Article

The Emergence of Technology in Physical Education: A General Bibliometric Analysis with a Focus on Virtual and Augmented Reality

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Abstract: Technology has been gradually introduced into our society, and the field of education is no exception due to technology's ability to improve the teaching–learning process. Furthermore, within the area of physical education (PE), its importance has been highlighted by the existence of specific apps for physical activity that can be used inside and outside the classroom to assess physical condition, as well as through the potential that virtual and augmented reality can have in such assessment. Therefore, the main objectives for this study were (1) to perform a bibliometric analysis of the articles published in the Web of Science (WoS) on technology in PE and (2) to analyze the articles published on augmented or virtual reality in PE found through this search. The results show that although studies on technology in PE (461 articles) have begun to consolidate over the last five years (there was a turning point in 2015), with the USA being the most influential country in this area, specific research on the use of augmented reality (AR) and virtual reality (VR) is still at a very early stage (22 articles with a small growth in 2017), with Spain being the most influential country; much more research is needed to achieve its consolidation.

1. Introduction

The growing use of technology in society has been the driving force behind the digitization of education, as education policymakers and society in general believe that technology can improve education [1]. This is why education systems around the world are incorporating digital skills into their curricula and assessments [2,3], and are encouraging teachers to include technologies in the classroom, either as a tool to facilitate learning or as a means for formative assessment [4]. Thus, it can be seen that there are high expectations that digital technology will optimize student learning in schools and this is reflected in the increase in educational policies and new curricula [5].

Therefore, the adoption of technology has become an emerging aspect of the broader discussion within the field of education in general, as well as in the specific case of physical education (PE) [6]. In fact, with an increasing number of technologies available, physical educators have begun to explore applications of technology related to physical education environments [1]. However, while there has been an increase in support and research on the integration of technology and training into general teacher education, there are not enough research and programming efforts related to the integration of

technology into specific disciplines, such as PE [7,8], and the opportunities for digital technologies to shape PE in new and positive ways should be explored [6].

Therefore, focusing on technology in PE is particularly important, given the specific technologies used in this discipline [9]. It is also important to note that it has been suggested that the integration of the appropriate assessment of students' physical ability into the PE curriculum is an essential element of PE [10,11], highlighting the need to apply technology in physical fitness testing for young people to improve the accuracy of test results and to address the problems of deprivation due to space and time constraints [12]. In addition, several researchers have found positive results regarding the impact of the use of these technologies in PE settings in terms of different aspects, such as understanding and cognitive motivation of students [13–17], motor skills performance [17–21], and the levels of physical activity in the classrooms [22,23], among other aspects.

Regarding the technology used in PE, this includes everything from physical activity (PA) trackers and versatile devices that can record and track movement and therefore can help students self-assess (e.g., cameras, pedometers, heart rate monitors, PA watches), to various mobile applications and active video games (e.g., motion analysis or global positioning system (GPS) applications), as well as health-related apps [6,8,24–26]. In addition, within these, virtual reality (VR) and augmented reality (AR) are emerging technologies that are gaining special interest in the educational field [27–29].

In relation to VR and AR, both are based on the experience of living through the use of technology, although they are different terms. AR refers to the combination of elements from the real world and elements from the virtual world [30]. It offers the possibility of mixing and combining two environments: the physical and the digital in real time through the use of emerging and easily accessible technologies, such as smartphones or tablets [29]. In relation to how AR can be incorporated into the field of education, the research carried out is limited but growing [31], with this possibly being one of the great problems it has regarding its incorporation into teaching.

Regarding VR, the person can be at home or in a classroom, and by means of this technology, be transported to a totally different context by means of the images, sounds, and videos that are presented [32]. It is worth noting that there are many areas where VR can be integrated, but the subject of PE is presented as a flexible and adaptable area for this approach [27]. The main advantage of this tool applied to education is the possibility of recreating and exploring different environments, whether real or fantasy, to study different types of phenomena [33]. Therefore, the main difference between them lies in the fact that VR generates a totally virtualized world without resorting, like AR, to the introduction of virtual elements within real spaces.

This is significant at the intersection of PE and VR and PE and AR because they are technologies that can be easily introduced within the PE classes, and they can improve the learning process of the physical activity practice. In fact, some authors have highlighted the suitability of these technological tools to be used in the PE subject [27,34], both to teach key concepts of PE and to increase students' physical activity. This is because students can use these technologies to learn motor skills in a new way, such as imitating the movement of an expert avatar [34], and thus learn new movements or improve their technique; and to learn abilities, such as reaction, coordination, and spatial skills [35], as well as develop some offensive skills [36].

