education sciences

Review

Analysis of *Scratch* Software in Scientific Production for 20 Years: Programming in Education to Develop Computational Thinking and STEAM Disciplines

Pablo Dúo-Terrón

Department of Information and Communication Technologies Applied to Education, Faculty of Education, International University of La Rioja (UNIR), 26006 Logroño, Spain; pablo.duo@unir.net

Abstract: Scratch is an educational software based on visual programming blocks. It was created in 2003 by the Massachusetts Institute of Technology Media Lab (MIT) and it develops computational thinking (CT) skills from an early age in schools and allows STEM (science, technology, engineering and mathematics) projects to be carried out. The aim of this research is to know the development of the scientific production of the Scratch programme in the educational field in scientific articles in WoS and its link with the STEM field. The methodology used in this study is of a bibliometric nature with an analysis of the development in the scientific literature and co-words. The Scratch in Education (Scratch-EDU) programme has been studied using the Web of Science (WoS) database. WoS, Vosviewer and SciMAT were used to extract the results and a total of 579 manuscripts were analysed. The results of the study show that the first scientific article on Scratch published in WoS dates back to 2004, although it is from 2011 when a considerable volume of studies began to appear in the scientific literature, and moreover, in recent years the scientific literature relates Scratch-EDU with topics and keywords related to the STEM field. The conclusions of the study are that the Scratch programme has had a progressive evolution in the scientific field related to education from 2012 to 2020, mainly in proceedings papers, with a decrease in manuscripts in the last two years. The emerging themes and keywords that have most influenced Scratch-EDU manuscripts in recent years are related to the terms "Implementation" and "Curriculum", connected in turn, with terms such as "pedagogy", "public school" or "students". Another term that stands out in the development of scientific evolution is "Computational Thinking", associated with topics such as "Primary Education", "Learning" or "Problem Solving". Finally, a discussion and conclusion of the results has been carried out, which can serve as a turning point for future lines of research on programming and CT in the STEM field from an early age in education.

Keywords: Scratch; education; STEM; STEAM; computational thinking; SciMAT; Web of Science

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1. Introduction

Twenty-first century learning skills and abilities are a necessity in our rapidly changing times [1] due to the onslaught of technology and are of great importance to the new generations [2]. In recent years, many countries have updated curricula and syllabuses in compulsory education [3–6] by introducing the basic concepts of computing and science, to develop students' computational thinking (CT) skills, thus fostering other subjects such as science, technology, engineering and mathematics (STEM) disciplines [7], so that young people are equipped to face the challenges of the future and to make the most of the opportunities offered by technology [8]. One of the ways to develop this STEM field as a teaching tool [9] is block programming from an early age. These skills enable the understanding of the artificial world around us, such as the home or workplace, which are controlled by human designed systems [10].

1.1. Development of Computational Thinking Skills

The first approaches to the term CT occurred in the 1960s and 1970s when Papert described it as procedural thinking in the use and development of programming skills and algorithmic designs [11]. For Wing [12,13], the first person to introduce the term CT into the scientific field in 2006, CT is the development and knowledge that people acquire by thinking like a computer programmer. CT is a fundamental and analytical skill that children of the 21st century should develop [14] because it allows students to abstract [15] from a problem solving situation [16] and break it down into simpler ones until a solution is found [17].

In today's labour market, knowledge and skills in digital and social competences are required [18], as it allows teamwork and the development of socio emotional skills [19]. Therefore, schools must train students to learn and practice CT skills in order to be able to use new technologies and to face the challenges of the 21st century, where technology is a reality in any area of knowledge [20]. In this way, countries such as Spain already include the term CT in their curricula from Pre-school to Baccalaureate [21].

In the field of education, the Scratch programme (Scratch-EDU) is linked to CT skills development [22]. The potential benefits of Scratch-EDU for learning programming through mathematics have activated this field of research [23], because it allows for exploring, thinking, applying and consolidating mathematical concepts [24], where students can check in situ what it is for and how concepts such as negative numbers, planes and coordinate axes [25], angles, degrees, operations or geometry [26] are applied throughout the world. In this way, it reduces the workload of teachers in a teaching–learning task [27], as the students are the protagonists of this process. This philosophy of project work based on CT fosters the "Maker" culture in Makerspaces [28] or Classrooms of the Future, i.e., to create, develop, research, explore, interact and present [21,29], allowing for the stimulation of vocations in STEM [30].

1.2. Scratch in Education

Scratch dates back to 2003 (Figure 1), and the previous 20 years have made it one of the most popular programming languages in the educational world [31]. In turn, this technology can be a powerful tool for integrating art (A) and creativity in schools [32] by developing skills in STEAM disciplines [33]. In addition, students can explore and learn important skills such as algorithmic and critical thinking [34,35] in a fun way through the creation of projects, making it not only a one-to-one programme, but also a diverse and welcoming online community [36] that generates motivation [37–40] and sparks interest even in the scientific field of neuroeducation [41].

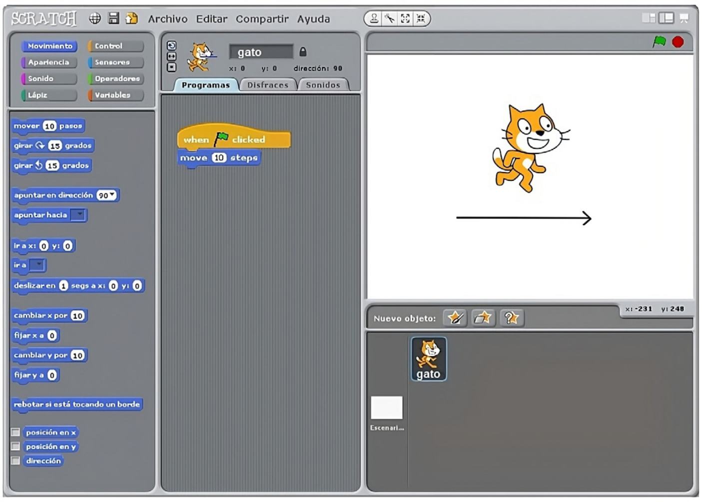

Figure 1. Scratch Software 1.0.

Students and users can be encouraged to share, collaborate and reinvent other users' creations from anywhere in the world, where computer syntax is not a problem and programming can be started from scratch [42]. It also features video tutorials that enable self-regulated and self-directed learning [43]. Thanks to Scratch's multilingual support available in more than 50 languages, languages can be learned [44] and this makes it accessible to a wide variety of people from different cultural and linguistic backgrounds. As a result of this internationalisation, "Scratch Day" [45] or "Hour of Code" [46], i.e., worldwide gatherings where schools celebrate the use of this tool, can be large or small events, for beginners or for more experienced "Scratchers".

The programming fundamentals of Scratch-EDU, tailored for children and adults, encourages inclusion and diversity in the classroom, and has even proven to be an engaging and successful tool [47] for bridging the gender gap in computer science and programming education [48] that has historically been dominated by men. By having a visual programming language, it makes programming more accessible to young people and people who do not have advanced reading and writing skills [49,50]. This allows for adaptation to the needs and learning paces of students [51] because it allows them to personalise and adapt their programming experience according to their individual needs and preferences, generating efficiency and interaction [52], and regardless of background or previous knowledge and skills in programming [53]. In addition, Scratch 3.0 has an offline desktop version for computers and smartphone applications, offering the opportunity to be used in those parts of the world where the Internet is difficult to reach.

1.3. STEM Projects through Scratch

Scratch, being a free software programme because it can be reinvented if you have programming knowledge [54], allows you to connect other educational resources that promote CT and that are a launching pad for STEM projects [55–58], even encouraging creativity, logical reasoning [59] and art to develop STEAM disciplines [60]. This can have a transdisciplinary, multidisciplinary and interdisciplinary influence in schools [50] because it allows you to create interactive stories, games, animations, music and art [48]. In this way, there is a competence formation of the student, for example, the development of entrepreneurial competence to elaborate 3D designs by composing geometric bodies [61,62].

Programming and robotics are perceived as difficult and challenging [63,64]; however, the first approaches to Scratch in school are related to linear floor robots such as Beebot or Bluebot [65]. Furthermore, educational boards are available in Scratch extensions such as Makey Makey [66–68] designed by students at the Massachusetts Institute of Technology Media Lab (MIT), or other types of boards such as Microbit [69], with built in sensors and digital pins. The function of these boards is to connect the virtual world with the real world, and they also serve as a "hub" or "brain" for other robots in the educational sphere, thus familiarising and connecting students with the world of programming and robotics [70–72]. Moreover, Scratch has direct extensions to robots with their own hubs such as Mindstorm [73] or Lego [74].

Another outstanding function is the approach to the world of artificial intelligence (AI) through machine learning [75] and Scratch for students from an early age and for teachers [76], with programmes that use machine learning [77] to carry out classifications, train the machine and generate predictions. Programmes such as Machine Learning for Kids or LearningML have a fork or bridge to Scratch to carry out AI projects [78]. According to [77], introducing AI content in schools is necessary to awaken vocations among young people and to address the growing number of STEM and AI positions expected in the near future, and it also connects different basic knowledge from various areas of knowledge in a multidisciplinary and competency based manner [79].

All these functions allow students to become familiar and acquire knowledge with the world of programming, being a bridge to more advanced and powerful resources in the field of computer science such as the Arduino board [80,81], Raspberry Pi [82], mobile application creations such as MIT APP Inventor [83,84], robot simulators such as Open Roberta [85] or textual programming language such as Python [86], C++ or Java [87].

1.4. Twentieth Anniversary of Scratch Software

In 2023, Scratch will be 20 years old, after its creation by the Lifelong Kindergarten Group of the MIT [88,89] (Figure 2), led by Mitchel Resnick, researcher, teacher and designer of creative and educational technological tools [90]. Although there have previously been programmes to introduce the world of programming in schools from an early age, such as Alice [91] or Logo in the 1960s, these have gradually disappeared due to a lack of teacher training [92], although the latter has now been transformed into the LEGO Mindstorms robot [93].

