





Review

# Robotics in Education: A Scientific Mapping of the Literature in Web of Science

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**Abstract:** The technological revolution has created new educational opportunities. Today, robotics is one of the most modern systems to be introduced in educational settings. The main objective of this research was to analyze the evolution of the “robotics” concept in the educational field while having, as a reference point, the reported literature in the Web of Science (WoS). The methodology applied in this research was bibliometrics, which we used to analyze the structural and dynamic development of the concept. The collection of WoS studies on robotics in education began in 1975. Its evolution has been irregular, reaching peak production in 2019. Although the focus was on collecting studies with educational knowledge areas, other knowledge areas were also present, such as engineering and computing. It was found that the types of manuscript most commonly used to present scientific results in this area are proceedings papers. The country with the highest level of production in this field of study is the United States. The results confirm the potential of this type of study in the scientific field. The importance of this technology in the training of future surgeons and in the results they produce in their own learning was also detected.

**Keywords:** robotics; education; Web of Science; bibliometric



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## 1. Introduction

Today's society is involved in a technological revolution that started in the early 20th century [1]. This revolution has occurred in the diverse fields in which society is divided, from business, social, and health fields to the educational field. In other words, this technological explosion has deeply changed the way we interact, cure diseases, and learn [2].

Focusing on the educational field, information technologies have led to a significant, though sometimes slow, change in all current teaching and learning processes [3]. This technological revolution in education has not always been related to a direct improvement of current teaching and learning processes [4]. In this regard, the incorporation of different technological tools in any educational process must be related to an improvement of the pedagogical process. As never before, teachers cannot be oblivious to this transformation and should be willing to introduce new tools to help students develop creative, collaborative, and active learning [5].

Today, there are many methodologies that can help teachers to transform their daily teaching, such as active methodologies [6], but there are also new tools and devices that allow us to approach the most complex aspects of existing technologies in the educational field, such as robotics [7,8].

Robotics have taken on a special interest in today's education, and the number of educational programs introducing this aspect into their curriculum has grown in recent years, especially in developed countries [9]. The advantages and potential of introducing

these systems in education were detected by several authors more than 20 years ago [10]. Among the most relevant advantages of this type of system, we found its direct bond with the improvement of learning [11], the development of specific cognitive skills [12], or the learning of complex scientific concepts [13].

The use of robotics in education can be considered from two well-distinguished perspectives. On the one hand, the perspective related to the programming of devices or software and, on the other, that which is associated to the assembly and operation of devices or hardware [14]. This difference is decisive for posing our activities within the classroom, which must be adapted, as with any technology, depending on the needs of the students [15]. Though most robotics educational applications focus exclusively on programming or in subjects directly related to technology [16], the truth is that they can be applied to a much wider range of subjects, such as mathematics, languages, music, or art [17].

Robotics in education can be seen as an underlying branch of robotics [18], which focuses on training students in the development, design, and construction of robots [19]. To do this, students must generate robots by building the robot itself and establishing its capabilities through software [20].

It can be said that the main purpose of educational robotics is to teach students to design and create a programmable robot [21] capable of performing various actions, including moving, responding to environmental stimuli, or communicating through sound, light, or images [22–24]. In addition, the application of robotics in the educational field involves other associated factors in the education of students [25], including contributing to the development of logical thinking, psychomotor skills, and spatial perception of students [26], promoting student autonomy through the development of their own projects [27] and the active involvement of students in the teaching and learning process [28], promoting creativity, research, and understanding oriented toward the computer world [29], generating students' problem-solving skills [30], encouraging the development of students' digital competence [31], associating it with other pedagogical methods, such as project learning, collaborative learning, or cooperative learning [32], and encouraging functional learning given that it generates resources that can be applied in the social environment [33]. Therefore, it can be said that robotics in education generates a series of advantages [34], including learning to work in a team [35], increasing self-confidence [36], promoting entrepreneurship [37], developing skills [38], identifying and taking an interest in other disciplines [39], increasing concentration [40], increasing creativity [41], and promoting curiosity and increasing interest in mathematics [42].

A widely used branch of education for robotics is science, technology, engineering, arts, and mathematics (STEAM) education for training based in these subject areas [43]. The usual approach when implementing robotics in education is to provide students with robotics kits [44]. Such a kit should have materials adapted to their age and abilities [45]. A kit for students aged 6–10 years should not contain the same materials as a kit for students aged 16–18 years [46]. There are a number of computer resources that allow robotics to be applied in education, including Scratch, Wedo 2.0, Lego Boost, Makey Makey, Arduino, and Microbit [47–50]. The application that is used depends on the purpose and capacity of the learners [51].

It is important to keep in mind that robotics in education can be presented from several perspectives [52–55]: learning robotics, where students learn to design, build, and program a robot; learning with robotics, where robots are tools that serve to promote student learning; and robots for education, where the robot is the main tool for the learning process. This last option is related to telepresence in the educational sphere, where robots are used to develop distance learning [56].

The truth is that robotics in the educational field does not form part of the curriculum today [57]. This is developed through specific methods during teaching and learning processes or through extracurricular activities [58]. For robotics to be an integrated part of education systems, a number of aspects must be considered, which may make its inclusion

in schools difficult [59]. These include its high cost [60], the need to train teachers in the use of technological resources [61], students' own digital competence [62], and the need for the pedagogical training of teachers [63].

Knowing how the term "robotics" has evolved within the educational scientific literature is therefore a valuable resource for many teachers and researchers. Having a detailed view of its evolution allows us to focus efforts, as teachers and researchers, in specific fields, learn how studies on the subject have advanced, and even detect the rise of new and future research niches.

## 2. Justification and Objectives

This work arises from the projection that robotics has potential in today's different learning spaces [64–67]. For this reason, this study analyzed the term "robotics" in education (ROBEDU) from a bibliometric aspect of scientific production [68]. Bibliometry is considered a method of scientific analysis focused on publications on a state of the art. This methodology contributes to revealing to the scientific community, and to all interested readers, the progress and significance of a certain topic or concept throughout history. For this, a series of variables or bibliometric indicators used in the indexing of each study (year, authors, keywords, journal, countries, language, and source of origin being among the most prominent) are taken into account. Therefore, bibliometrics is beneficial as a research methodology as it reveals the journey made by a certain topic [69]. Another fundamental aspect is the selection of an impact database in order to carry out a pertinent and in-depth study from which interesting results can be obtained, allowing conclusions to be reached and relevant prospects to be considered. In this case, the selected database for the documentary report is the Web of Science (WoS), which is considered to be one of the most relevant databases in the field of social sciences, of which education is a part of it [70].

In this particular research, an innovative research process has been used. It is about the analysis of documentary performance and the scientific mapping of the literature concerning these concepts. For effective development of the study, the guidelines and models established by experts in this type of research have been followed. This allowed the development of the study to follow an investigative structure for the analysis as well as for the presentation of the data validated by experts [71,72].

The purpose of this work was based on the analysis of the evolution of ROBEDU in WoS publications, that is, from when this subject appeared in the scientific literature, its evolution over time, and the concepts to which it is linked. All this is due to a deep analysis of the publications on ROBEDU where the conceptual connections established between the different studies were extracted. This allowed the establishment of not only what has been done so far but also of future trends on this state of the art. As far as our knowledge reaches, and after leading a search in the expert literature, no study analyzing the concept of robotics at a documentary level using these techniques has been reported. In providing a knowledge base, this study will contribute to a reduction in the gap found in the impact literature and to the future work of other researchers. Therefore, this research is positioned under an exploratory and a novel nature. Likewise, this work aims to present to the scientific community the implications and future trends [73] of this educational technology.

Based on all the above, the objectives formulated in this study were to (1) know the documentary performance of ROBEDU in WoS, (2) establish the scientific evolution of ROBEDU in WoS, (3) find the most significant thematics of ROBEDU in WoS, and (4) trace the most influential authors of ROBEDU in WoS.

## 3. Materials and Methods

### 3.1. Research Design

Bibliometrics was established as the research methodology to achieve the objectives of this study. This methodology quantifies and evaluates scientific documents in detail [74,75]. We developed a research design that allows several actions such as searching, recording,

analyzing, and predicting the literature on the state of the art [76]. The proposed design is based on a cword analysis [77] and on the analysis of the  $h$ ,  $g$ ,  $hg$ , and  $q^2$  indices [78]. Each of the different analytical processes to be carried out allow the preparation of maps that integrate nodes on the performance and location of various terminological subdomains and the evolution of the themes over time [79] of ROBEDU in WoS.