In addition, these technological tools allow for the work of transversal themes that can vary depending on the theme of the game and the intention of the teacher, which makes this proposal an interesting option for working transversally with other subjects [37]. Furthermore, they help to bring environments closer, such as facilities or natural environments that education centers do not have, and thus generate new scenarios of physical sports practice that can attract students' attention [38], enriching students' motor experiences. Furthermore, through the use of these technologies, the integration of people with functional diversity in the classroom can be fostered because they facilitate the adaptation of physical sports practice environments, as well as encouraging teamwork and cooperation [35].

However, although bibliometric analyses have been carried out on m-learning and AR in education [32], as well as on AR and its role in education [27] and higher education through virtual

laboratories [39], no specific analysis was found within the field of PE. The bibliometric studies carried out on the use of technology in PE were carried out from the perspective of information and communication technology (ICT) [40], as well as VR [37]. However, none of these studies focused solely on the Web of Science (WoS), nor did they address the perspective of technology in PE in general and the specific use of AR and VR through bibliometric maps. Therefore, the main objectives of this study were (a) to perform a bibliometric analysis of the articles published in WoS on technology in PE and (b) to analyze within this search the articles published on augmented or virtual reality in PE. For this purpose, the following questions guided this research:

- RQ1: How did the articles published on technology in PE and AR and VR evolve over time?
- RQ2: Which authors have published the highest number of articles on technology in PE in general and specifically on AR and VR, and which ones were most cited?
- RQ3: Which countries, academic journals, and institutions were focusing the most attention on technology in PE in general and specifically on AR and VR in PE?
- RQ4: What networks of co-authorship, co-words, and thematic analysis reflect studies on technology in PE and specifically on AR and VR?

The results showed that the number of published articles has increased significantly over the last five years, especially from 2015 onwards (RQ1). In relation to referenced authors, Goodyear was the author with the highest number of publications and citations in this field, followed by Casey, both from English institutions (RQ2). However, co-authoring networks were still scarce and small, with few consolidated networks at present. The thematic analysis showed three different lines within this field of study: (a) the training and implementation of technologies in the educational context that were more related to fitness and training evaluation; (b) the motivation of the use of technologies and gamification in PE classes, and their role in combating obesity; and (c) the training of PE teachers in the use of new technologies in the classroom (RQ4). Finally, within this search, in relation to the specific use of two technologies in PE that are acquiring great value, namely AR and VR, the number of articles found was very limited (22 articles), with a small increase from 2017 onward (RQ1). The most influential authors in this field were Arribas-Cubero, Gallego-Lema, and Muñoz-Cristobal, all of them belonging to Spanish institutions (RQ2). In this case, collaboration networks among authors are more scarce and less consolidated, although some are larger (RQ4).

In order to answer the research questions and achieve the research objectives, this article is divided into different sections as follows. After presenting the framework on which the work is developed, the method of the study is presented, in which, first, the process of searching and collecting data is explained, and second, the process of downloading and debugging the data, as well as the different analyses, are elaborated upon. The results are then presented: First, those relating to the search for technology and PE in general, starting with the basic indicators of quantity and quality and ending with the different maps of co-authoring, co-word, and thematic analysis. Later, in this same section, all the articles found on VR or AR in PE are presented, also presenting the results related to the quantity and quality of this production first, and then the co-authorship and co-word maps. Finally, the results of this bibliometric analysis are discussed, the limitations and future lines of research are presented, and this article ends with the conclusions of the results found.

2. Materials and Methods

2.1. Data Collection

To collect the data, a search in the Web of Science (WoS) Core Collection^{TM} was performed. This database was selected because the impact factor (IF) is the most common indicator used for evaluating scientific journals [41], and the vast majority of bibliographic analysis articles have used [42,43]. Therefore, the search was performed in the WoS Core Collection^{TM} using the following indicators (1900–2019): Web of Science Core Collection, Derwent Innovations Index, KCI-Korean

Journal Database, MEDLINE, Current Contents Connect, SciELO Citation Index, and Russian Science Citation Index. The following indices were including during this search: Science Citation Index Expanded (1900–present), Social Sciences Citation Index (1956–present), Arts & Humanities Citation Index (1975–present), and Emerging Sources Citation Index (2015–present).