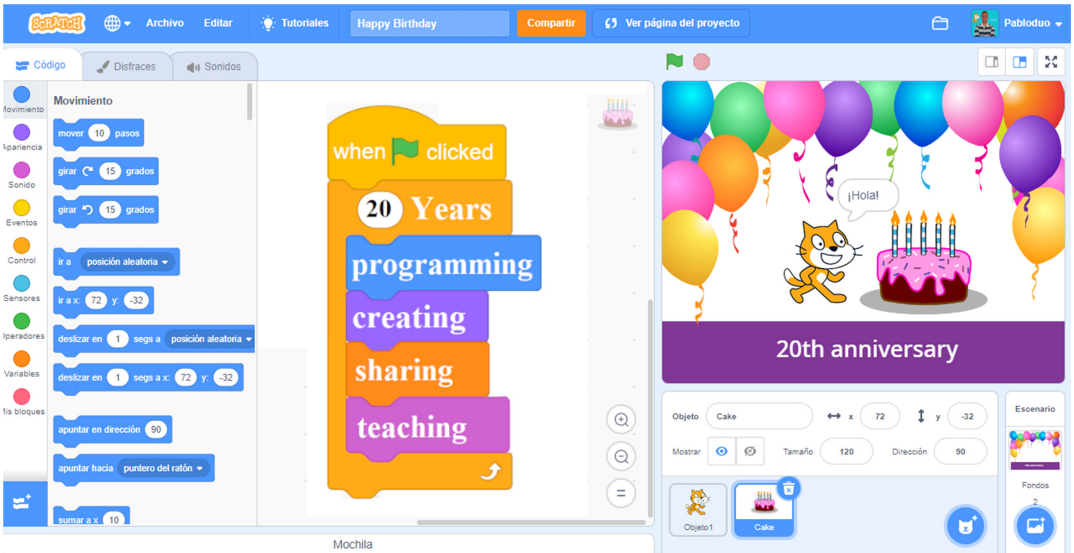

Figure 2. Scratch interface.

The peculiarity of Scratch is that its website in 2021 reached more than 40 million registrations and more than 100 million projects [94] from all over the world on the platform [95] because it is an open community. These data, however, may vary, as some people may have created an account but not used it for a long time. In addition, since 2014, the Scratch Jr. version has also been available for younger children, with an adaptation of simpler Scratch programming blocks [20] dedicated to children between 5–7 years old, with more than 19 million users [96] and available in a downloadable version as an App for IOS and Android.

Although the programme was created in 2003, it was not until 2007 that the Scratch platform was published as an online resource on the Internet [97], with the Scratch 1.0 version. Subsequently, several versions have been developed by MIT, namely, Scratch 2.0 in 2013 and the current Scratch 3.0 in January 2019, with a more intuitive version of its interface [98] moving from Flash to evolve to HTML5. The Scratch programme was created [99] for people who want to get started in the world of the basics of programming [100], especially children, because of the intuitive visual programming blocks with colours [101–103], but also for teachers [104] of any educational stage, including university students [105,106], who may need to get started in the world of computational thinking (CT) and programming without advanced knowledge [107].

1.5. Justification of the Study

This study has an original and exploratory component because there is no other study on an educational tool that has remained robust and solid in the educational world for 20 years and has been the subject of scientific studies. Today, learning to program is considered one of the key 21st century skills to develop CT [108] and STEM skills; therefore, this research focuses on an analysis of the Scratch educational programme in WoS, analysing its performance and a scientific mapping [109] of the linked documents.

The study is based on a bibliometric development of the scientific literature taken from the Web of Science (WoS) database [110]. This database was selected because it encompasses different areas of the field of education; moreover, it is recognised for its prestige and strength, covering journal citation reports (JCR) [111]. For this reason, the author considers this database to be relevant for extracting and analysing the different types of documents linked to the subject matter of the study. A process has also been developed at the analytical level of previous research [112], so that this work can be considered a solid and contrasted study within the scientific community.

This research provides new avenues of study and knowledge in the field of education and can expand the scientific studies on the world of programming. This work serves as a basis to help researchers, teachers, administrations and educational policy in general to visualise the benefits and potential of the world of programming in schools from an early age as demonstrated in the theoretical framework. Although there are recent educational resources and programmes related to learning programming, studying the long-lasting lifespan of Scratch offers guarantees for drawing conclusions and future trends in programming.

Following the above rationale, this bibliometric analysis work set itself the following main objective: to analyse the Scratch program in the educational field in scientific articles in WoS and its connection with the STEM field.

In turn, this main objective leads to the formulation of the following specific objectives:

- To identify the most prominent terms and keywords for Scratch software in scientific articles in WoS from 2003 to 2022.
- To reveal the evolution of main keywords of Scratch software in three time periods.
- To describe the scientific performance of Scratch software in WoS, in relation to the evolution, countries, languages, areas of knowledge, types of documents, titles of publications, affiliations, authors and most-cited documents.

2. Materials and Methods

2.1. Research Design

The research approach is a bibliometric study. This design was chosen because of its potential to accurately measure and examine the publications indexed in the WoS reference database. The research methodology used in this study was bibliometric in nature and this approach was chosen because of the potential it offers to accurately quantify and analyse publications indexed in a database under study [113]. Consequently, the study design offers the possibility to search, catalogue, study and predict the different documents that revolve around the topic in question [114].

The research is also complemented by a co-word study that allows the analysis of the keywords of the studied documents and their connections between the analysed publications. This makes it possible to predict future trends that can be identified as relevant. To perform the latter, a map of nodes is drawn up which allows us to observe productivity, the influence of the different terminological subcategories and the progress or evolution of the subject under study. The bibliometric indices of the h-Index, g-Index, hg-Index and q^2-Index have been used as the indicators of analysis.

2.2. Procedure

In order to avoid possible biases in the research, a meticulous protocol of steps has been followed, as detailed below.

Firstly, in January 2023, the WoS database was chosen to enter the term “Scratch” to be analysed, without limiting any time period, resulting in a total of 38,705 documents. In order to limit the volume of documents related to the educational field, the following search areas were selected from the WoS database: “Education Educational Research”, "Education Scientific Disciplines", "Psychology Educational" and "Education Special", limiting the study to a total of 1023 documents. Furthermore, the following indexes were used: SCI-EXPANDED, SSCI, AHCI, ESCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, CCR-EXPANDED and IC. These documents were downloaded and integrated into the statistical programme SciMAT.

In order to filter the Scratch-EDU term in detail, the standardised protocol of the PRISMA declaration [115] was taken into consideration, as shown in Figure 3. Excluded were those articles that lacked a publication date (n = 32), documents published prior to 2003 because it was in that year that Scratch was created (n = 29) and those from the year 2023 (n = 2) because the author of the research chose to study complete years, i.e., from 2003 to 2022 (n = 31). Analysing the articles in alphabetical order, we found 2 duplicate documents and 43 without abstracts, which were excluded.

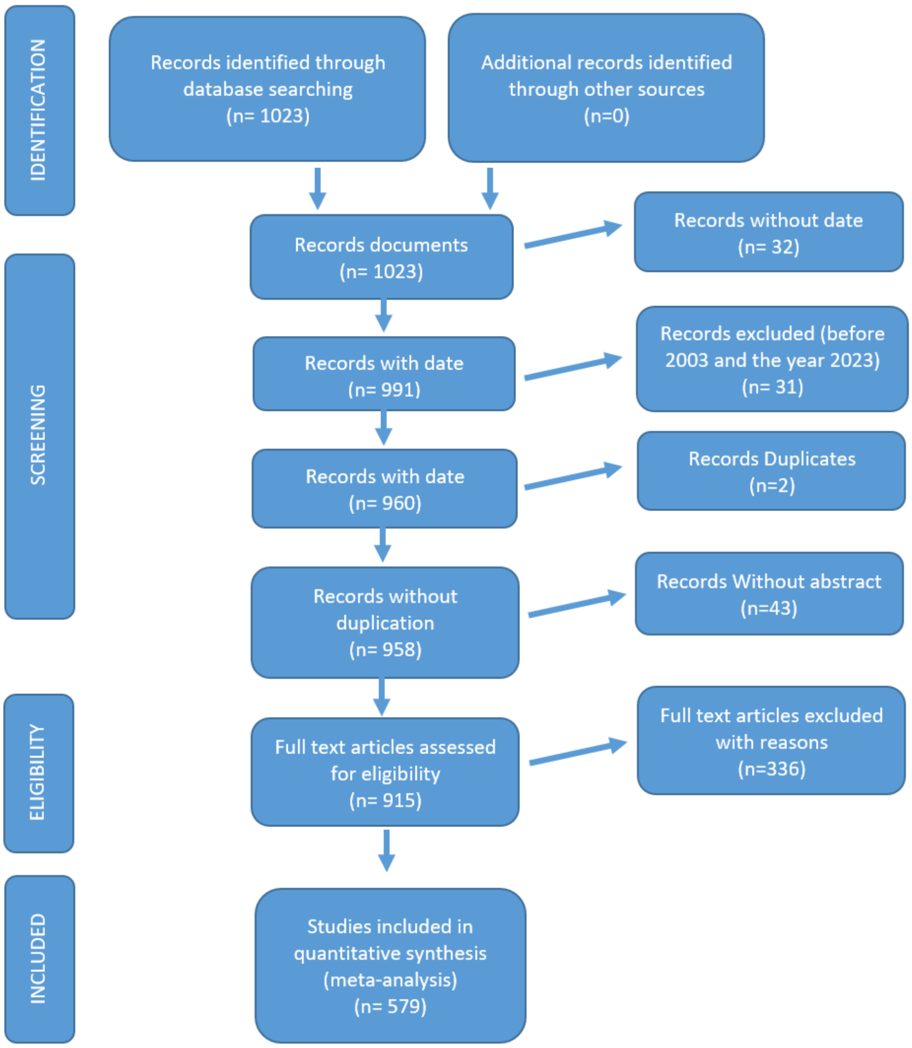

Figure 3. Flowchart according to the PRISMA declaration.

Finally, we proceeded to the most laborious and thorough task of the study, i.e., reading the summaries and, in the case of doubts about the subject, reading the article itself, in order to corroborate that we were indeed including documents related to programming in the educational field with Scratch software. A total of n = 336 documents were excluded for different reasons. One reason was that the term "Scratch" is polysemic and also means "start from scratch" and was not related to the research topic. In addition, articles that were not related to the topic of the study were removed. Finally, those documents that did mention Scratch software, but in an indirect way, were also eliminated, i.e., they investigated other similar programming block programs, comparing them with Scratch, but this was not the main object of the study. In total, the research was reduced to 579 published documents. For the extraction of the keywords in the whole period studied (2003–2022), from a total of 2771 items, those terms that coincided in their meaning, but written in different ways, were grouped, resulting in a total of 1774 keywords for analysis.