### 3.2. Procedure

Taking impact studies as the reference [80–82], the document analysis process was set in several actions. The first action was focused on the selection of the database to be analyzed. In this case, WoS was chosen, as it is a database with recognized worldwide prestige. The second action was based on the delimitation of concepts. In this case, the concept “robotics” was chosen, as it was the most significant term for this study. The third action focused on the creation of a precise search equation. In this case it was “robotic\*” in [TITLE] in the categories of “Education Educational Research”, “Education Scientific Disciplines”, “Psychology Educational”, and “Education Special”. Finally, the fourth action focused on applying this equation in the main WoS collection, which contains several indices (SCI-EXPANDED, SSCI, A and HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, and IC).

These performances yielded a total of 1037 publications. To improve the literary reporting process, different criteria for both exclusion and inclusion were defined [83]. The exclusion criteria focused on removing the publications of the year 2020, since the year had not yet finished, as it could lead to a bias in the research if it was included ( $n = 100$ ). Repeated or poorly indexed documents in WoS were also suppressed ( $n = 9$ ). This reduced the documentary sample to 926 publications. Figure 1 shows a flow diagram that collects the actions carried out with the PRISMA protocol.

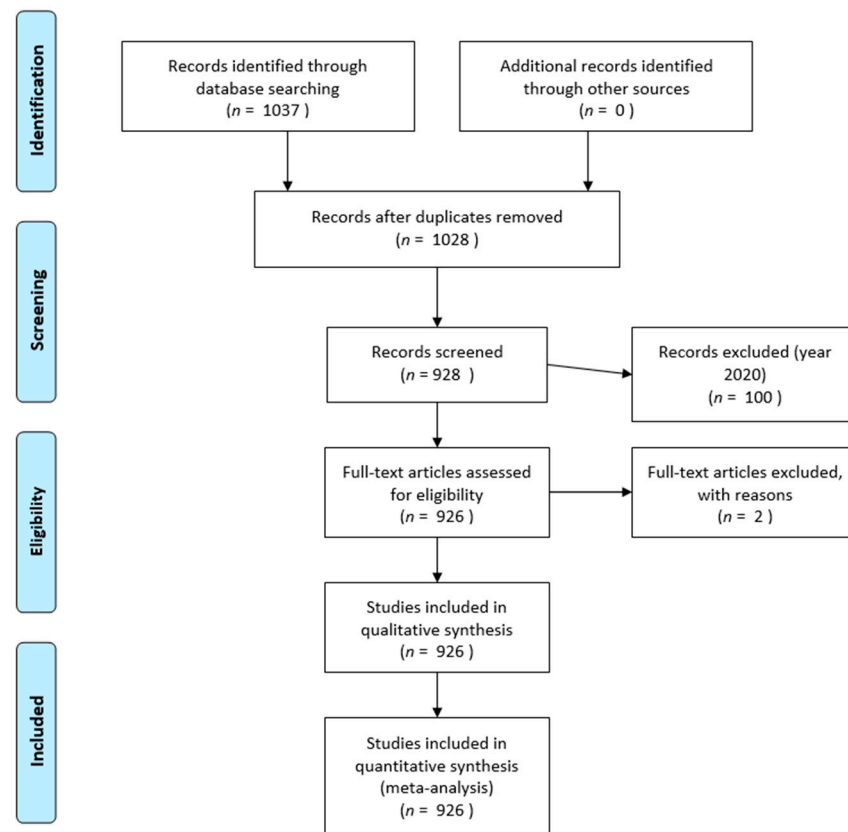


Figure 1. Flowchart according to the PRISMA declaration.

On the other hand, different inclusion criteria, taken from the expert literature, were established [84,85] to optimally represent scientific production and performance: year of publication (all production); language ( $x \geq 7$ ); areas of knowledge ( $x \geq 140$ ); type of documents ( $x \geq 10$ ); institutions ( $x \geq 15$ ); authors ( $x \geq 15$ ); sources of origin ( $x \geq 40$ ); country ( $x \geq 35$ ); and the four most cited documents ( $x \geq 109$ ).

### 3.3. Data Analysis

To carry out the analytical process of the literature, various programs were used. Specifically, the Analyze Results and Creation Citation Report were used as tools to define the year, authorship, country, type of document, institution, language, media, and most cited documents. In addition, SciMAT was used to carry out all necessary actions to accomplish the structural and dynamic development at the longitudinal level of the scientific documents and to execute the analysis of cowords. For efficient use of the programs, the premises established in preceding studies were followed [86,87].

As postulated by experts [88], the analysis of cowords was carried out in four processes:

- **Recognition:** In this process, the keywords ( $n = 1969$ ) of the different publications were analyzed. Next, the co-occurrence node maps were designed. In addition, a normalized network of cowords was developed. Likewise, the most relevant keywords were determined ( $n = 1863$ ). This process concluded with the delimitation of the most prominent topics and terms by means of a clustering algorithm [89].
- **Reproduction:** In this process, the thematic networks and strategic diagrams articulated in four sections were designed. The upper right section shapes the relevant and motor themes. The upper left section reflects the deep-rooted, isolated issues. The lower left section represents issues in disappearance or in projection. The lower right section reflects the underdeveloped and cross-cutting themes. This process considers the principles of density (network internal strength) and centrality (connection degree between networks) [90].
- **Determination:** In this process, the reported documental volume was classified in three time periods based on the principle of equality of publications in each interval [91]. The periods were as follows: P1 = 1975–2012, P2 = 2013–2016, and P3 = 2017–2019. The strength of association between these periods arises from the number of keywords in common. For the authors' analysis, a single period, covering all existing production, was considered (PX = 1975–2019).
- **Performance:** In this process, various production indicators linked to the inclusion criteria were defined [92,93] (Table 1).

**Table 1.** Production indicators and inclusion criteria.

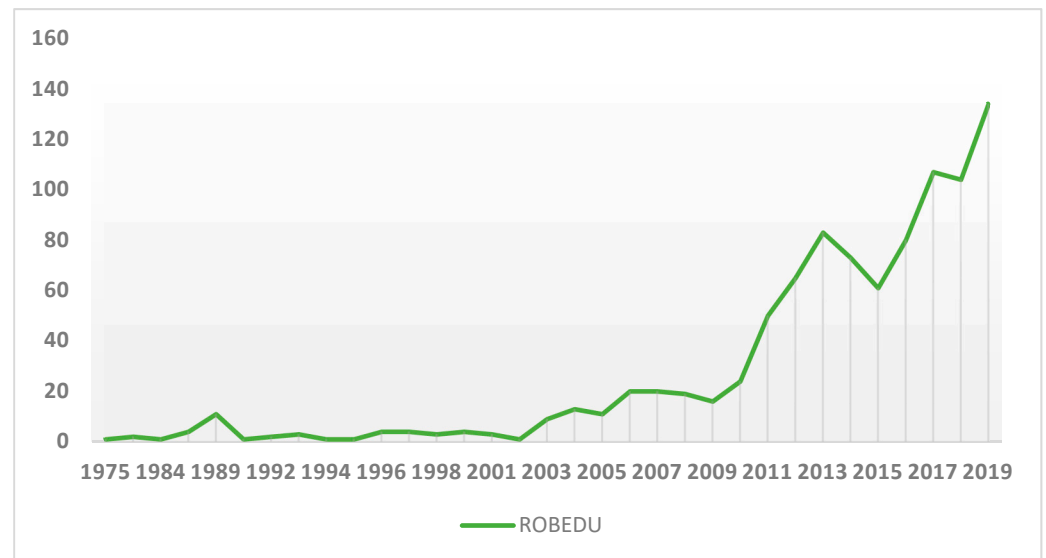
Configuration	Values
Analysis unit	Keywords authors, keywords WoS
Frequency threshold	Keywords: P <sub>1</sub> = (2), P <sub>2</sub> = (2), P <sub>3</sub> = (2) Authors: P <sub>X</sub> = (3)
Network type	Co-occurrence
Co-occurrence union value threshold	Keywords: P <sub>1</sub> = (1), P <sub>2</sub> = (2), P <sub>3</sub> = (2) Authors: P <sub>X</sub> = (2)
Normalization measure	Equivalence index: $e_{ij} = c_{ij}^2 / \text{Root}(c_i - c_j)$
Clustering algorithm	Maximum size: 9; Minimum size: 3
Evolutionary measure	Jaccard index
Overlapping measure	Inclusion rate

## 4. Results

### 4.1. Performance and Scientific Production

The production volume of ROBEDU in WoS was 926 manuscripts. The first documents compiled in this database go back to 1975. From that date to 2019, the evolution of this topic was uneven. From 1975 to 1998, production was not continuous, with leaps of

years in scientific production. From 2000 to 2010, scientific production was constant but irregular in terms of production volume, which did not exceed 50 products per year. From 2011 onwards, production increased considerably, although unsteadily. From 2011 to 2013, production increased. From 2014 to 2015, the production trend decreased and then increased. This increase in production continued into 2016 and beyond, with a small break in 2018 (Figure 2).