The data was gathered from the online database run by Thomson Reuters (New York, NY, USA), which contains academic publications and information regarding the authors and the publications. An advanced search using theme (TS) as the search field was performed using the following search equation: TS = (("virtual reality") OR ("augmented reality") OR (technolog*)) AND ("physical education")), obtaining 504 documents. Then, the search was redefined, and the book chapters, and the articles' proceedings papers were deleted, leaving only the articles and early citation articles. Finally, a total of 461 articles were obtained.

Second, a more specific search was performed within the articles of the previous search, and the term technology was deleted from the equation presented above, leaving the equation as follows: TS = ((("virtual reality") OR ("augmented reality")) AND ("physical education")). This search yielded 23 results, considering the indexes presented above and applying the filter articles. In this case, one book chapter was deleted, leaving this search with a total of 22 articles. Therefore, of the 461 articles collected in the first search related to the use of new technologies in PE in general, 22 of them were related specifically to the use of AR and VR in the PE.

These two searches (general and specific) were performed on 6 November 2019. No filters of language or publication year were used. All the records were downloaded in plain text format with the following fields: authors, keywords, abstract, year published, subject category, publication name, ISSN (International Standard Serial Number), and times cited, for further analyses with the bibliometric software presented in the next section.

2.2. Data Analysis

The first step was to check the records of the downloaded resources. All duplicate records were deleted before performing the bibliometric analysis. Moreover, the missing data of the records were completed by looking for that information in other sources, and the authors' names were standardized. Then, these indicators were used to analyze the data: years, authors, countries, institutions, and journals. Moreover, co-occurrence analysis was performed to analyze the relationship between authors and keywords by creating bibliometric maps.

A bibliometric analysis of quality and quantity was performed. In fact, not only the number of publications found by a researcher, but also the quality of the journals in which they were published [44]; these details have been fundamental factors for years, and therefore, it is very relevant and useful to know this information. In the first analysis, the productivity of technology in PE was analyses in general, while in the second analysis, the productivity of the articles published about AR and VR in PE were analyzed. The analysis was performed in two different phases. First, the basic bibliometric indexes (number of articles published by year, by author, by country, by institution, and by journal) were calculated. Toward this aim, the statistical software HistCite (ver. 2010.12.6; HistCite Software LLC, NY, USA) was used. In these cases, both the quality and quantity indexes were considered to analyze the research on VR and AR in PE.

Focusing on the qualitative indexes, the total global citation score (TGCS) and the total local citation score (TLCS) are recommended [45], and they were considered as indicators in this study. The first index, the TGCS, is related to the number of times that a document included in a search has been cited in the whole WoS Core Collection. The second index, the TLCS, is related to the number of times that a document included in a collection (the search performed) has been cited by other documents within the same collection [46]. These two indicators were calculated using the software HistCite.

Second, the relationships between authors and keywords were analyzed by performing co-authoring and co-keyword analysis using BibExcel (ver. 2011.02.03; Olle Persson, Umea University, Umea, Sweden) and Pajeck (ver.3.14, 2013.11.12; Batagelj and Mvar, University of Ljubljana, Ljubljana,

Slovenia). The first program was used to analyze the co-authoring and co-keywords and to generate the document to create the network maps. The second one was used to draw the maps. Finally, a thematic analysis was also performed, in which the title and abstract terms were analyzed. The software VOSviewer (ver.1.6.8; Nees Jan van Eck and LudoWaltman, Leiden University, Leiden and Erasmus University, Rotterdam, The Netherlands) was used to analyze this data and to create the maps.

3. Results

This section gives the results obtained from the generic bibliometric search first (technologies in PE), and then presents the results of the specific search within this general search (AR and VR in PE). To do this, the basic indicators (years, authors, journals, countries, and institutions) are presented, followed by co-occurrence (co-author and co-word) and thematic analyses.

3.1. General Search: Technologies in Physical Education

A total of 461 articles, published in 203 journals, written by 1001 researchers from 584 institutions from 50 countries were found. In this section, the indicators related to years of publication and most productive authors, journals, institutions, and countries, as well as co-author and co-word networks and thematic analysis is presented.