2.3. Data Analysis

Two programs, namely, SciMAT and Vosviewer, were used to carry out the data analysis. To extract the documents related to the Scratch programme longitudinally, together with the progression of keywords in various periods of time, the performance of the authors of all the literature extracted and the most cited documents were identified. In this way the SciMAT software established the following protocol:

Recognition: the keywords of the different publications (n = 579) that were studied. Co-occurrence maps were generated by means of nodes. A network of co-words was created with the most prominent and important ones (n = 2711). Moreover, the programme's own algorithm was in charge of unifying the most relevant terms and topics.

Reproduction: The diagram quadrant was designed with the purpose of establishing the terms according to their scientific production. The diagram was divided into four quadrants (Q) (Figure 4). The top right quadrant (Q1) highlights the most prominent and driving themes, the top left quadrant (Q2) highlights the more solitary or disused themes, the bottom left quadrant (Q3) highlights the disappearing or emerging themes, and the bottom right quadrant (Q4) highlights the cross cutting, multidisciplinary or underdeveloped themes. The programme itself classified these themes according to their density (internal strength) and the connectivity between the different nodes and networks (centrality) [116]. A topic network was also developed (Figure 5) that corresponded to the linking of terms to the main research topic. Figure 6 shows a map with the evolution of terms in the three periods.

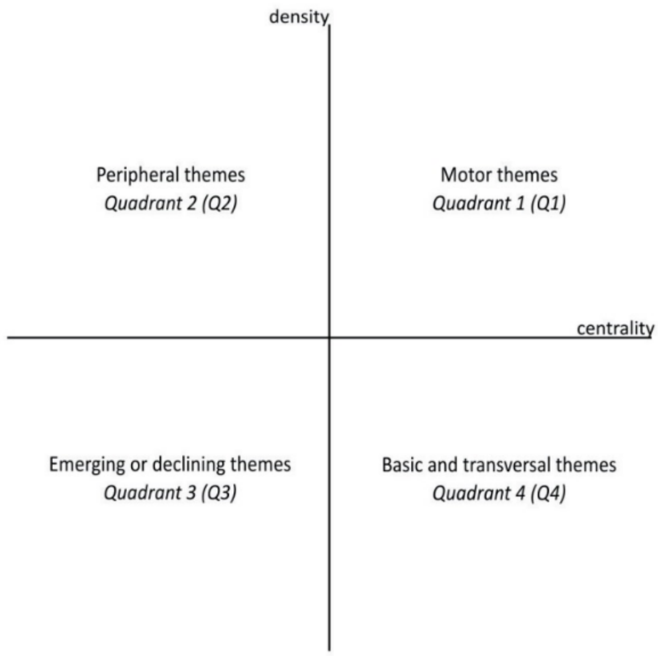

Figure 4. Strategic diagram.

Determination: In order to classify and analyse the evolution of publications and their nodes, time periods were established. These periods were designed according to the following criteria: a balance between the volume of documents and the division of three time periods. These periods ran as follows: P1 = 2003–2016; P2 = 2017–2019; and P3 = 2020–2022. For the authors' study, however, only one time period, 2003–2022, was used, along with the rest of the Scratch analysis. The most important themes, together with the keywords for the different periods, were calculated using the strength of association between them.

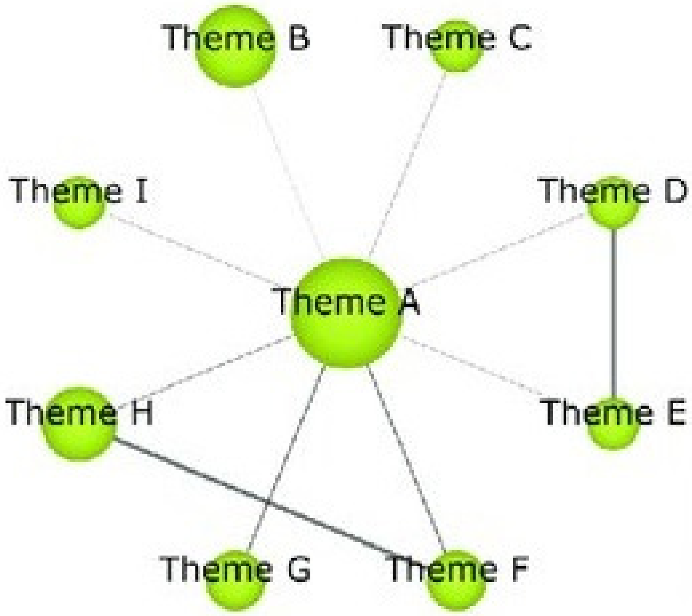

Figure 5. Thematic network.

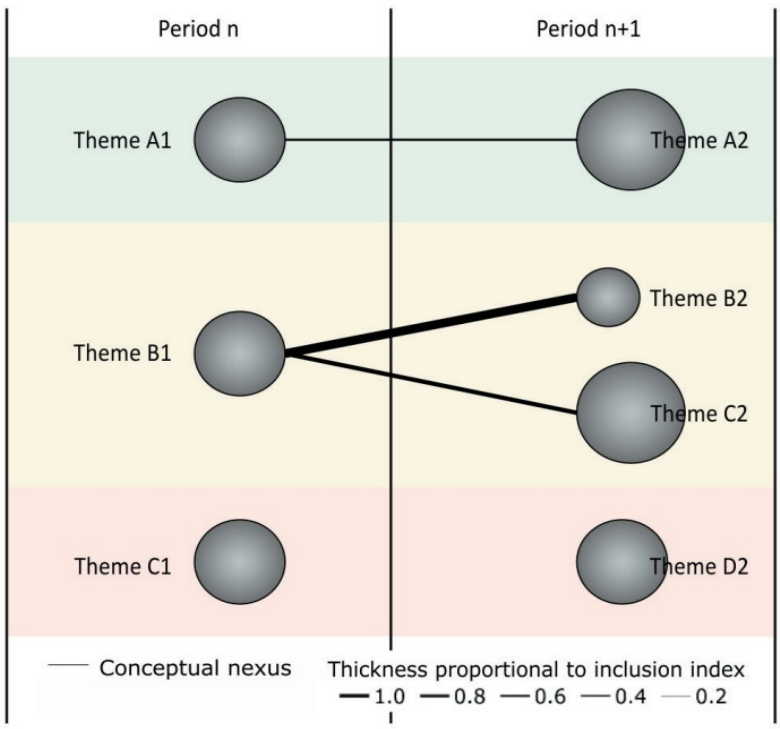

Figure 6. Thematic evolution.

Performance: Finally, the development of the main themes was analysed using the designed time intervals. Finally, the values and output indicators that were linked to the inclusion criteria were delimited (Table 1).

Table 1. Inclusion criteria.

Configuration	Values
Analysis unit	Keywords in Web of Science (WoS)
Frequency threshold	Keywords: P_1 = 151, P_2 = 221, and P_3 = 207
Select unit of analysis	Words (author's words and source's words)
Kind of matrix	Co-occurrence
Co-occurrence union value threshold	Keywords: P_1 = (2), P_2 = (2), and P_3 = (2)
Normalisation measure	Equivalence index
Clustering algorithm	Simple centres algorithm (maximun network size = 12; minimum network size = 2)
Document mapper	Core mapper
Quality measures	h-index; g-index; q2-index; hg-index and sum citations
Longitudinal map	Evolution map = Jaccard's index; overlapping map = inclusion index

With the WoS plain text file, the scientific performance in relation to evolution in scientific production, countries (x > 27), languages (x > 10), areas of expertise, types of documents (x > 6), affiliations (x > 8) and title of publications (x > 24) was carried out. In addition, a network map with the 30 most-cited keywords of the entire research period (P = 2003–2022) in different documents (X > 20) was made with the Vosviewer software. Moreover, in order to collect the data linked to the scientific production in a generic and optimal way from the manuscripts, the countries (X > 10), document sources (X > 38) and organisations (X > 5) were included.

3. Results

3.1. Structural and Thematic Development

To reveal the results of the evolution of Scratch keywords, Figure 7 shows the development of the three periods analysed. In this picture you can see the relevant data for analysis. In the first circle on the left, corresponding to the first period (P1) 2003–2016, which contained 151 documents, 254 keywords appeared, of which 123 (48%) are repeated in the second period, with a total of 131 disappearing as indicated by the ascending arrow above the first circle. Then, in the second circle corresponding to the period (P2) 2017–2019 with 221 documents, it can be seen how the number of keywords increased by 275, of which 152 new ones appeared in reference to the first period studied. Finally, in the third circle, which refers to the third period (P3) 2020–2022 with 207 documents, the number of keywords increased to 399, of which 144 keywords from the second period were retained. In addition, 255 new keywords were included in the last three years. The fact that 48% of the keywords were retained from the first to the second period and 52% from the second to the third period indicates that the research has been undergoing new lines of research in the process of stabilisation.

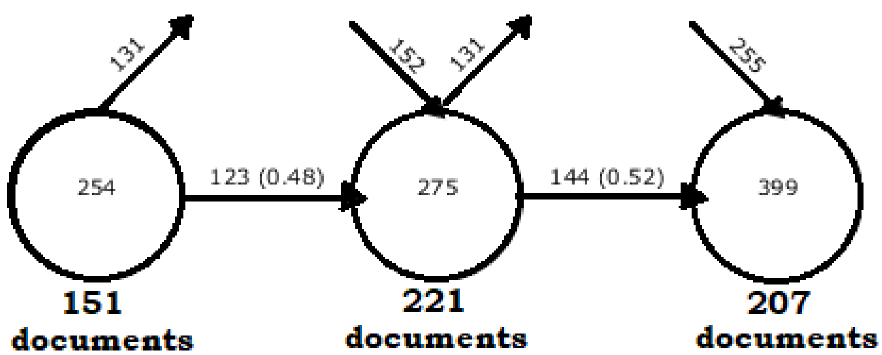

Figure 7. Overlapping map 2003–2022.