**Figure 2.** Evolution of scientific production.

The manuscripts that deal with ROBEDU were written mainly in English, which accounted for more than 95% of the production. Spanish and Portuguese also appeared but in a very low volume (Table 2).

**Table 2.** Scientific language used.

Language	<i>n</i>
English	888
Spanish	35
Portuguese	8

There were two knowledge areas that stood out in the ROBEDU field of study. These were “Education Educational Research” and “Education Scientific Disciplines”. The other areas, with lower production levels, were focused on the knowledge areas of engineering and computer science (Table 3).

**Table 3.** Areas of knowledge.

Area of Knowledge	<i>n</i>
Education Educational Research	590
Education Scientific Disciplines	539
Engineering Multidisciplinary	177
Engineering Electrical Electronic	151
Computer Science Interdisciplinary Applications	145

The volume of manuscripts generated in conference communications stood out considerably, being higher than the other types of documents. The high production volume of existing research articles was also significant (Table 4).



**Table 4.** Types of document.

Document Type	<i>n</i>
Proceedings paper	563
Article	345
Book chapter	35
Editorial material	17

There were no major differences between the various institutions worldwide in ROBEDU's scientific production. The University System of Georgia had the highest volume of production (Table 5).

**Table 5.** Institutions.

Institution	<i>n</i>
University System of Georgia	22
Tufts University	19
State University System of Florida	16
Carnegie Mellon University	15

As with the institutions, no author stood out above the rest in terms of production volume. Interestingly, several authors had the same volume of scientific production (Table 6).

**Table 6.** Most prolific authors.

Author	<i>n</i>
Adamchuk, V.I.	16
Barker, B.S.	16
Bers, M.U.	16
Grandgenett, N.	16
Nugent, G.	16

In accordance with the type of manuscript, the main source of production was conference proceedings. Among the magazines with the most production, Advances in Intelligent Systems and Computing stood out (Table 7).

**Table 7.** Source of provenance.

Source Title	<i>n</i>
ASEE Annual Conference Exposition	79
Frontiers in Education Conference	62
Advances in Intelligent Systems and Computing	46
INTED Proceedings	41
IEEE Transactions on Education	40

The country with the largest volume of production was the United States. Spain followed with a much smaller volume of production (Table 8).

**Table 8.** Country.

Country	<i>n</i>
USA	351
Spain	105
Italy	39
Brazil	35

The most cited manuscripts, mainly research articles, present a high volume of citations. The most cited manuscript, almost doubling its successor, is [94]. This work includes

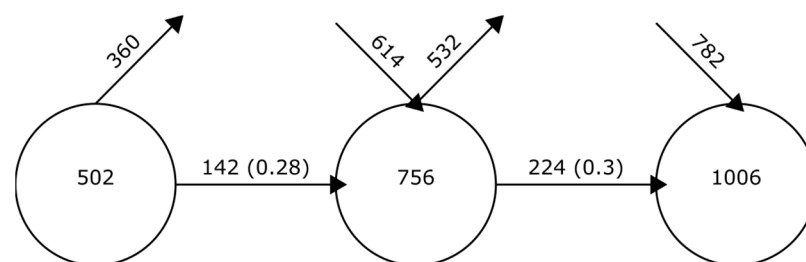
a systematic review on the application of robotics in educational centers. The main findings focus on the virtues of this educational technology to improve the learning process, but with caution, since studies have appeared in which there were no improvements. It also offers a series of implications for educators and professionals in this field of knowledge. It is followed by [95] with 190 citations. This study focuses on revealing the findings achieved after the application of a project that combines robotics with programming in students no more than 4 years old. The main results focus on the improvements produced in the interest and in the learning capacity on topics concerning robotics, its programming and, as a consequence, computational thinking. It is followed by [96] with 128 citations. In this research, we tried to verify the improvement of the performance of adolescent students through robotics. The students were divided into a control and experimental group. Prepost tests were performed. The findings reflect that students who received a teaching and learning process through robotics obtained better scores than those who did not use it. The fourth most cited article was [97] with 109 citations. In this work, a hybrid learning experience was carried out in higher education, combining the face-to-face plane with virtuality through content management platforms of a robotic nature. The findings reached determine the demonstrated effectiveness in both learning and performance of university students (Table 9).

**Table 9.** Most cited articles.

Reference	Citations
[94]	328
[95]	190
[96]	128
[97]	109

#### 4.2. Structural and Thematic Development

The evolution of keywords in adjacent periods showed a medium-low percentage of coincidence. Between the first period (1975–2011) and the second period (2013–2016), the percentage of coincidence was 28%, and, between the second period (2013–2016) and the third period (2017–2019), the percentage of coincidence was 30%. This indicates that the scientific community is establishing common research bases, though at a low volume. The coincidence percentages show the appearance of new research trends in the ROBEDU field of study (Figure 3).



**Figure 3.** Continuity of keywords between adjacent intervals.

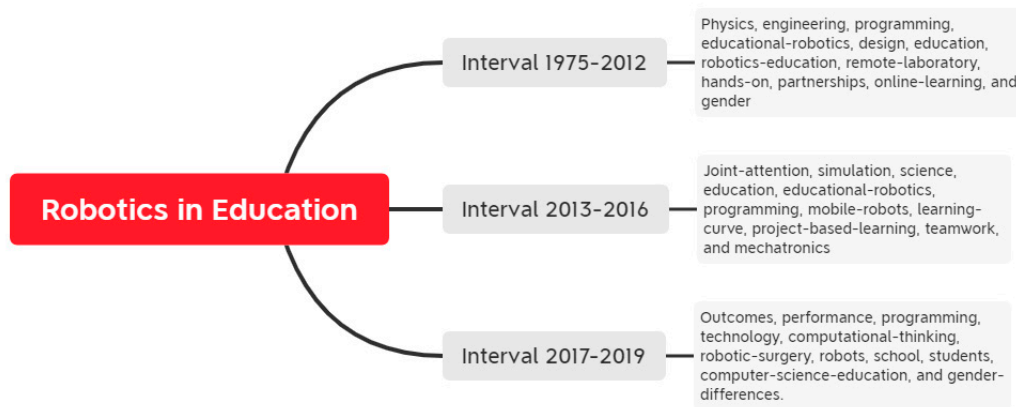
Academic performance offers information on the bibliometric values of the thematic resulting from the cword analysis. In the first period (1975–2011), the thematic “education” has the highest bibliometric values. In the second period (2013–2016), the two most prominent thematic have similar bibliometric values. They are “science” and “education”. In the third period (2017–2019), there are also two prominent thematic with similar bibliometric values. In this case, the two thematic are “programming” and “computational-thinking” (Table 10).