3.1.1. Basic Bibliometric Indicators

Years

Focusing on the number of articles published by year, Figure 1 shows how the first articles on this subject were published in 1994. Since then, the number of articles remained stable until 2015, when there was a large increase. The year in which the greatest number of articles was published on this subject was 2017. The results are shown in Figure 1 below:
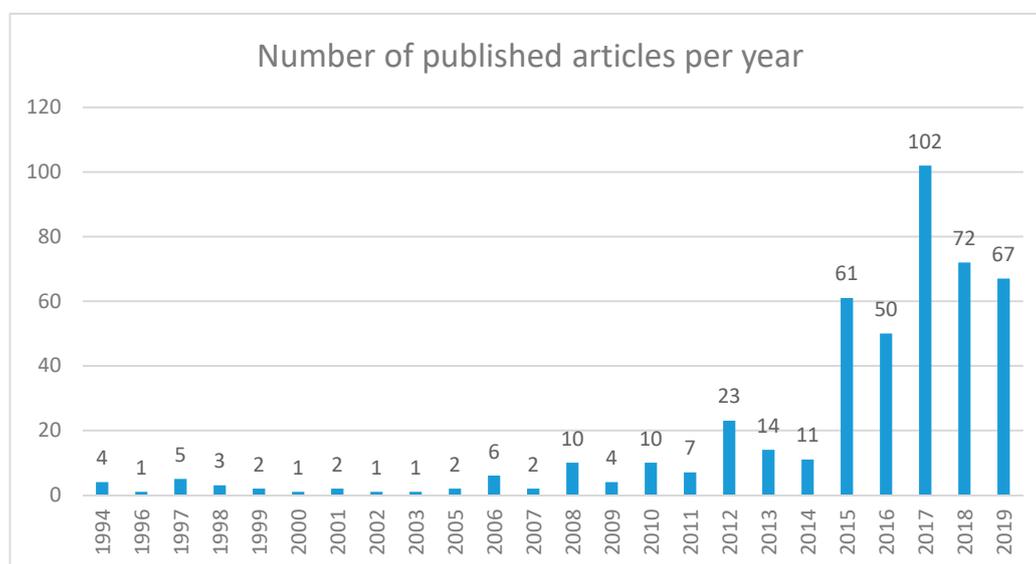

Figure 1. Evolution of the number of articles published on technologies in physical education (PE) in the Web of Science (WoS).

Authors

In relation to the authors, 1001 researchers published at least one article on this subject. Among all of them, the researchers who published a greater number of articles were V.A. Goodyear with seven articles, followed by A. Casey, B. Hyndman, and A. Wrench with five articles each. The author with

the highest number of citations (TGCS) was V.A. Goodyear. Table 1 below shows the authors ordered by the number of publications, highlighting those that were most productive.

Table 1. Most productive authors (≥4 papers), with affiliations, total local citation score (TLCS), and total global citation score (TGCS).

Authors	Affiliation	Articles	TLCS	TGCS
V.A. Goodyear	University of Birmingham	7	18	117
A. Casey	Loughborough University	5	22	110
A. Wrench	University of South Australia	5	4	36
B. Hyndman	Charles Sturt University	5	2	8
H.F. Arribas-Cubero	Universidad de Valladolid	4	0	9
V. Gallego-Lema	Universidad de Valladolid	4	0	9
E. Jones	West Virginia University	4	0	1
M.D. Kudryavtsev	Siberian Federal University	4	3	13
J.A. Muñoz-Cristobal	Universidad de Valladolid	4	0	9
14 researchers	-	3	-	-
76 researchers	-	2	-	-
902 researchers	-	1	-	-

Journals

A total of 203 journals published a specific article on this subject. Of all these, the journal *Sport Education and Society* stood out as it was the one with the highest number of articles published on this subject (33) and has the highest number of citations received (457). Second, with 26 articles published on this subject, was the journal *Agro Food Industry Hi-Tech*, that has published the most articles; however, these have not received any citations within the WoS.

On the other hand, in relation to the impact factor of the journals, the journal *Physical Education and Sport Pedagogy* was the journal with the highest impact factor (IF = 2.04, Q2 of 2018) among those with the highest number of articles published on this subject. Table 2 shows the journals that published the most articles, with the number of citations and their impact factors.

Table 2. Journals with the highest number of publications, citations (TLCS and TGCS), and impact factor (IF).