3.2. Results Related to the First Study Objective

To identify the most prominent themes and keywords of the analysed Scratch-EDU manuscripts during the three periods, a map was generated using the Jaccard's Index [117]. In Figure 8, the relationship between the different time periods can be seen in three columns, making connections of the themes and keywords. If the thematic linkage is represented with a continuous line, it means a thematic and therefore conceptual relationship; however, if the line is dashed, it means that the connection is term- and keyword-based and, therefore, not conceptual. Another aspect to take into account in this figure is the thickness of the line; the thicker the line, the greater the number of relationships. If we analyse this figure we can see that in the first period the terms "Computational Thinking and "Games" were linked to "Computational Thinking" in the second period and, in turn, to "Scratch" in the third period in a very notable and outstanding way in the scientific literature.

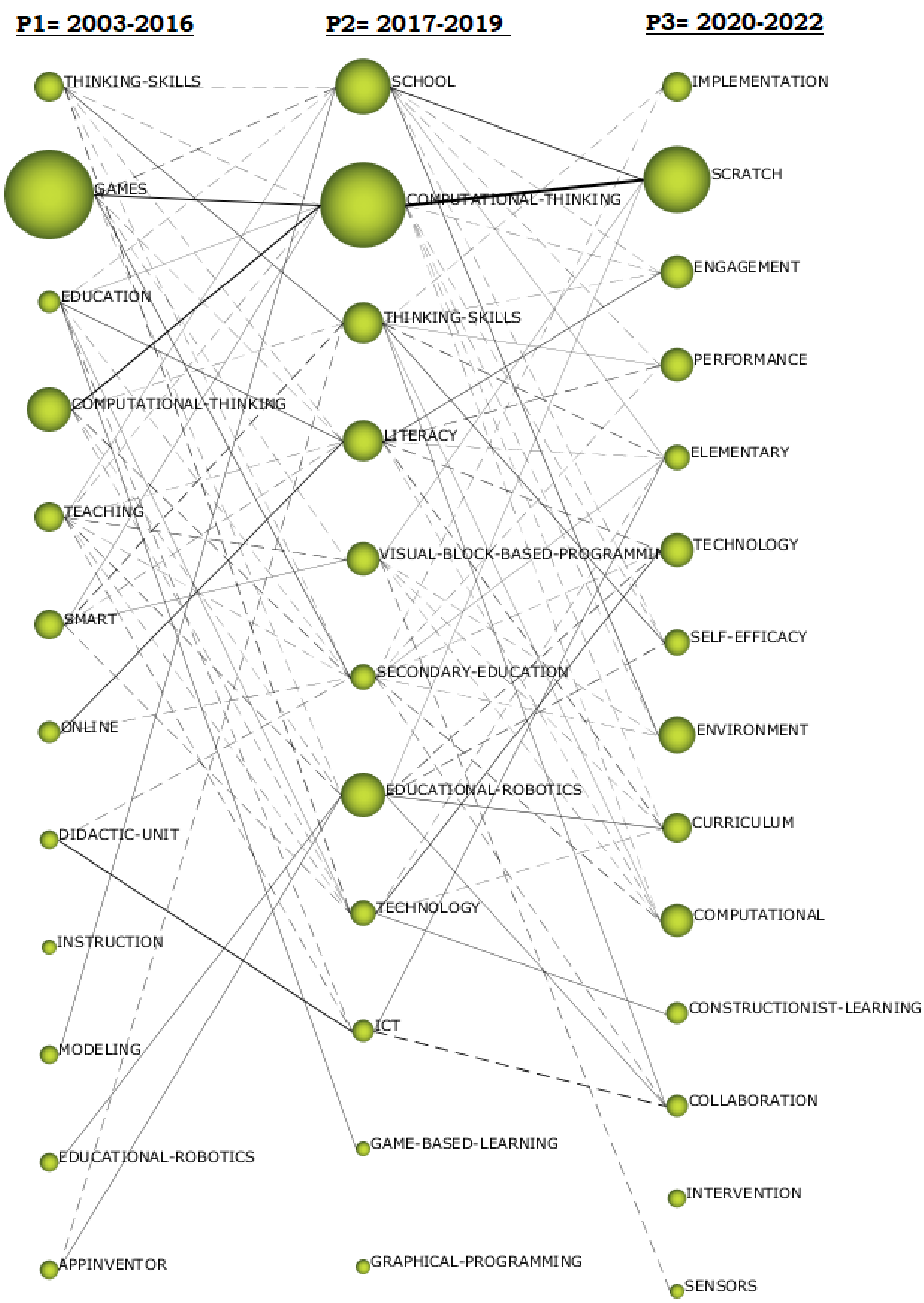

Figure 8. Evolution map.

The keywords most used during these 20 years in the scientific production of Scratch were: the term "Scratch" itself, followed by "Programming" and "Computational Thinking" as the most prominent. Educational research focuses on the Primary education stage, specifically K–12, as the most researched age. In the STEM field, although there were 27 manuscripts that cited it, there were terms linked to this field and STEAM, such as mathematics, creativity, science or technology. Table 2 shows the list in order of the 30 most used keywords in the field of research, as well as the number of documents cited. Figure 9 below shows a network of co-occurrences of the 30 keywords extracted above.

Table 2. Most cited keywords in documents in the period 2003–2022.

Order	Theme	Documents	Order	Theme	Documents
1	Scratch	310	16	Coding	33
2	Programming	180	17	Skills	33
3	Computational-thinking	173	18	Students	33
4	Computer science Education	93	19	Creativity	31
5	Learning	89	20	Children	30
6	Primary-education	79	21	Science	30
7	Block-based-programming	68	22	Technology	30
8	Education	60	23	Problem-solving	29
9	Game-based-learning	59	24	STEM	27
10	K-12	59	25	Pedagogy	25
11	Robotics	51	26	Curriculum	23
12	Design	48	27	Motivation	22
13	School	38	28	Secondary education	21
14	Mathematics	36	29	e-learning	21
15	Teachers	36	30	Gender	21

3.3. Results Related to the Second Objective of the Study

The data presented below show a variety of information of great significance for the study. On the one hand, a strategic diagram is provided to define the value of the themes that have resulted from the study of the co-word analysis in the various time periods P1, P2 and P3. In particular, Callon's analysis [118] was used, which produces a clustering of topics and keywords depending on the centrality (strength of the relationship between external links) and density (strength of the relationship between internal links). The bibliometric indicators provide insight into the value of the various research fields, such as the h-Index, g-Index, hg-Index and q^2-Index. Finally, a cluster network with the most outstanding words in the different time intervals is shown.

3.3.1. First Period Studied (P1 = 2003–2016)

Looking at the analysis of the first period (2003–2016) with a total of 151 documents analysed, we can observe (Figure 10 and Table 3) that the term "Games" is located in the Q1 quadrant as a driving term, together with "Education", "Teaching" and "Thinking Skills". In addition, the author highlights the term "Computational Thinking" in quadrant Q4 as a core or cross-cutting theme related to Scratch. Figure 11b shows the cluster "Games" with the highest number of documents, which in turn is related to terms such as "Scratch", "Programming", "Learning", "Curriculum" or "Primary Education". Table 3 shows the distribution of the terms in the different quadrants, as well as the value of the different indices studied together with the sum of citations.

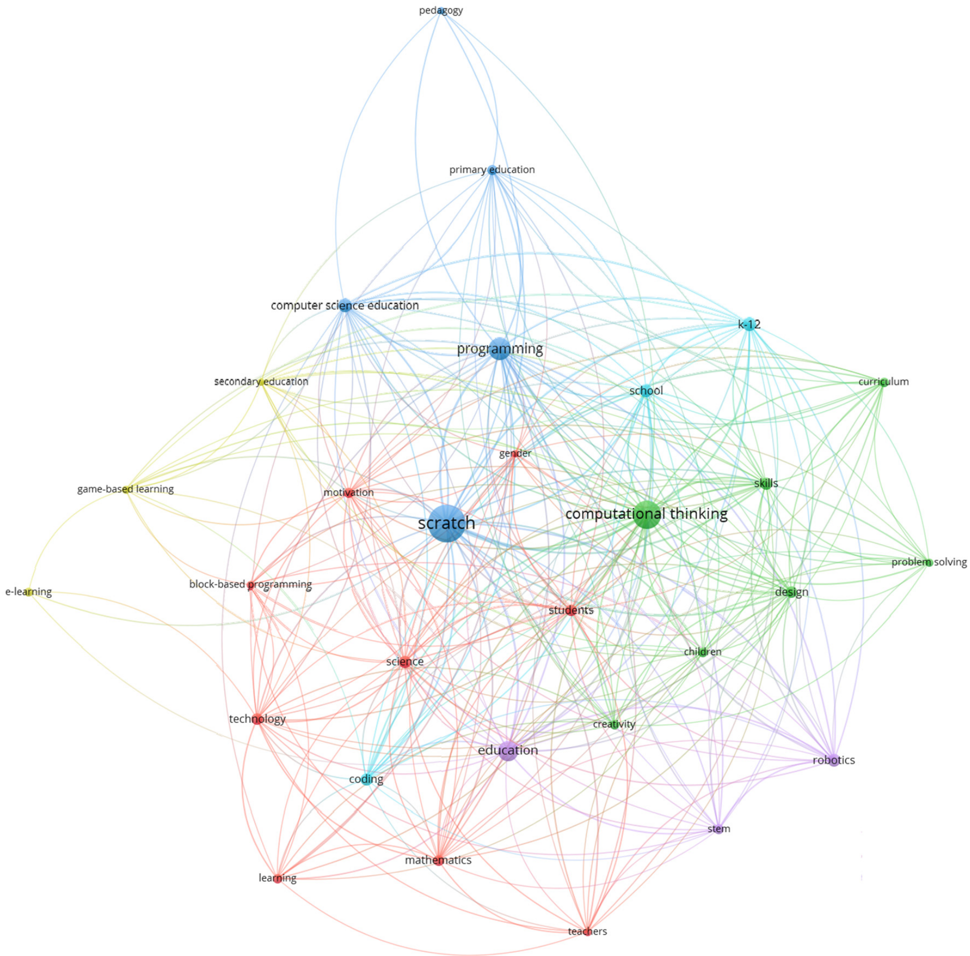

Figure 9. Network map of most-cited terms 2003–2022.