**Table 10.** Thematic performance in robotics in education (ROBEDU).

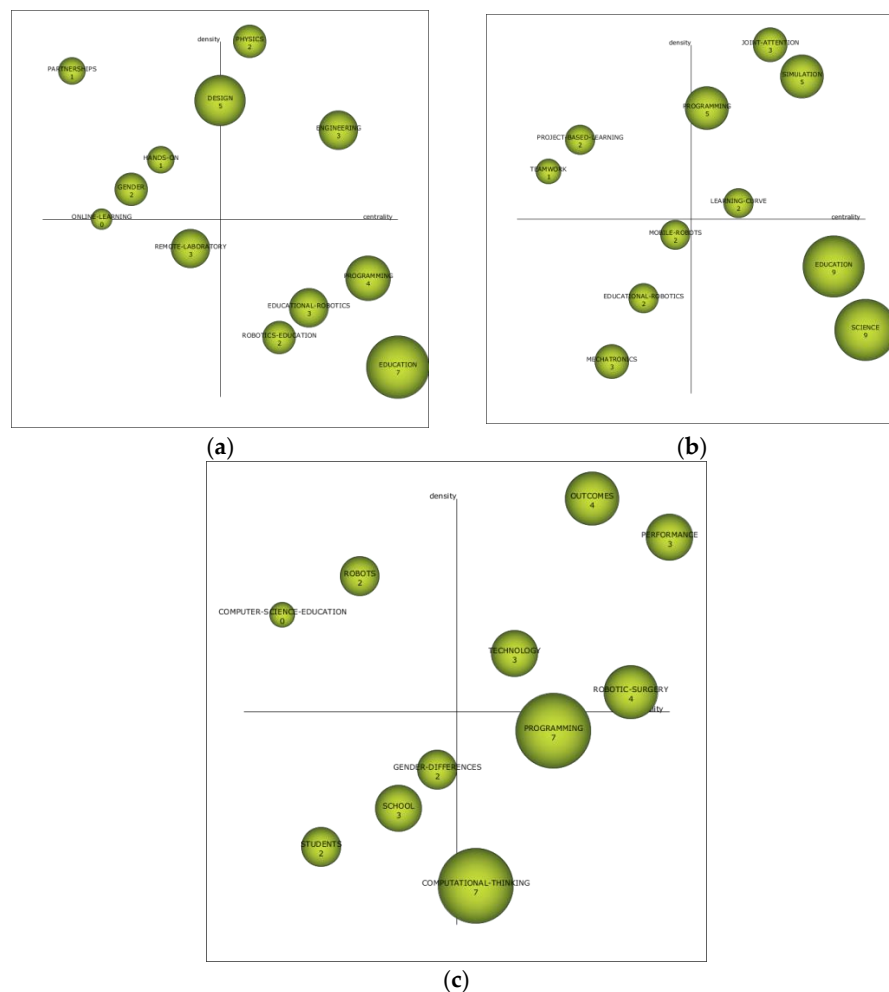
Denomination	Works	Interval 1975–2012		Index hg	Index q2	Citations
		Index h	Index g			
Physics	3	2	2	2	12.08	86
Engineering	8	3	4	3.46	4024	23
Programming	11	4	7	5.29	9.38	83
Educational-robotics	8	3	5	3.87	4.58	99
Design	5	5	5	5	8.06	106
Education	8	7	8	7.48	9.9	186
Robotics-education	5	2	2	2	5.1	16
Remote-laboratory	3	3	3	3	10.82	151
Hands-on	2	1	2	1.41	3.32	12
Partnerships	2	1	2	1.41	5.2	28
Online-learning	2	0	0	0	0	0
Gender	2	2	2	2	13.93	103
Denomination	Works	Interval 2013–2016		Index hg	Index q2	Citations
		Index h	Index g			
Joint-attention	3	3	3	3	8.12	64
Simulation	7	5	5	5	8.06	60
Science	14	9	11	9.95	12.37	390
Education	29	9	18	12.73	13.08	335
Educational-robotics	10	2	7	3.74	9.27	57
Programming	7	5	5	5	10	317
Mobile-robots	7	2	2	2	2.45	8
Learning-curve	5	2	3	2.45	6.16	38
Project-based-learning	4	2	3	2.45	3.46	11
Teamwork	6	1	1	1	1	1
Mechatronics	3	3	3	3	5.74	47
Denomination	Works	Interval 2017–2019		Index hg	Index q2	Citations
		Index h	Index g			
Outcomes	8	4	8	5.66	10.2	88
Performance	10	3	4	3.46	4.24	29
Programming	58	7	12	9.17	11.22	185
Technology	10	3	7	4.58	7.35	51
Computational-thinking	32	7	13	9.54	11.53	180
Robotic-surgery	7	4	6	4.9	5.66	37
Robots	7	2	3	2.45	4.24	16
School	7	3	6	4.24	3.46	37
Students	5	2	4	2.83	6	26
Computer-science-education	4	0	0	0	0	0
Gender-differences	4	2	4	2.83	6	28

The strategic thematic diagrams, categorized according to the h-index, mark the value and relevance of the various thematics in a set time period. The diagrams are presented on a Cartesian axis. In this case, the  $y$ -axis shows density and the  $x$ -axis shows centrality. Density represents the external relationship of the thematics, while centrality represents the internal relationship. The evolution of the research on robotics in the educational field is represented in Figure 4.



**Figure 4.** Synoptic representation of the evolution of robotics in education in the lines of research.

The data represented in Figure 5 indicate that in the first period (1975–2012) the motor thematics were “physics”, which is related to “sensors”, “robotic-assisted-teaching”, “interactive-learning-environments”, “camera”, “laboratories”, “learning-environments”, “skills”, and “intelligent-tutoring-systems”; and “engineering”, which is related to “computer-science”, “mathematics”, “nasa”, “competition”, “technology”, “stem”, “science”, and “outreach”. In this period, the most relevant studies were concerned with physics, focused on engineering studies, where active teaching methods based on robotics were applied.



**Figure 5.** Strategic diagrams by ROBEDU h-index: (a) interval 1975–2012; (b) interval 2013–2016; and (c) interval 2017–2019.

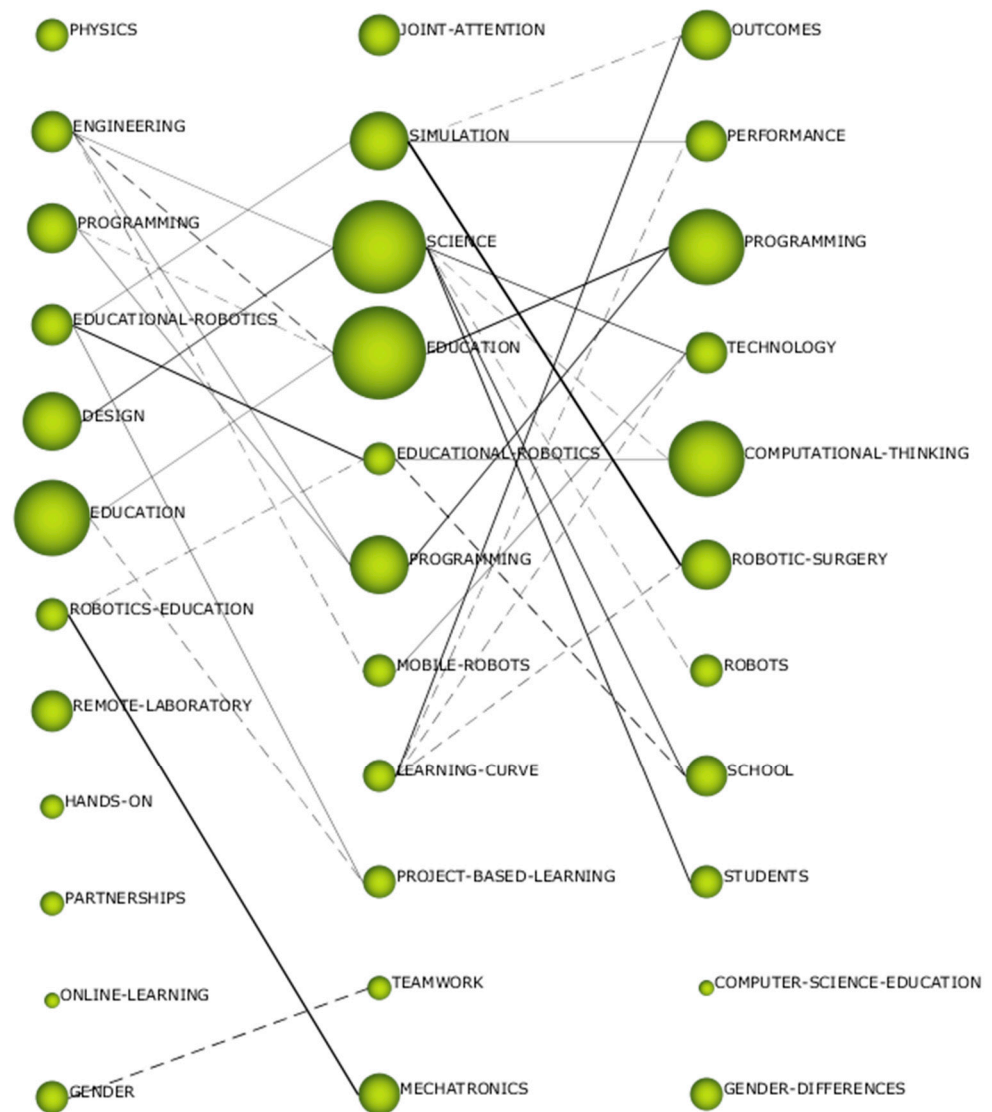
In the second period (2013–2016), the main thematic were “programming”, which is related to “early-childhood”, “concept-mapping”, “prekindergarten”, “engineering”, and “early-childhood-education”; “joint-attention”, which is related to “imitation”, “motor”, “music-therapy”, “behavior”, “young-children”, “autism”, “individuals”, and “rhythm”; “simulation”, which is related to “resident-training”, “robotic-training”, “robotic-prostatectomy”, “surgery”, “face”, “performance”, “robotic-surgery”, and “radical-prostatectomy”; and “learning-curve”, which is related to “validation”, “surgical-education”, “experience”, and “simulator”. In this period, the focus of studies on robotics in education expanded. In this case, the use of robotics was addressed in various educational stages, in the attention of students with special educational needs, and, above all, in the educational field to carry out simulations.