Journal	Articles	TLCS	TGCS	IF (2018)
Sport Education and Society	33	52	457	1.96 (Q2)
Agro Food Industry Hi-Tech	26	0	0	0.30 (Q4)
International Journal of Emerging Technologies in Learning	16	3	11	-
Pedagogics Psychology Medical-Biological Problems of Physical Training and Sports	16	9	34	-
Quest	16	15	142	1.82 (Q3)
Science and Education	16	0	4	1.21 (Q3)
Movimento	14	3	12	0.31 (Q4)
Journal of Teaching in Physical Education	10	23	105	1.78 (Q3)
Physical Education of Students	10	7	34	-
European Physical Education Review	9	6	53	2.00 (Q2)
Physical Education and Sport Pedagogy	9	9	47	2.04 (Q2)
Physical Educator-US	9	8	16	-
Journal of Physical Education Recreation and Dance	8	5	15	-
Educational Sciences-Theory & Practice	7	0	0	0.53 (Q4)
Retos-Nuevas Tendencias en Educacion Fisica Deporte y Recreacion	7	2	7	-
Tomsk State University Journal	7	0	2	-
Journal of Human Sport and Exercise	6	0	16	-
1 journal with 5 papers	5	-	-	-
4 journals with 4 papers	16	-	-	-
8 journals with 3 papers	24	-	-	-
24 journals with 2 papers	48	-	-	-
149 journals with 1 paper	149	-	-	-

Countries

In relation to the authors' countries, researchers from 50 different countries published at least one article on this subject (Table 3). Most of the researchers came from the USA (73), followed by China (72) and Spain (45). The following table shows the countries that published the highest number of articles:

Table 3. Countries with the highest number of published articles and citations (TLCS, TGCS, and TGCS/Article).

Country	Art	TLCS	TGCS	TGCS/Article
USA	73	83	950	13.50
China	72	3	51	0.70
Spain	45	14	238	5.29
Ukraine	42	13	62	1.48
Australia	33	33	337	10.21
UK	33	64	448	13.58

Institutions

Of the 461 articles published on this topic, researchers from 584 different institutions took part. In 14 of the articles, some of their authors were from the University of Granada, in seven of them from West Virginia University and in six of them from the University Queensland and the University of SevilleTable 4 below shows the institutions with the highest number of articles published.

Table 4. Institutions with the highest number of published articles and citations (TLCS and TGCS).

Institution	Articles	TLCS	TGCS
University of Granada	14	1	173
West Virginia University	7	1	5
University Queensland	6	14	80
University of Seville	6	2	13
Siberian Fed University	5	3	13
University Birmingham	5	14	61
9 institutions	4	-	-
21 institutions	3	-	-
90 institutions	2	-	-
458 institutions	1	-	-

3.1.2. Co-Author, Co-Word, and Thematic Analysis Networks

Due to the high number of authors, to represent the co-author network, a threshold of two or more collaborations was established. Using this criterion, 57 authors were identified. The authors were gathered into 21 research networks or groups. All groups were small, with one consisting of five researchers, three consisting of four researchers, six groups consisting of three researchers, and 11 groups consisting of two researchers.