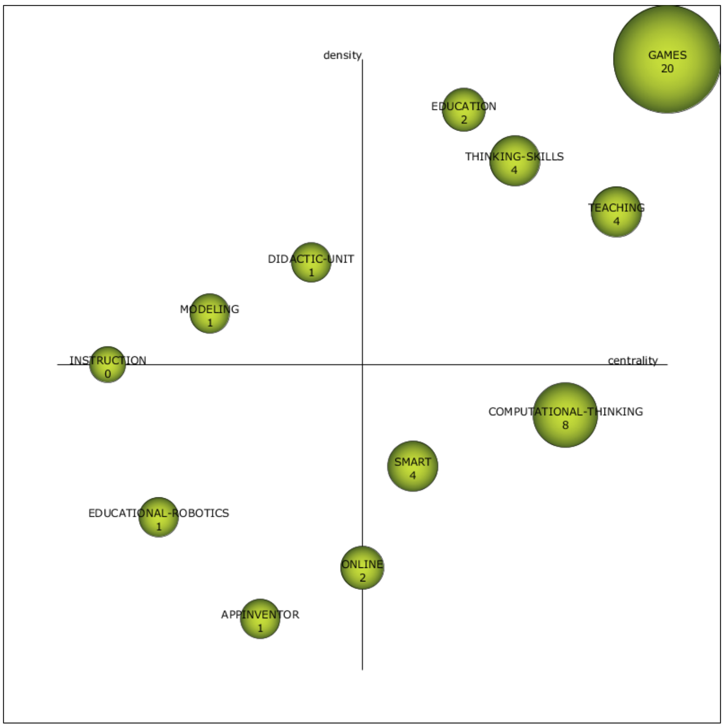

Figure 10. Strategic diagram of the 1st period (2003–2016).

Table 3. 1st Period Cluster Information (2003–2016).

Keywords	Quadrant	Documents	Sum Citations	h-Index	g-Index	hg-Index	q^2-Index
Thinking-skills	Q1	7	263	4	4	4	14.7
Games	Q1	68	1525	20	38	27.57	27.2
Education	Q1	10	33	2	3	2.45	7.21
Computational-thinking	Q4	16	598	8	13	10.2	16.97
Teaching	Q1	10	338	4	8	5.66	17.2
Smart	Q4	4	52	4	4	4	6
Online	Q3	3	17	2	3	2.45	4.69
Didactic-unit	Q2	2	5	1	1	1	2.24
Instruction	Q2	1	0	0	0	0	0
Modeling	Q2	1	25	1	1	1	5
Educational-robotics	Q3	1	26	1	1	1	5.1
APPInventor	Q3	1	18	1	1	1	4.24

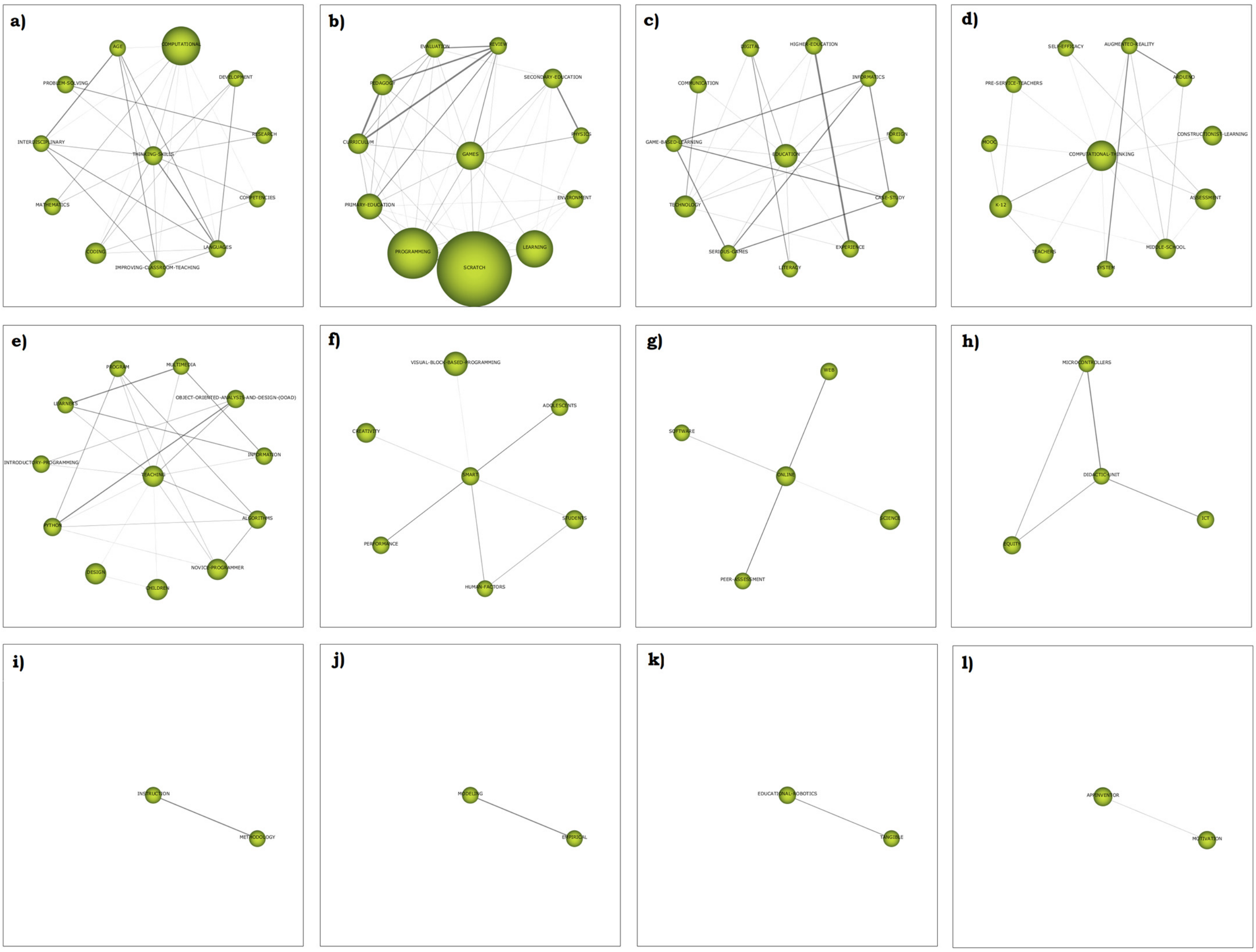

Figure 11. Information on the cluster network of the 1st period (2003–2016). Strategic diagram (h-index) and performance from 2003 to 2016. Themes include (**a**) "Thinking-Skills", (**b**) "Games", (**c**) "Education", (**d**) "Computational-Thinking", (**e**) "Teaching", (**f**) "Smart", (**g**) "Online", (**h**) "Didactic-Unit", (**i**) "Instruction", (**j**) "Modelling", (**k**) "Educational-Robotics" and (**l**) "APPInventor".

3.3.2. Second Period Studied (P2 = 2017–2019)

During P = 2, the topic with the highest bibliometric index was "Computational Thinking" with a large difference over the rest, located in quadrant Q1 with other terms such as "School", Thinking Skills" and "Literacy". In relation to the basic and cross-cutting themes, "Educational Robotics" and "Secondary School" are shown (Figure 12). In the cluster term analysis (Figure 13a) it can be seen how Scratch research is mainly related to "School" and associated with terms such as "Makerspaces", "Coding" or "Teaching". Another term with a large bibliometric contribution in this second period was "Computational Thinking", associating Scratch with terms such as "Programming", "Education", "Learning" or "Problem Solving" (Figure 11b). Table 4 shows the distribution of the terms in the different quadrants, as well as the value of the different indices studied together with the sum of citations. In the STEM domain, the technology domain in Figure 13h is related to terms such as creativity, abstraction, interdisciplinarity or mathematics.

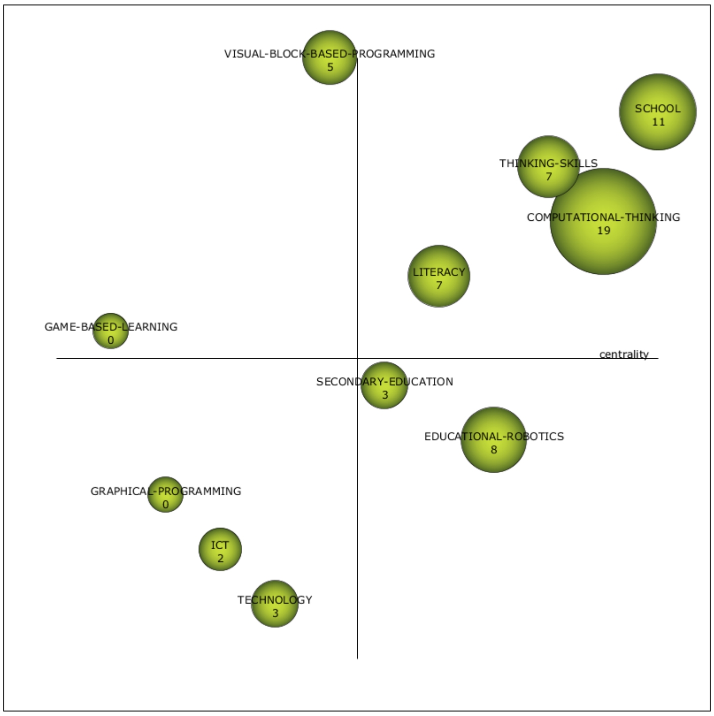

Figure 12. Strategic diagram of the 2nd period (2017–2019).

Table 4. Information on the cluster network of the 2nd period (2017–2019).