In the third period (2017–2019), the motor thematic were “outcomes”, which is related to “residency-training”, “resection”, “surgical-education”, “learning-curve”, and “minimally-invasive”; “performance”, which is related to “self-efficacy”, “validation”, “surgery-simulator”, “computer-simulation”, “expert”, “virtual-reality”, “stereotypes”, and “girl”; “technology”, which is related to “teaching/learning-strategies”, “perception”, “needs”, “attitudes”, and “choice”; “experience”, which is related to “science” and “elementary-education”; and “robotic-surgery”, which is related to “robotic-training”, “curriculum”, “simulation”, “simulator”, “tool”, “impact”, and “resident-training”. In this period, the line of research established in the previous period was maintained, with added aspects such as simulation, self-efficacy, science, and stereotypes in the use of robotics. In addition, in this period, we must highlight the themes “student”, “school”, and “gender-differences”, which given their position in the diagram can be considered as the future motor thematic of the ROBEDU field of study.

#### 4.3. Thematic Evolution of Terms

The thematic evolution represents the connection between the various themes generated between adjacent periods. This connection can be of two types: conceptual and non-conceptual. The conceptual connection occurs when the two themes represented have a third theme in common. The non-conceptual connection occurs when the connection between themes occurs only through keywords. The conceptual connection is presented with solid lines, and the non-conceptual connection is presented with a broken line. Another feature to bear in mind is the line thickness. The thicker the line is, the more themes or keywords concur between them. This type of connection represents the value and level of coincidences existing in a field of study.

The data shown in Figure 6 indicate several aspects. Firstly, there is no conceptual gap, as the topic “programming” appears in all periods. Secondly, although the topic “programming” appears in all periods, it cannot be considered to be setting an established and solid line of research in the ROBEDU field of study. In this case, there is no consolidated line in all three periods, though the one established by “educational-robotics–educational-robotics–computational-thinking” may slightly stand out. What can certainly be said is that some strong research lines are starting to be generated, made visible from the second period. This is the case of “simulation–robotic-surgery”, “education–programming”, “science–technology”, “science–school”, and “science–student”. Finally, it can be observed that there are not many connections between themes from adjacent periods; nevertheless, conceptual rather than non-conceptual connections predominate. This shows that there are not many shared lines of research.



**Figure 6.** Thematic evolution by h-index.

#### 4.4. Authors with the Highest Relevance Index

Regarding the authors, Figure 7 shows that the most relevant are Candelas, F.A., Rihtarsic, D., and Loreto-Gómez, G. In addition, Hamner, E. and Sutinen, E. must be taken into account due to their location in the diagram, which places them as relevant authors in this field of study.

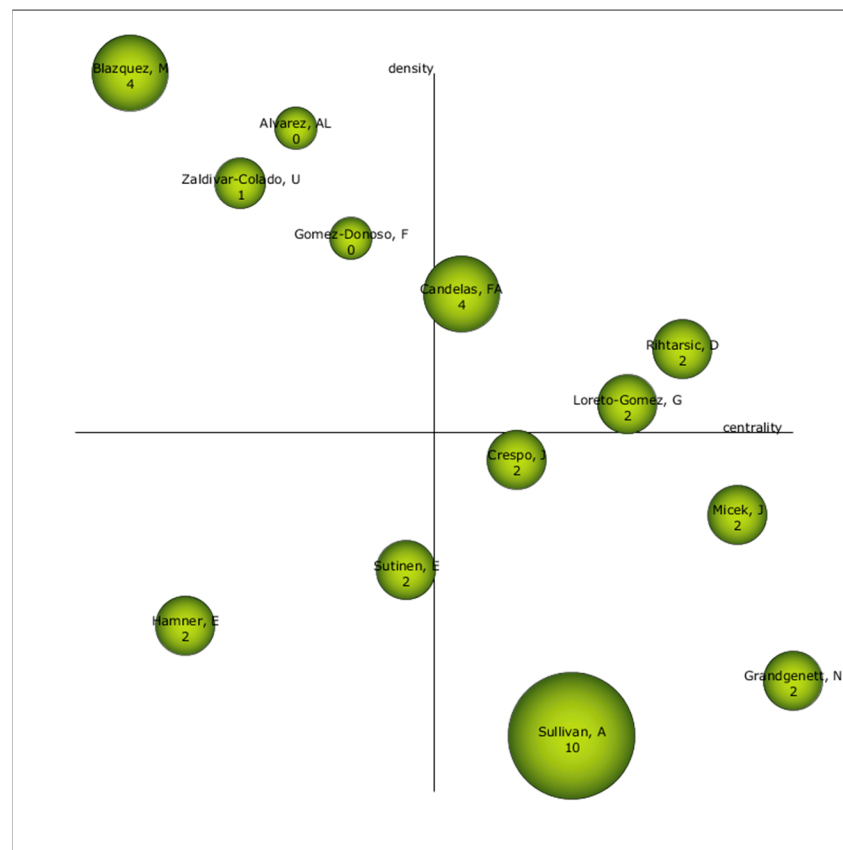


Figure 7. Strategic author diagram of the entire production.

## 5. Discussion and Conclusions

Technology has changed the way we interact and learn [1]. Therefore, teachers should include its use in their pedagogical practice as one more element so that students can learn in a collaborative and active manner [5]. There is a variety of hardware and software that allows the implementation of robotics in the teaching and learning process. As analyzed in other studies, robotics has not yet been implemented in a concrete way in education systems. However, due to the potential it offers for the academic development of students, it will probably be included in the not-too-distant future as a specific subject in various education systems [25–41,47–50].

Regarding the performance analysis and scientific production on robotics in education, the first publication appeared in 1975. The evolution of the volume of production has been uneven, showing an irregular production from 1975 to 1998. There was a low production of documents between 1975 and 2010. However, scientific production increased from 2010 to 2019, with 2019 having the highest production peak with respect to the thematic.

The most used language for publishing in this field of study is English. Two purely educational publication areas stand out, although engineering and computer science areas also appear in the top positions. One of the most prolific institutions in terms of the thematic is the University System of Georgia; however, other institutions have a similar volume of production. As for the country, the United States is the largest producer of documents.

The types of documents produced are mostly proceedings papers. This indicates that the bases of the investigations are not settled at the time in the form of articles, perhaps showing new lines and trends in the investigation. Regarding the source of production, the minute number of books stands out (matching with the data obtained for the types of documents). The most productive journal in the ROBEDI field of study is *Advances in Intelligent Systems and Computing*. As for the authors, several stand out as the highest producers, with the volume of production being nearly the same among the first places. The most prominent relevant authors are Candelas, F.A., Rihtarsic, D., and Loreto-Gómez,

G. According to production and evolution, the authors that will probably be relevant in the future are Hamner, E. and Sutinen, E. With regard to citations, the manuscripts on ROBEDI have a considerable volume of citations, among which the most cited manuscript is that of [42] with 328 citations. In relation to the topics of these works, the most cited manuscript's topic is about the benefits of this educational technology to improve the learning process [94], and practical implications for teachers and professionals. The second most cited work's topic [95] is about the findings of applying robotics with programming on early stages of education. The third topic or work most cited [96] is about verifying the improvement of the performance of adolescent students through robotics. Additionally, finally, the fourth most cited article [97] is about a hybrid learning experience, which was carried out in higher education, combining the face-to-face plane with virtuality through content management platforms of a robotic nature.

On the other hand, in terms of structural and thematic development, the keyword coincidence level between adjacent periods is medium-low. This denotes a lack of established or fixed lines of investigation over time. Academic performance displays changes between the examined periods, moving from focusing on the educational field in general to focusing on science and on programming actions and computational thinking. This corroborates the keyword coincidence, demonstrating that there is no line of investigation established over time.

As for the strategic diagrams, they indicate that during the period between 1975 and 2012, the most relevant investigations pointed toward physics, focused on engineering studies, where active teaching methods based on robotics were applied. Later, in the period between 2013 and 2016, the focus of studies about robotics in education widened. In this case, the use of robotics is addressed in different educational stages, in the attention of students with special educational needs, and especially in the educational field for carrying out simulations. Then, in the period between 2017 and 2019, the line of research previously established is maintained, adding aspects such as simulation, self-efficacy, science, and stereotypes in the use of robotics. In the future, the field of study may focus on the students themselves, schools, and gender differences.