Among all of them, the one formed by V. Gallego-Lema, J. Muñoz Cristobal, H.F. Arribas-Cubero, and B. Rubia-Avi should be highlighted as they presented several publications among them, and therefore constituted a consolidated group. The other strongest collaboration relationships were between M. Catasus, M. Hernando, and C. Arevalo C, also forming a consolidated group, although with fewer collaborations than the previous one. Moreover, it is also necessary to highlight the relations between A. Casey and V.A. Goodyear, between V. Koryahin and O. Blavt, and between R. Garret and A. Wrench. These networks can be observed in Figure 2.
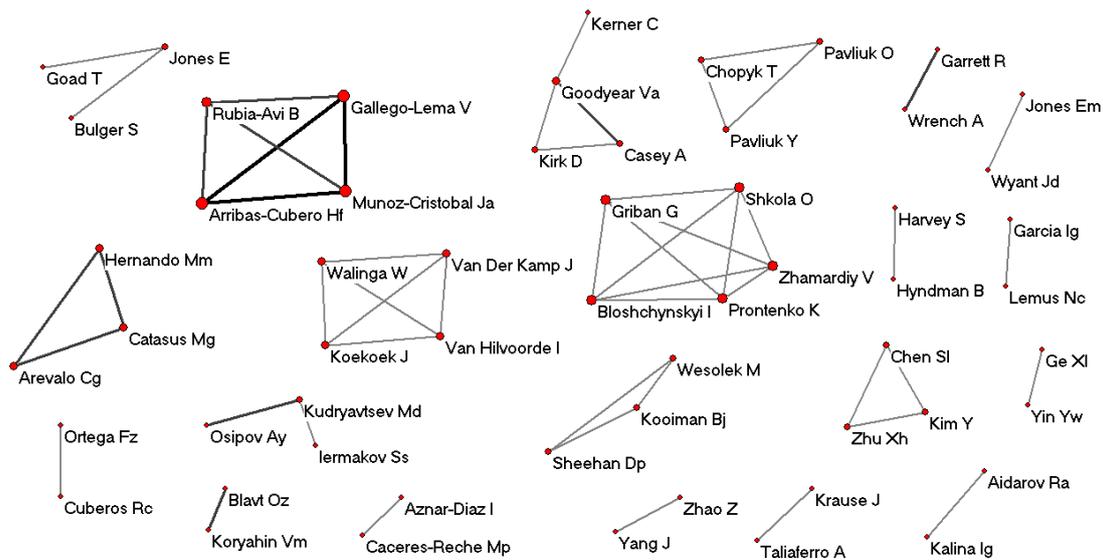
Figure 2. Co-authors networks (with equal to or greater than two co-authored articles).

Co-Word Network

Next, the relationships between the keywords were analyzed. Due to the high number of keywords, a threshold of three or more relationships between the words was established (Figure 3). There was only one network, which was composed of 30 terms. The term that most often appeared in articles on this subject was PE, which was the core of this large network, followed by the words "technology," "students," and "health" (larger vertices).
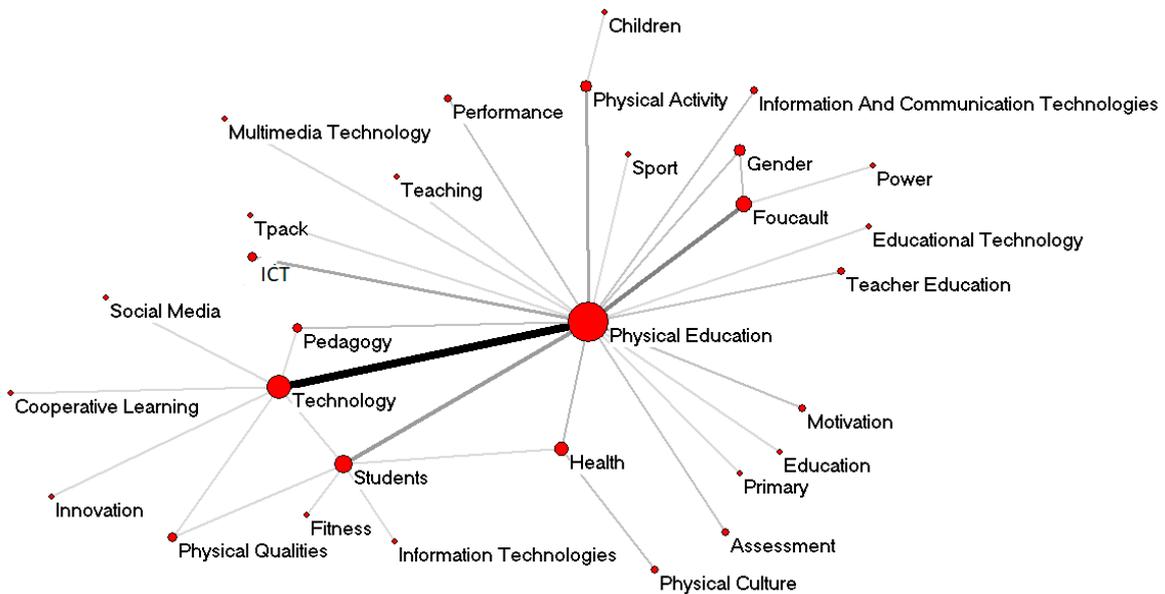

Figure 3. Co-word networks (with equal to or greater than three relationships).