Keywords	Quadrant	Documents	Sum Citations	h-Index	g-Index	hg-Index	q^2-Index
School	Q1	30	536	11	23	15.91	18.17
Computational-thinking	Q1	110	1092	19	29	23.47	24.27
Thinking-skills	Q1	15	120	7	10	8.37	9.17
Literacy	Q1	9	212	7	9	7.94	12.12
Visual-block-based-programming	Q2	14	84	5	9	6.71	7.07
Secondary-education	Q4	7	71	3	4	3.46	8.66
Educational-robotics	Q4	21	276	8	15	10.95	11.66
Technology	Q3	9	50	3	5	3.87	7.14
ICT	Q3	2	12	2	2	2	4.47
Game-based-learning	Q2	1	0	0	0	0	0
Graphical-programming	Q3	1	0	0	0	0	0

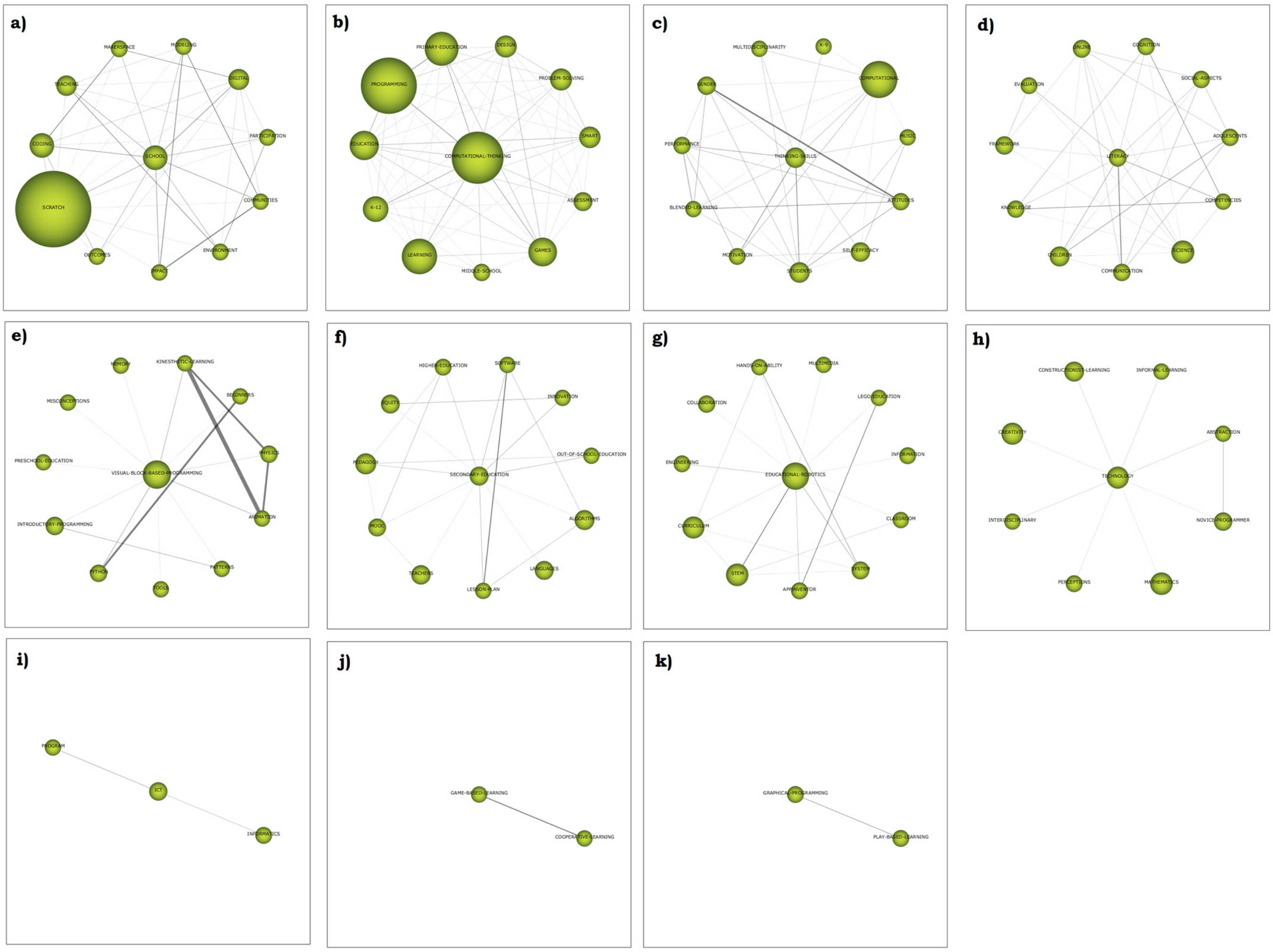

Figure 13. The 2nd period cluster information (2017–2019). Strategic diagram (h-index) and performance from 2017 to 2019. Themes include (**a**) "School", (**b**) "Computational-Thinking" (**c**) "Thinking-Skills", (**d**) "Literacy", (**e**) "Visual-Block-Based-Programming", (**f**) "Secondary-Education", (**g**) "Educational-Robotics", (**h**) "Technology", (**i**) "ICT", (**j**) "Game-Based-Learning" and (**k**) "Graphical-Programming".

3.3.3. Third Period Studied (P3 = 2020–2022)

In P = 3 it can be seen how the term Scratch with a value h-Index = 14 is related in quadrant Q1 to the term "Performance", followed by "Implementation or "Curriculum" (Figure 14). In turn, in Figure 15d, it can be seen that the term "Performance" is linked to terms in studies related to "Languages", "Cognition", "Children", "Fluid Intelligence", Feedback", "Peer Assessment" or "Improving Classroom Teaching". Table 5 shows the distribution of the cluster of terms in the different quadrants, as well as the value of the different indices studied together with the sum of citations. In Figure 15f, the term technology in scientific studies, including Scratch, is related to terms such as STEM, science, engineering, mathematics and competences.

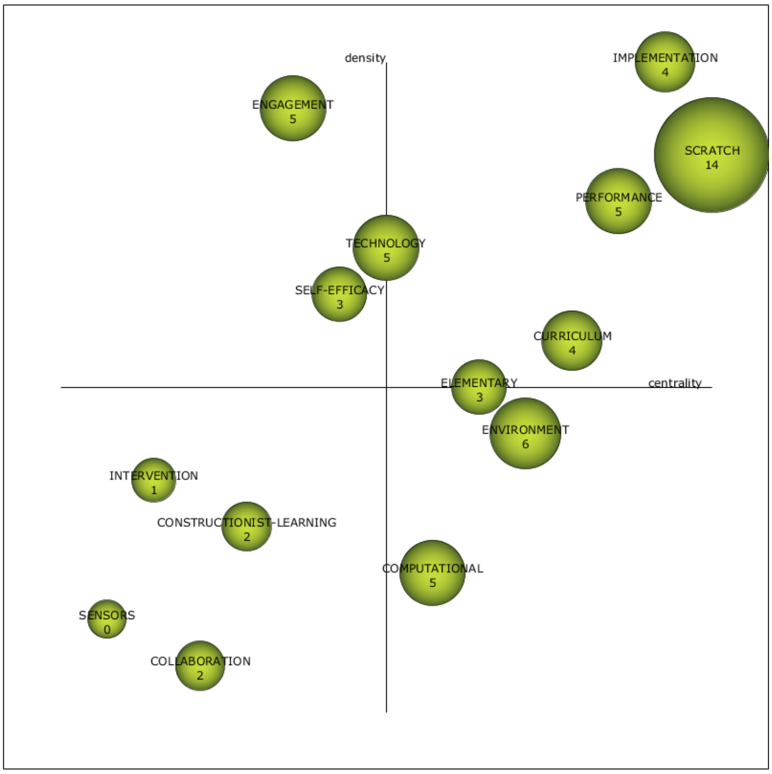

Figure 14. Strategic diagram of the 3rd period (2020–2022).

Table 5. 3rd Period Cluster Information (2020–2022).

Keywords	Quadrant	Documents	Sum Citations	h-Index	g-Index	hg-Index	q^2-Index
Implementation	Q1	8	110	4	7	5.29	11.31
Scratch	Q1	136	667	14	21	17.15	19.8
Engagement	Q2	12	62	5	7	5.92	6.71
Performance	Q1	12	98	5	9	6.71	6.71
Elementary	Q4	11	64	3	7	4.58	3.87
Technology	Q2	17	85	5	8	6.32	7.07
Self-efficacy	Q2	6	48	3	4	3.46	4.9
Environment	Q4	9	82	6	9	7.35	7.75
Curriculum	Q1	13	64	4	7	5.29	4.9
Computational	Q4	18	70	5	8	6.32	7.75
Constructionist-learning	Q3	2	10	2	2	2	3.46
Collaboration	Q3	3	8	2	2	2	3.16
Intervention	Q3	1	4	1	1	1	2
Sensors	Q3	1	0	0	0	0	0

The results in Figures 11, 13 and 15 in relation to the co-word analysis of the three periods and their position in the strategy diagram are grouped in Table 6. The different themes are placed in each period together with their centrality and density value. Thus, in this table it is possible to appreciate the changes that have evolved in the different periods and research. The fact that no term was repeated in the three periods means that the research has been evolving and changing its orientation.