The thematic evolution of terms indicates three main aspects. Firstly, there is no conceptual gap and, therefore, no line of research is recognized in the three periods; however, "educational-robotics-educational-robotics-computational-thinking" is slightly highlighted. Secondly, strong lines of research are observed from the second period onwards, highlighting "simulation-robotic-surgery", "education-programming", "science-technology", "science-school", and "science-student". Finally, there are not many connections between themes from adjacent periods, with the conceptual rather than the non-conceptual connections prevailing. This proves that there are not many shared research lines.

As this study has shown, the field of robotics in education has had an increase and consequent upswing in recent years, especially in 2019. Several parameters have shown that no lines of research have been established over time, but, at the same time, there are clues that, recently, the interest in the subject has been increasing. This opens a field of work for researchers on the thematic of robotics and education, which has expanded over recent years in the field of simulation and self-efficacy.

Regarding future prospects, this study shows the potential that the latest studies on the subject have, showing experts, whether researchers and/or teachers, the next path of research on the subject. In addition, a clear systematic review of the robotics and education aspects of recent research in the scientific literature can be carried out.

About the limitations of this study, it should be highlighted that the year 2020 was not included, since the year had not yet finished and the data would therefore not be real. Furthermore, future research could include a cword analysis on topics associated with the study topic.

With regard to the educational implications of this study, based on the analysis carried out, teachers would have the documents on the thematic of robotics and education at their disposal and the relevance that they have had and still have in the educational field. Proof of this is the finding of the use of robotics in various educational stages, in fore-



grounds particularly, and specifically in the attention of students with special educational needs, in the educational field to carry out simulations, and in self-efficacy with the use of robotics. Given the importance it has for the scientific community in general and teachers in particular, this study paves the way for new lines of work for both teachers and researchers.

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## References

1. Baller, S.; Dutta, S.; Lanvin, B. *Global Information Technology Report 2016*; Ouranos: Geneva, Switzerland, 2016.
2. Bardakci, S.; Ünver, T.K. Preservice ICT teachers' technology metaphors in the margin of technological determinism. *Educ. Inf. Technol.* **2019**, *25*, 905–925. [[CrossRef](#)]
3. Pavel, A.; Fruth, A.; Neacsu, M. ICT and E-Learning—Catalysts for Innovation and Quality in Higher Education. *Procedia Econ. Financ.* **2015**, *23*, 704–711. [[CrossRef](#)]
4. Pandolfini, V. Exploring the Impact of ICTs in Education: Controversies and Challenges. *Ital. J. Sociol. Educ.* **2016**, *8*, 28–53. [[CrossRef](#)]
5. Chen, C.-L.; Wu, C.-C.; Chen, C.-L.; Cheng-Chih, W. Students' behavioral intention to use and achievements in ICT-Integrated mathematics remedial instruction: Case study of a calculus course. *Comput. Educ.* **2020**, *145*, 103740. [[CrossRef](#)]
6. Segura-Robles, A.; Fuentes-Cabrera, A.; Parra-González, M.E.; López-Belmonte, J. Effects on Personal Factors Through Flipped Learning and Gamification as Combined Methodologies in Secondary Education. *Front. Psychol.* **2020**, *11*, 1103. [[CrossRef](#)]
7. Scaradozzi, D.; Screpanti, L.; Cesaretti, L. Towards a Definition of Educational Robotics: A Classification of Tools, Experiences and Assessments. In *Smart Learning with Educational Robotics: Using Robots to Scaffold Learning Outcomes*; Daniela, L., Ed.; Springer International Publishing: Cham, Switzerland, 2019; pp. 63–92.
8. Marín-Marín, J.-A.; Costa, R.S.; Moreno-Guerrero, A.-J.; López-Belmonte, J. Makey Makey as an Interactive Robotic Tool for High School Students' Learning in Multicultural Contexts. *Educ. Sci.* **2020**, *10*, 239. [[CrossRef](#)]
9. Miller, D.P.; Nourbakhsh, I. Robotics for Education. In *Springer Handbook of Robotics*; Siciliano, B., Khatib, O., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 2115–2134.
10. Papert, S. *Mindstorms: Children, Computers, and Powerful Ideas*; Basic Books, Inc.: New York, NY, USA, 2020.
11. Kubilinskiene, S.; Zilinskiene, I.; Dagiene, V.; Sinkevičius, V. Applying Robotics in School Education: A Systematic Review. *BJMC* **2017**, *5*, 50–69. [[CrossRef](#)]
12. Sullivan, F.R. Robotics and science literacy: Thinking skills, science process skills and systems understanding. *J. Res. Sci. Teach.* **2008**, *45*, 373–394. [[CrossRef](#)]
13. Williams, D.C.; Ma, Y.; Prejean, L.; Ford, M.J.; Lai, G. Acquisition of Physics Content Knowledge and Scientific Inquiry Skills in a Robotics Summer Camp. *J. Res. Technol. Educ.* **2007**, *40*, 201–216. [[CrossRef](#)]
14. Vargheese, M.G.; Education, M.T.; Suresh, M.J. *Beginner Robotics: Robotic Mechanics—With Lego Mindstorms: Volume 2*; CreateSpace Independent Publishing Platform: Scotts Valley, CA, USA, 2013; ISBN 978-1-4820-9038-3.
15. Ferreira, E.; Silva, M.J.; da Cruz Valente, B. Collaborative uses of ICT in education: Practices and representations of preservice elementary school teachers. In Proceedings of the 2018 International Symposium on Computers in Education (SIIE), Jerez, Spain, 19–21 September 2018; pp. 1–6.
16. Qureshi, M.; Syed, R. The Impact of Robotics on Employment and Motivation of Employees in the Service Sector, with Special Reference to Health Care. *Saf. Health Work* **2014**, *5*, 198–202. [[CrossRef](#)]
17. Marín-Marín, J.A.; Soler-Costa, R.; Moreno-Guerrero, A.J.; López-Belmonte, J. Effectiveness of Diet Habits and Active Life in Vocational Training for Higher Technician in Dietetics: Contrast between the Traditional Method and the Digital Resources. *Nutrients* **2020**, *12*, 3475. [[CrossRef](#)] [[PubMed](#)]
18. Sáez, J.M.; Buceta, R.; De Lara, S. Introducing robotics and block programming in elementary education. *RIED* **2021**, *24*, 95–113. [[CrossRef](#)]
19. Ruíz, F.; Zapatera, A.; Montes, N. Curriculum analysis and design, implementation, and validation of a STEAM project through educational robotics in primary education. *Comput. Appl. Eng. Educ.* **2020**, 1–15. [[CrossRef](#)]
20. Schina, D.; Esteve-González, V.; Usart, M.; Lizaro-Cantabrana, J.L.; Gisbert, M. The Integration of Sustainable Development Goals in Educational Robotics: A Teacher Education Experience. *Sustainability* **2020**, *12*, 85. [[CrossRef](#)]
21. Canas, J.M.; Perdices, E.; García-Pérez, L.; Fernández-Conde, J. A ROS-Based Open Tool for Intelligent Robotics Education. *Appl. Sci.* **2020**, *10*, 7419. [[CrossRef](#)]