As far as the relationships between words was concerned, the thickness of the lines must be taken into account, where the thicker the line between words, the more times they have appeared together. Bearing this in mind, it is worth noting the relationship between the keywords "physical education" and "technology," since this was undoubtedly the relationship that appeared most often. There was also a strong relationship between the terms "physical education" and "Foucault" and between "physical education" and "students."

Thematic Analysis

The thematic analysis used 273 different terms appearing in the titles and abstracts, which were grouped by categories (Figure 4). The criterion of inclusion was an occurrence frequency of >10. Then, the exclusion criteria were terms related to the design or methodology; therefore, a total of 41 terms were used. The terms that appeared in singular and plural were standardized. In this way, three small groups were identified from 1994–2019 (November), where each term was associated with different colors and lines (blue, green, or red):

- Blue cluster: Composed of seven terms, which refer to the training and implementation of technologies in educational contexts more related to fitness and training evaluation.
- Green cluster: Formed by 15 terms, which refer to the motivation of the use of technologies and gamification in PE classes, and their role in combating obesity.
- Red cluster: Composed of 19 terms related to the training of PE teachers in the use of new technologies in the classroom
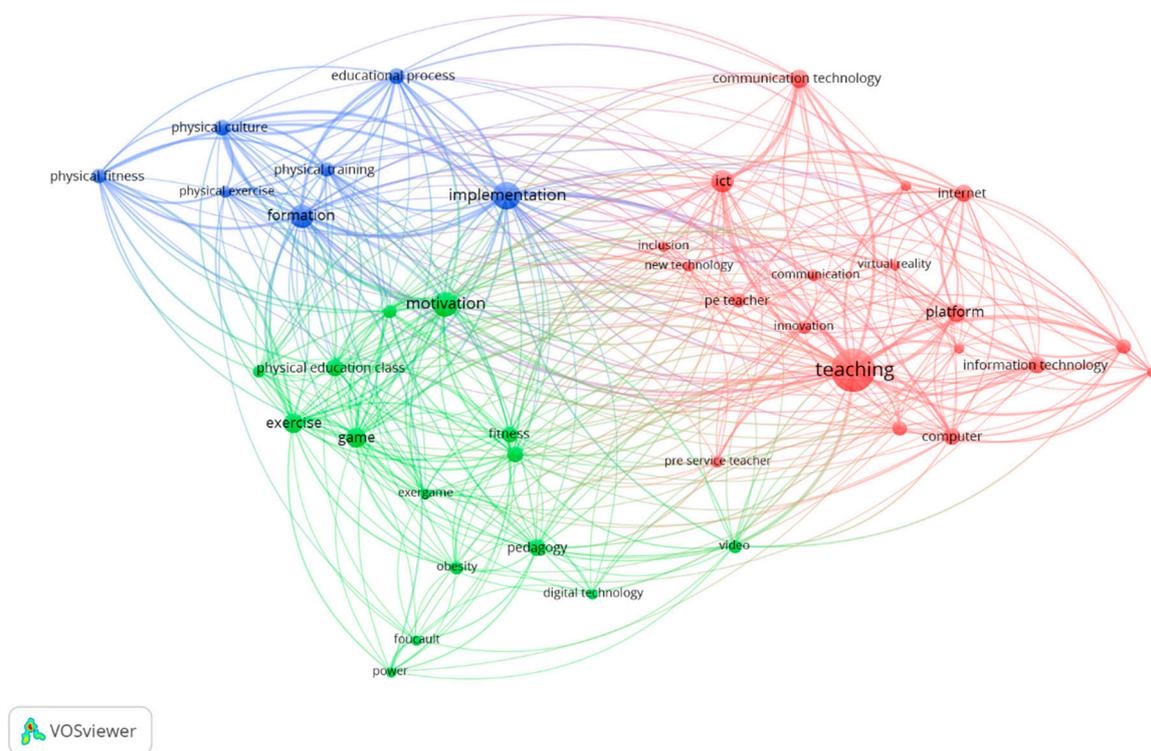

Figure 4. Clusters extracted from the words of the title and abstract fields (1994–2019).