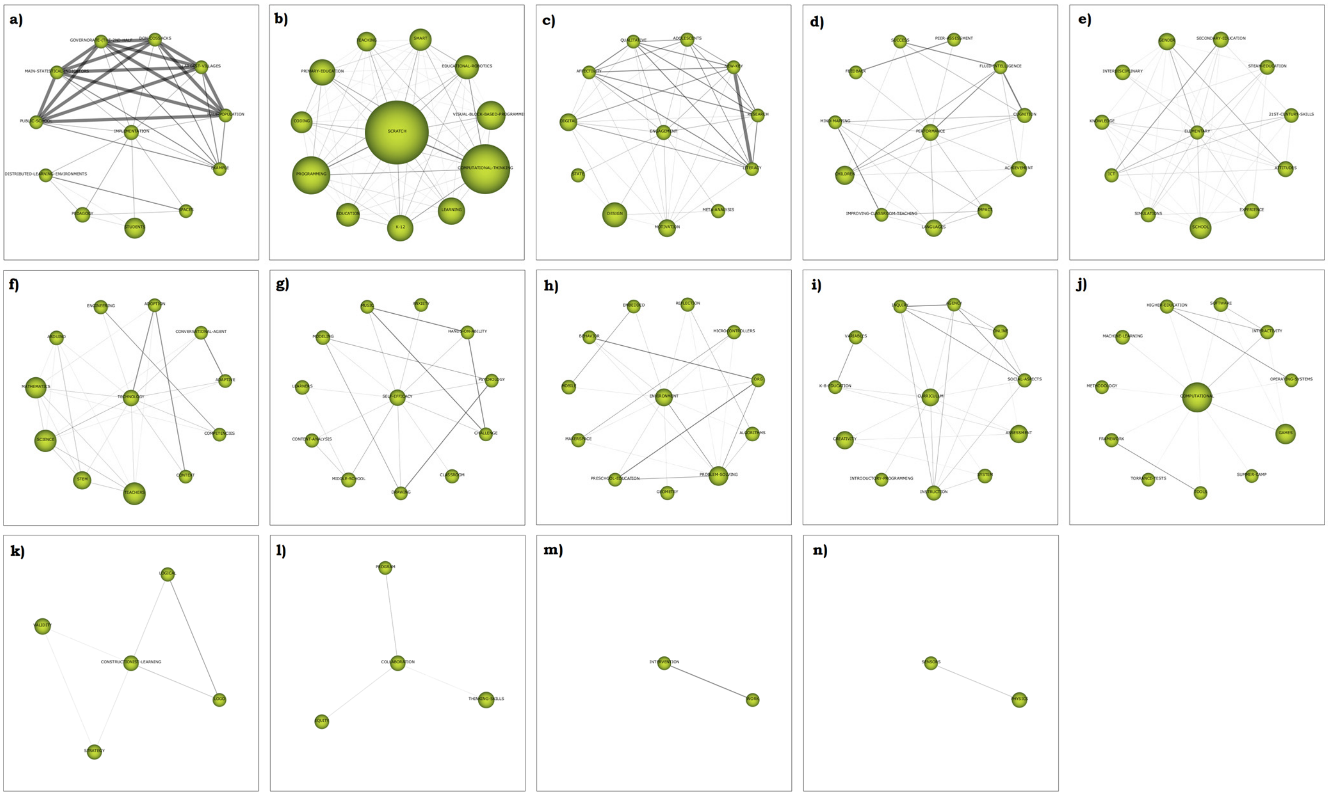

Figure 15. Information on the cluster network of the 3rd period (2020–2022). Strategic diagram (h-index) and performance from 2017 to 2019. Themes include (**a**) "Implementation", (**b**) "Scratch" (**c**) "Engagement", (**d**) "Performance", (**e**) "Elementary", (**f**) "Technology", (**g**) "Self-Efficacy", (**h**) "Environment", (**i**) "Curriculum", (**j**) "Computational", (**k**) "Constructionist-Learning", (**l**) "Collaboration", (**m**) "Intervention" and (**n**) Sensors".

Table 6. Main research topics related to Scratch-EDU from 2003 to 2022.

Name	P1 (2003–2016)	P2 (2017–1019)	P3 (2020–2022)
Thinking-skills	Q1 (50.65/23.53)	Q1 (86.16/20.02)	
Games	Q1 (62.24/36.7)		
Education	Q1 (40.43/24.59)		
Computational-thinking	Q4 (52.62/11.09)	Q1 (110.34/18.66)	
Teaching	Q1 (57.19/17.58)		
Smart	Q4 (25.76/8.79)		
Online	Q3 (19.91/8.25)		
Didactic-unit	Q2 (14.37/16.67)		
Instruction	Q2 (5.83/12.5)		
Modeling	Q2 (7.1/12.5)		
Educational-robotics	Q3 (7.02/8.33)	Q4 (68.98/7.73)	
APPInventor	Q3 (10.1/2.5)		
School		Q1 (121.06/22.19)	
Literacy		Q1 (67.43/15.26)	
Visual-block-based-programming		Q2 (50.15/25.17)	
Secondary-education		Q4 (63.32/9.22)	
Technology		Q3 (48.79/3.33)	Q2 (73.23/17.459)
ICT		Q3 (9.58/4.63)	

Table 6. *Cont.*

Name	P1 (2003–2016)	P2 (2017–1019)	P3 (2020–2022)
Game-based-learning		Q2 (5.14/12.5)	
Graphical-programming		Q3 (5.16/5.56)	
Implementation			Q1 (150.34/150.96)
Scratch			Q1 (156.99/34.64)
Engagement			Q2 (66.49/49.46)
Performance			Q1 (116.6/26.34)
Elementary			Q4 (78.67/15.58)
Self-efficacy			Q2 (70.52/16.56)
Environment			Q4 (81.58/14.61)
Curriculum			Q1 (94.26/15.81)
Computational			Q4 (76.53/6.94)
Constructionist-learning			Q3 (33.98/7.69)
Collaboration			Q3 (31.32/3.65)
Intervention			Q3 (17.66/12.5)
Sensors			Q3 (5.96/4.17)

3.4. Results Related to the Third Objective of the Study

The scientific production of the term Scratch-EDU was selected from 2003, when this programme was created, until the year 2022. The first article appeared in 2004 from researchers at MIT, where Mitchel Resnick, the creator of Scratch, is located [119]. In the WoS database, there were no new records of Scratch in relation to the educational field until 2007, after which there were several periods of interest. From 2007 to 2010 there were few scientific papers published, but from 2011 to 2015 this volume began to grow. From 2016 to 2020 there was a large growth in publications, with a slight decline in 2018, reaching 103 publications in 2020 (Figure 16). In the last two years of 2021 and 2022, the number of documents had decreased to approximately the 2016 levels.

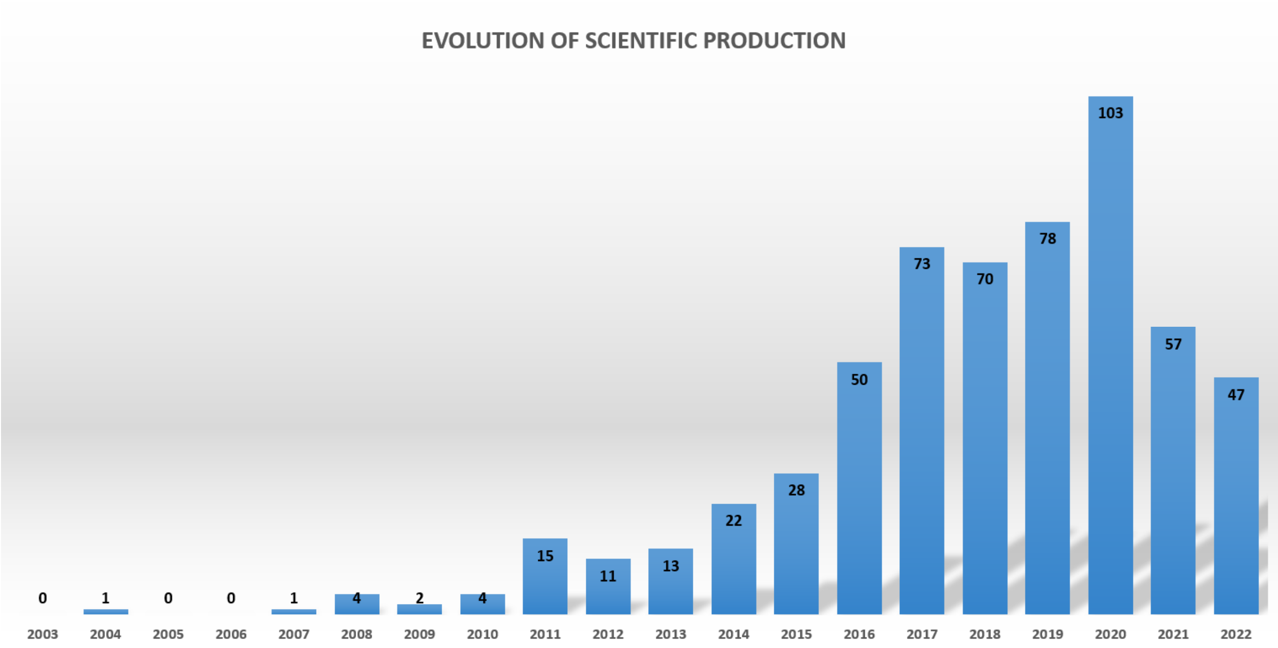

Figure 16. Scientific evolution of Scratch-EDU documents.

The country with the largest number of study documents on Scratch-EDU was the USA. The volume of publications was higher than in the rest of the countries, with twice as many documents as in the second country, Spain (Figure 17). Furthermore, the language most widely used in the publications extracted was English (Table 7).

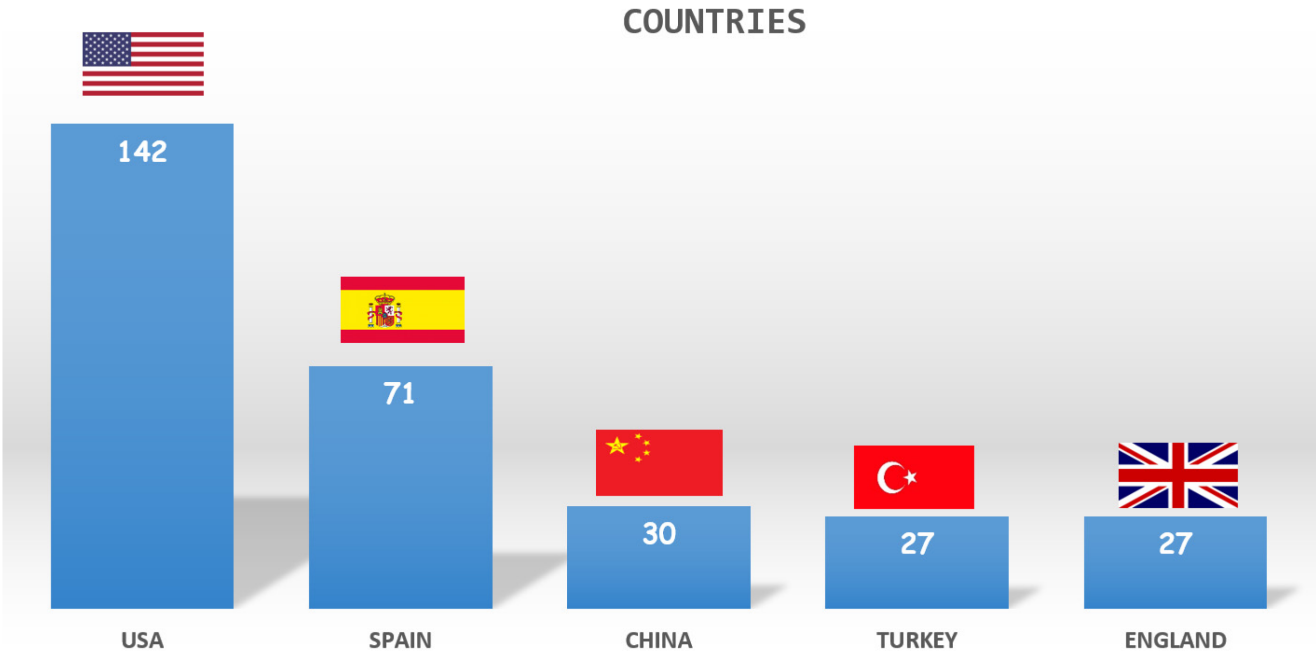

Figure 17. Countries with the highest number of scientific publications.