22. Yilmaz, E.; Koc, M. The consequences of robotics programming education on computational thinking skills: An intervention of the Young Engineer's Workshop (YEW). *Comput. Appl. Eng. Educ.* **2020**, 1–18. [[CrossRef](#)]
23. Chen, C.H.; Yang, C.K.; Huang, K.; Yao, K.C. Augmented reality and competition in robotics education: Effects on 21st century competencies, group collaboration and learning motivation. *J. Comput. Assist. Learn.* **2020**, *36*, 1052–10662. [[CrossRef](#)]
24. Zhong, B.C.; Zheng, J.J.; Zhan, Z.H. An exploration of combining virtual and physical robots in robotics education. *Interact. Learn. Environ.* **2020**, 1–13. [[CrossRef](#)]
25. Tang, A.L.L.; Tung, V.W.S.; Cheng, T.O. Teachers' perceptions of the potential use of educational robotics in management education. *Interact. Learn. Environ.* **2020**, 1–12. [[CrossRef](#)]
26. Alemi, M.; Taheri, A.; Shariati, A.; Meghdari, A. Social Robotics, Education, and Religion in the Islamic World: An Iranian Perspective. *Sci. Eng. Ethics* **2020**, *26*, 2709–2734. [[CrossRef](#)]
27. Caballero-González, Y.A.; García-Valcarcel, A. Learning with Robotics in Primary Education? A Means of Stimulating Computational Thinking. *Educ. Knowl. Soc.* **2020**, *21*, 1–10. [[CrossRef](#)]
28. Turan, S.; Aydogdu, F. Effect of coding and robotic education on pre-school children's skills of scientific process. *Educ. Inf. Technol.* **2020**, *25*, 4353–4363. [[CrossRef](#)]
29. Naik, R.; Mandal, I. Robotic simulation experience in undergraduate medical education: A perspective. *J. Robot. Surg.* **2020**, *14*, 793–794. [[CrossRef](#)] [[PubMed](#)]
30. Zhong, B.C.; Li, T.T. Can Pair Learning Improve Students' Troubleshooting Performance in Robotics Education? *J. Educ. Comput. Res.* **2020**, *58*, 220–249. [[CrossRef](#)]
31. Gorjup, G.; Liarokapis, M. A Low-Cost, Open-Source, Robotic Airship for Education and Research. *IEEE Access* **2020**, *8*, 70713–70721. [[CrossRef](#)]
32. Chootongchai, S.; Songkram, N.; Piromsopa, K. Dimensions of robotic education quality: Teachers' perspectives as teaching assistants in Thai elementary schools. *Educ. Inf. Technol.* **2019**, 1–21. [[CrossRef](#)]
33. Vega, J.; Canas, J.M. Open Vision System for Low-Cost Robotics Education. *Electronics* **2019**, *8*, 1295. [[CrossRef](#)]
34. Díaz-Lauzurica, B.; Moreno-Salinas, D. Computational Thinking and Robotics: A Teaching Experience in Compulsory Secondary Education with Students with High Degree of Apathy and Demotivation. *Sustainability* **2019**, *11*, 5109. [[CrossRef](#)]
35. Gaudiello, I.; Zibetti, E. Educational Robotics in Science Education: Why and how. *Enfance* **2019**, *3*, 309–332. [[CrossRef](#)]
36. Ospennikova, E.; Ershov, M.; Iljin, I. Educational Robotics as an Inovative Educational Technology. *Procedia Soc. Behav. Sci.* **2015**, *214*, 18–26. [[CrossRef](#)]
37. Blackley, S.; Howell, J. The Next Chapter in the STEM Education Narrative: Using Robotics to Support Programming and Coding. *Australas. J. Teach. Educ.* **2019**, *44*, 51–64. [[CrossRef](#)]
38. García-Valcarcel, A.; Caballero-González, Y.A. Robotics to develop computational thinking in early Childhood Education. *Comunicar* **2019**, *27*, 63–72. [[CrossRef](#)]
39. Parent, S.; Iatauro, S. Global Robotics Competition Meets Inclusive Education: The Exceptional Journey of Five Resilient Students. *Learn. Landsc.* **2019**, *12*, 29–32. [[CrossRef](#)]
40. Moreno-Guerrero, A.J.; Rodríguez, C.; Ramos, M.; Sola, J.M. Secondary Education students' interest and motivation towards using Aurasma in Physical Education classes. *Retos* **2020**, *38*, 333–340. [[CrossRef](#)]
41. Yi, H. Robotics and kinetic design for underrepresented minority (URM) students in building education: Challenges and opportunities. *Comput. Appl. Eng. Educ.* **2019**, *27*, 351–370. [[CrossRef](#)]
42. Hsieh, S.J. Development and Evaluation of Remote Virtual Teach Pendant for Industrial Robotics Education. *Int. J. Eng. Educ.* **2019**, *35*, 1816–1826.
43. Hinojo-Lucena, F.J.; Dúo-Terrón, P.; Ramos, M.; Rodríguez-Jiménez, C.; Moreno-Guerrero, A.J. Scientific Performance and Mapping of the Term STEM in Education on the Web of Science. *Sustainability* **2020**, *12*, 2279. [[CrossRef](#)]
44. Vivas, L.; Sáez, J.M. Integration of educational robotics in Primary Education. *RELATEC* **2019**, *18*, 107–129. [[CrossRef](#)]
45. Vega, J.; Canas, J.M. PiBot: An Open Low-Cost Robotic Platform with Camera for STEM Education. *Electronics* **2018**, *7*, 430. [[CrossRef](#)]
46. Moreno-Guerrero, A.J.; Alonso, S.; Ramos, M.; Campos-Soto, N.; Gómez, G. Augmented Reality as a Resource for Improving Learning in the Physical Education Classroom. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3637. [[CrossRef](#)]
47. Fonseca, N.M.; Freitas, E.D.C. Computer applications for education on industrial robotic systems. *Comput. Appl. Eng. Educ.* **2018**, *26*, 1186–1194. [[CrossRef](#)]
48. Morze, N.V.; Gladun, M.A.; Dziuba, S.M. Formation of key and subject competences of students by robotics kits of Stem-Education. *Inf. Technol. Learn. Tools* **2018**, *65*, 37–52. [[CrossRef](#)]
49. Esposito, J.M. The State of Robotics Education Proposed Goals for Positively Transforming Robotics Education at Postsecondary Institutions. *IEEE Robot. Autom. Mag.* **2017**, *24*, 157–164. [[CrossRef](#)]
50. Merkouris, A.; Chorianopoulos, K.; Kameas, A. Teaching Programming in Secondary Education through Embodied Computing Platforms: Robotics and Wearables. *ACM Trans. Comput. Educ.* **2017**, *17*, 1–22. [[CrossRef](#)]
51. López, J.A.; López-Belmonte, J.; Moreno-Guerrero, A.J.; Pozo, S. Effectiveness of Innovate Educational Practices with Flipped Learning and Remote Sensing in Earth and Environmental Sciences—An Exploratory Case Study. *Remote Sens.* **2020**, *12*, 897. [[CrossRef](#)]
52. Galimullina, E.Z.; Ljibimova, E.M.; Sharafeeva, L.R. Introduction of the robotics in education of children and youth. *Turk. Online J. Des. Art Commun.* **2017**, *7*, 738–744. [[CrossRef](#)]
53. Viegas, J.V.; Villalba, K.O. Education and Educative Robotics. *RED* **2017**, *54*, 1–13. [[CrossRef](#)]

