - pedagogical methods and evaluation - and in the attention of students with special educational needs. Probably in the future the lines of research will begin to focus on self-regulation of learning, computational-thinking and gamification.

The main limitations of this research are due to the characteristics of the WoS data purification. Thus, you can find repeated documents, and even others that are not related to the subject of the study. Furthermore, the intervals of the analyzed documents show differences as a function of the time intervals. Researchers have established their own criteria within these parameters, in order to show consistent results. That is why, after these established criteria and decisions taken, the results that are presented would be useful for the scientific community due to the rigor followed for their realization.

With regards to future lines of research, this same research could be carried out but applying inclusion and exclusion criteria, such as specific areas, which serve their teachers in their work, given their usefulness, such as a foreign language, math or social studies.

6. Study implications

Based on the results of this original study, different implications of a theoretical and practical nature are detected. On a theoretical level, this work involves organizing and presenting scientific production in terms of the subject, which means that years of scientific work are radiographed through this document. In addition, this assumes that there are trends, which are useful for researchers and even teachers, since they can guide their work towards them.

As for the practical implications, they also affect teachers, researchers and the scientific field in general. These implications are associated with the theoretical implications mentioned above, but they go a little further, since, based on this radiography on the publications, teachers can apply certain information to their teaching practice, which has already been proven in other situations and through which benefits have been obtained. With what we would not be talking about the dissemination of knowledge through this study (which has already been said of the importance of its usefulness) but it can also influence the pedagogical practices of teachers to improve the teaching-learning processes. This fact is considered of crucial usefulness for teachers, since having tools that help them improve these processes are important. But in addition, not only for teachers, but also people in charge of institutions, they can also apply different knowledge in these documents presented to promote changes in them, which is considered useful in this sense as well.

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