Table 7. Scientific languages used.

Languages	n
English	544
Spanish	16
Portuguese	11

In the WoS database, there were a total of 2468 authors who had intervened alone or in groups in research on Scratch-EDU. Below, those researchers with more than seven interventions are shown in Table 8. Three authors had nine publications, namely, Almeida, R.; Castro, M. and Blázquez, M.

Table 8. Most influential authors.

Name	Full Name	Documents
Almeida, R	Almeida, Ricardo	9
Castro, M	Castro, Manuel	9
Blázquez, M	Blázquez, Manuel	9
Robles, G	Robles, Gregorio	8
Plaza, P	Plaza, Pedro	8
Sancristobal, E	Sancristobal, Elio	8
Moreno-León, J	Moreno-León, Jesús	7
Román-González, M	Román-González, Marcos	7
Carro, G	Carro, German	7

In relation to the most cited manuscripts on Scratch, of the 579 documents extracted in the WoS, Table 9 shows the five most cited, with little difference between the first two. The article entitled "Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools", stood out with 208 citations.

Table 9. Most-cited documents.

Title	Authors	Year	Citations
Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools	Román-Gonzalez, M, Saez-Lopez, JM, Vazquez-Cano, E	2016	208
Programming by Choice: Urban Youth Learning Programming with Scratch	Maloney, J, Peppler, K, Kafai, YB, Resnick, M, Rusk, N	2008	199
Learning computer science concepts with Scratch	Armoni, M, Meerbaum-Salant, O, Ben-Ari, M	2013	166
Designing for deeper learning in a blended computer science course for middle school students	Cooper, S, Grover, S, Pea, R	2015	156
An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing	Ke, FF	2014	151

In addition, Scratch-EDU covered two main areas of knowledge, and these were "Educational Research" (n = 338) and "Scientific Disciplines in Education" (n = 229). In addition, there were two other areas of knowledge, but with a smaller volume of documents, namely, "Psychology Educational" (n = 8) and "Education Special" (n = 3).

In relation to the types of documents used by the scientific community that studies Scratch, the community preferred "Proceeding Papers" (n = 325), followed by "Research Articles" (n = 243). These two types of documents formed the bulk of the studies extracted in this research, followed by "Early Access" (n = 17), Book Chapters (n = 10) and Review Article (n = 6).

The titles of publications were mostly conference publications; therefore, the top five were "Frontiers in Education conference" (n = 42), as well as "INTED Proceedings" (n = 42), "EDULEARN Proceedings" (n = 40), "IEEE Global engineering education conference" (n = 33) and "Education and information technologies" (n = 24).

Of all the institutions involved in the documents researched on Scratch-EDU, the "Universidad Nacional de Educación a Distancia (UNED)" (n = 22) in Spain stood out in first place, with twice as many manuscripts as the "State University System of Florida" (n = 11). It was followed by the "Universida de Coimbra" (n = 10), "University of Chicago" (n = 10), "Universidad Rey Juan Carlos" (n = 9), and "Harvard University" (n = 8). The "Massachusetts Institute of Technology (MIT)" (n = 8) stood out in this position because it was the institution where Scratch was created.

4. Discussion

Scratch-EDU is considered a tool that allows for transforming the knowledge of researchers into practices and methodologies that integrate this programme at any age. This allows for the development of competencies related to CT in schools as pointed out by [107]; however, [80] considers didactics and the ability to integrate programming skills in the classroom to be important. Otherwise, as [92] points out, the lack of teacher training, not only in knowledge related to CT and programming, but also in knowing the methodology to develop it in the classroom can lead to the disappearance of these programmes.

It is, therefore, a question of responding to the needs of the evolution of our society and to the competences demanded by administrations in order to obtain practical and integrated training. The needs of trainers without experience in programming from a base and in a progressive manner can lead to the creation of Scratch projects with long blocks, duplicates and scripts that affect and make it difficult to understand a programme, as pointed out by [120]. Moreover, it is considerable to note that in higher education, students may become demotivated because programming activities do not meet their expectations, as expressed by [121].

In relation to the first and second objectives of the study, following the analysis and results of the study of the main themes and keywords of the Scratch-EDU programme, the research themes in scientific production are related to the competence terms [61,62] alive and present in the current 21st century education, such as CT [34,35], creativity [32], robotics [71,72] or AI [76,77], and disciplines that allow people to be trained in the STEM field [55–58].

In the results of the evolution of the main themes of Scratch-Edu, the link between "programming with visual blocks" and "curriculum" was found according to [39]. Programming using visual blocks allows for solving problems in a transversal way linking competences from different areas [21], contrary to the textual programming language, which is considered more difficult in education according to [87]. In addition, the results of the P3 cluster include that through technology with Scratch projects, these projects are related to all STEM disciplines, namely, science, engineering and mathematics and, in addition, to STEAM by relating to creativity, which in the words of [33] is linked to art.

For this reason, the results of this study in line with [20] show that the aim should be to encourage teachers to recognise that programming is increasingly present in classrooms and to show the use of CT as a skill and ability for access to the 21st century labour market, as pointed out by [1]. To this end, educational programming languages can be used by integrating both theoretical content and practice to motivate and incentivise academic success and performance in class and to reduce anxiety about computer programming, taking into account the work in [122]. In addition, programming is a skill that has allowed educational inclusion in these types of practices in recent years [24], and as object of studies by neuro-educators as stated by [41].

Focusing on the evolution of the Scratch themes and keywords, the results of the P1 study show how play and thinking skills are key driving terms for programming by playing in education because students can create interactive games that teach specific concepts in a fun and engaging way as argued by [60], and that are compatible with the teaching of robotics [63,64] by bringing mathematical concepts and problem solving into play in a proficient way, as pointed out by [23,24]. In P2, the research results present CT and school as the motor themes and keywords, in line with [3–6], which point out that through Scratch, CT skills can be developed in schools with many countries including it in their educational plans. In P3, the driving themes of this study are implementation and curriculum, in line with [39,79], which considers it necessary to introduce subjects or areas related to information and communication technology (ICT) or computer science in education that develop programming skills from an early age. In addition, Scratch-EDU is a tool associated with emerging terms in recent years in the scientific field of collaboration and constructionist learning that is being developed in Classrooms of the Future as established by [21,29].

In relation to the third objective of the study, to describe the scientific performance of Scratch software in the WoS, and despite studying Scratch from its beginnings to the present day, interest in the scientific community was irregular practically until the first decade of its existence. From this point onwards, it began to generate a trend and increased in production from 2012 to 2020, with a slight decline in 2008. It was in the last two years that it suffered a sharp drop in studies, by practically halving. This drop can be explained by the appearance of the COVID-19 pandemic, as has occurred in other educational fields such as robotics [70] or STEAM [110]. The performance of the scientific production shown in the study consolidated English as the language most used in publications and the USA as the country that has most promoted Scratch-EDU documents, despite being a collaborative programme and a community that reaches millions of users around the world [3–6,36,94]. This could be due to the fact that the English language is more present in scientific articles.

However, the main institutions that have carried out research studies on Scratch-EDU are distributed by country, with the National University of Distance Education (UNED) in Spain standing out, followed by universities in the USA and Portugal. In this way, the Spanish Marcos Román, affiliated to this University, is the co-author of the most-cited document. Furthermore, we found the Portuguese Ricardo Almeida as a prominent author having published mainly in conferences, being this modality, and the one with the highest volume of documents within the scientific community, with articles of a "proceedings paper" nature, above the research articles, that is, those which were first presented at a conference and, subsequently, have been adapted for a publication [123] such as the Frontiers in Education conference or INTED Proceedings.

5. Conclusions

The author concludes that after the development of the scientific production of Scratch, it is now considered a bridge in schools, especially from Primary education onwards because of its ease of use and its intuitive visual interface without having to worry about the syntax of the code. In relation to the main objective of the study, with Scratch, students can carry out STEM or STEAM projects in classrooms that require CT skills, problem solving, creativity and collaboration through practices and experiences with programming blocks, educational boards, robotics, simulators, mobile applications or AI and Machine Learning. Therefore, although it is designed to introduce students to the world of programming, it is possible to carry out STEM-competence projects that involve developing knowledge and different areas related to science, technology, mathematics, physics, languages or art, among others [124].

There are countries that integrate ICT areas into their curricula or that include CT in a cross-cutting manner from an early age; therefore, we can consider Scratch to be a solid, effective and scientifically studied programme, especially since the last decade, as an open educational resource with educational benefits that develop skills in students that are increasingly important in today's technological world. For this reason, those administrations and educational policies interested in the initiation of CT as a launch pad for STEM-competence projects may consider the Scratch programme.

If school is synonymous with teaching the world around us to become more critical, and less manipulable citizens, and to develop skills to access the increasingly digitalised labour market, the first step should then be to establish and start from schools, projects based on CT that allow students to learn in an experimental and inclusive way the basic knowledge of different areas, while acquiring digital competence. In addition, this has the requirements to work collaboratively in Makerspaces or Classrooms of the Future [29], while taking into account diversity.

The limitations of this analysis are directly centred on the exclusivity of the extraction of the documents in the WoS database. In addition, the term Scratch in education has been linked by the author only to research fields related to education, excluding others such as engineering or computer science. In relation to future lines of research, it would be useful to investigate the relationship between a learning programming and performance in other areas of the curriculum, as well as the impact on the gender gap and access to the labour market.

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