54. Salgarayeva, G.I.; Bazarbayeva, A. STEAM system in Education and Robotics. *News Natl. Acad. Sci. Repub. Kazakhstan* **2017**, *2*, 81–86.
55. Deniz, C.; Cakir, M. A novel designed interactive training platform for industrial robot offline programming and robotics education. *Int. J. Robot. Autom.* **2017**, *32*, 665–672. [[CrossRef](#)]
56. Zalewski, J.; González, F. Evolution in the Education of Software Engineers: Online Course on Cyberphysical Systems with Remote Access to Robotic Devices. *Int. J. Online Eng.* **2017**, *13*, 133–146. [[CrossRef](#)]
57. Kanbul, S.; Uzunboylu, H. Importance of Coding Education and Robotic Applications for Achieving 21st-Century Skills in North Cyprus. *Int. J. Emerg. Technol. Learn.* **2017**, *12*, 130–140. [[CrossRef](#)]
58. Vitale, G.; Bonarini, A.; Matteucci, M.; Bascetta, L. Toward Vocational Robotics an Experience in Post-Secondary School Education and Job Training Through Robotics. *IEEE Robot. Autom. Mag.* **2016**, *23*, 73–81. [[CrossRef](#)]
59. Takacs, A.; Eigner, G.; Kovacs, L.; Rudas, J.J.; Haidegger, T. Teacher’s Kit Development, Usability, and Communities of Modular Robotic Kits for Classroom Education. *IEEE Robot. Autom. Mag.* **2016**, *23*, 30–39. [[CrossRef](#)]
60. Wallace, M.L.; Freitas, W.M. Resources for Underwater Robotics Education. *J. Ext.* **2016**, *54*, 1–3.
61. Mester, G. Massive open online courses in education of robotics. *Interdiscip. Descr. Complex Syst.* **2016**, *14*, 182–187. [[CrossRef](#)]
62. Núñez, A.J. Robotics Education Done Right: Robotics Expansion (TM), A STEAM Based Curricula. *Contemp. Trends Issues Sci. Educ.* **2016**, *44*, 169–185. [[CrossRef](#)]
63. Sánchez, E.; Cózar, R.; González-Calero, J.A. Robotics in the teaching of knowledge and interaction with the environment. A formative study in Early Childhood Education. *RIFOP* **2019**, *94*, 11–28.
64. Arís, N.; Orcos, L. Educational robotics in the stage of secondary education: Empirical study on motivation and STEM skills. *Educ. Sci.* **2019**, *9*, 73. [[CrossRef](#)]
65. Zhong, B.; Xia, L. A systematic review on exploring the potential of educational robotics in mathematics education. *Int. J. Sci. Math. Educ.* **2020**, *18*, 79–101. [[CrossRef](#)]
66. Tan, P.J.B.; Hsu, M.H. Designing a system for English evaluation and teaching devices: A PZB and TAM model analysis. *Eurasia J. Math. Sci. Technol. Educ.* **2018**, *14*, 2107–2119. [[CrossRef](#)]
67. Tan, P.J.B. An empirical study of how the learning attitudes of college students toward English e-tutoring websites affect site sustainability. *Sustainability* **2019**, *11*, 1748. [[CrossRef](#)]
68. Segura-Robles, A.; Moreno-Guerrero, A.J.; Parra-González, E.; López-Belmonte, J. Review of Research Trends in Learning and the Internet in Higher Education. *Soc. Sci.* **2020**, *9*, 101. [[CrossRef](#)]
69. Ellegaard, O.; Wallin, J.A. The bibliometric analysis of scholarly production: How great is the impact? *Scientometrics* **2015**, *105*, 1809–1831. [[CrossRef](#)] [[PubMed](#)]
70. Carmona-Serrano, N.; López-Belmonte, J.; López-Núñez, J.-A.; Moreno-Guerrero, A.-J. Trends in autism research in the field of education in Web of Science: A bibliometric study. *Brain Sci.* **2020**, *10*, 1018. [[CrossRef](#)] [[PubMed](#)]
71. López-Belmonte, J.; Moreno-Guerrero, A.J.; López-Núñez, J.A.; Pozo-Sánchez, S. Analysis of the Productive, Structural, and Dynamic Development of Augmented Reality in Higher Education Research on the Web of Science. *Appl. Sci.* **2019**, *9*, 5306. [[CrossRef](#)]
72. Cobo, M.J.; López, A.G.; Herrera, E.; Herrera, F. Science mapping software tools: Review, analysis, and cooperative study among tools. *J. Am. Soc. Inf. Sci. Technol.* **2011**, *62*, 1382–1402. [[CrossRef](#)]
73. Rodríguez-García, A.M.; López-Belmonte, J.; Agreda-Montoro, M.; Moreno-Guerrero, A.J. Productive, Structural and Dynamic Study of the Concept of Sustainability in the Educational Field. *Sustainability* **2019**, *11*, 5613. [[CrossRef](#)]
74. Leung, X.Y.; Sun, J.; Bai, B. Bibliometrics of social media research: A co-citation and co-word analysis. *Int. J. Hosp. Manag.* **2017**, *66*, 35–45. [[CrossRef](#)]
75. López-Belmonte, J.; Parra-González, M.E.; Segura-Robles, A.; Pozo-Sánchez, S. Scientific Mapping of Gamification in Web of Science. *Eur. J. Investig. Healthpsychol. Educ.* **2020**, *10*, 832–847. [[CrossRef](#)]
76. Martínez, M.A.; Cobo, M.J.; Herrera, M.; Herrera, E. Analyzing the scientific evolution of social work using science mapping. *Res. Soc. Work Pract.* **2015**, *25*, 257–277. [[CrossRef](#)]
77. Carmona-Serrano, N.; Moreno-Guerrero, A.-J.; Marín-Marín, J.-A.; López-Belmonte, J. Evolution of the Autism Literature and the Influence of Parents: A Scientific Mapping in Web of Science. *Brain Sci.* **2021**, *11*, 74. [[CrossRef](#)]
78. Hirsch, J.E. An index to quantify an individual’s scientific research output. *Proc. Natl. Acad. Sci. USA* **2005**, *102*, 16569–16572. [[CrossRef](#)] [[PubMed](#)]
79. Moreno-Guerrero, A.J.; Gómez-García, G.; López-Belmonte, J.; Rodríguez-Jiménez, C. Internet Addiction in the Web of Science Database: A Review of the Literature with Scientific Mapping. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2753. [[CrossRef](#)]
80. López-Robles, J.R.; Otegi-Olaso, J.R.; Porto, I.; Cobo, M.J. 30 years of intelligence models in management and business: A bibliometric review. *Int. J. Inf. Manag.* **2019**, *48*, 22–38. [[CrossRef](#)]
81. López-Belmonte, J.; Marín-Marín, J.A.; Soler-Costa, R.; Moreno-Guerrero, A.J. Arduino Advances in Web of Science. A Scientific Mapping of Literary Production. *IEEE Access* **2020**, *8*, 128674–128682. [[CrossRef](#)]
82. Moral-Muñoz, J.A.; Herrera-Viedma, E.; Santisteban-Espejo, A.; Cobo, M.J. Software tools for conducting bibliometric analysis in science: An up-to-date review. *El Prof. De La Inf.* **2020**, *29*, e290103. [[CrossRef](#)]
83. Moreno-Guerrero, A.J.; López-Belmonte, J.; Marín-Marín, J.A.; Soler-Costa, R. Scientific development of educational artificial intelligence in Web of Science. *Future Internet* **2020**, *12*, 124. [[CrossRef](#)]

84. López-Núñez, J.A.; López-Belmonte, J.; Moreno-Guerrero, A.J.; Ramos, M.; Hinojo-Lucena, F.J. Education and Diet in the Scientific Literature: A Study of the Productive, Structural, and Dynamic Development in Web of Science. *Sustainability* **2020**, *12*, 4838. [[CrossRef](#)]
85. Moreno-Guerrero, A.J. Estudio bibliométrico de la producción científica en Web of Science: Formación Profesional y blended learning. *Píxel-Bit. Rev. De Medios Y Educ.* **2019**, *56*, 149–168. [[CrossRef](#)]
86. Montero-Díaz, J.; Cobo, M.J.; Gutiérrez-Salcedo, M.; Segado-Boj, F.; Herrera-Viedma, E. Mapeo científico de la Categoría «Comunicación» en WoS (1980-2013). *Comunicar* **2018**, *26*, 81–91. [[CrossRef](#)]
87. López-Belmonte, J.; Segura-Robles, A.; Moreno-Guerrero, A.-J.; Parra-González, M.-E. Projection of E-Learning in Higher Education: A Study of Its Scientific Production in Web of Science. *Eur. J. Investig. Healthpsychol. Educ.* **2021**, *11*, 3. [[CrossRef](#)]
88. Parra-González, M.; Segura-Robles, A.; Vicente-Bújez, M.; López-Belmonte, J. Production Analysis and Scientific Mapping on Active Methodologies in Web of Science. *Int. J. Emerg. Technol. Learn.* **2020**, *15*, 71–86. [[CrossRef](#)]
89. Herrera-Viedma, E.; López-Robles, J.R.; Guallar, J.; Cobo, M.J. Global trends in coronavirus research at the time of Covid-19: A general bibliometric approach and content analysis using SciMAT. *El Prof. De La Inf.* **2020**, *29*, e290103. [[CrossRef](#)]
90. Callon, M.; Courtial, J.P.; Lavoie, F. Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemistry. *Scientometrics* **1991**, *22*, 155–205. [[CrossRef](#)]
91. López-Belmonte, J.; Moreno-Guerrero, A.J.; López-Núñez, J.A.; Hinojo-Lucena, F.J. Augmented reality in education. A scientific mapping in Web of Science. *Interact. Learn. Environ.* **2020**, 1–15. [[CrossRef](#)]
92. López-Belmonte, J.; Segura-Robles, A.; Moreno-Guerrero, A.J.; Parra-González, E. Machine Learning and Big Data in the Impact Literature. A Bibliometric Review with Scientific Mapping in Web of Science. *Symmetry* **2020**, *12*, 495. [[CrossRef](#)]
93. Carmona-Serrano, N.; López-Belmonte, J.; Cuesta-Gómez, J.L.; Moreno-Guerrero, A.J. Documentary Analysis of the Scientific Literature on Autism and Technology in Web of Science. *Brain Sci.* **2020**, *10*, 985. [[CrossRef](#)]
94. Vavassoru, B.; Barreto, F. Exploring the educational potential of robotics in schools: A systematic review. *Comput. Educ.* **2012**, *58*, 978–988. [[CrossRef](#)]
95. Bers, M.U.; Flannery, L.; Kazakoff, E.R.; Sullivan, A. Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Comput. Educ.* **2014**, *72*, 145–157. [[CrossRef](#)]
96. Barker, B.S.; Ansoorge, J. Robotics as Means to Increase Achievement Scores in an Informal Learning Environment. *J. Res. Technol. Educ.* **2007**, *39*, 229–243. [[CrossRef](#)]
97. Jara, C.A.; Candelas, F.A.; Puente, S.T.; Torres, F. Hands-on experiences of undergraduate students in Automatics and Robotics using a virtual and remote laboratory. *Comput. Educ.* **2011**, *57*, 2451–2461. [[CrossRef](#)]