Furthermore, a density map was also generated with the title and abstract terms. The color of the map points represents the density of the terms (red represents a higher density and blue represents a lower density). The density of the map point was calculated by utilizing the number of neighboring terms and the number of terms [47]). The greatest densities in the cluster were for the terms "teaching," "implementation," "formation," "exercise," and "fitness." These results are presented in Figure 5.
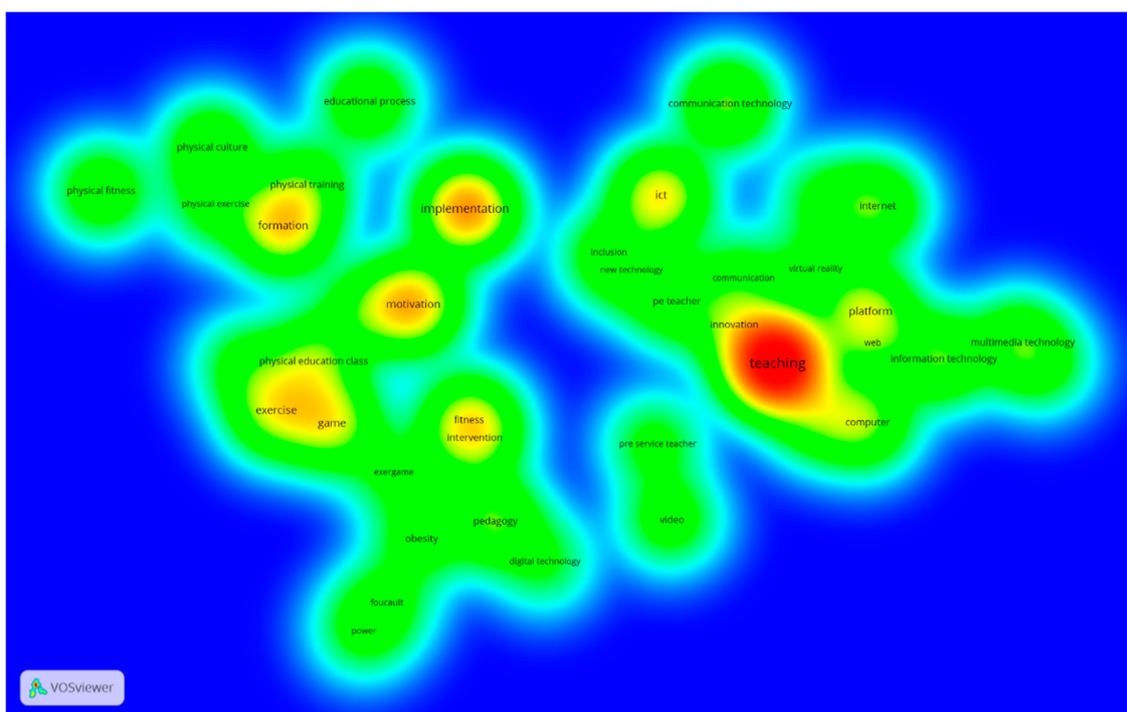
Figure 5. Density map of the words extracted from the title and abstract fields.

Now that the search data on technologies and PE in general have been presented, in the following section, the results from the specific search on AR and VR in PE are presented.

3.2. Specific Search: VR in PE

A total of 22 articles written by 55 researchers from 27 institutions and 11 different countries were published on AR and VR in PE; these articles were published in 18 different journals between 1994 and November 2019. In Table 5, these articles are compiled, along with the number of citations.

The article that received the highest number of citations (TGCS = 14) was the article from Hsiao [14], which proposed a better way to use information technology through the integration of AR in the educational process. To this end, an AR–fitness system was proposed, which combined physical exercises with academic lessons and associated tests. This combined learning environment implemented four standard schemes of physical fitness training with cognitive learning in five categories of knowledge: cardiopulmonary resistance, flexibility, explosiveness, muscular resistance, and sports injury. It was concluded that the AR–fitness based on combining exercises with learning lessons to improve the health of students as they continued to learn significantly improved the academic learning of the students.

The article with the second-highest number of citations (TGCS = 13) was the paper from Ruiz-Ariza et al. [48], which analyzed the effect of playing Pokémon GO for 8 weeks on cognitive performance (memory, selective attention, concentration, mathematical calculation, and linguistic reasoning) and emotional intelligence (well-being, self-control, emotionality, and sociability) in adolescents. The results showed that the players walked an average of 54 km and spent 40 min a day playing in this period. Boys played more and reached a higher level of play than girls. The adolescents who played with this application significantly increased their concentration levels, their selective attention, and their levels of sociability. Therefore, this application increased, in a playful way, the amount of daily exercise in teenagers, and could positively affect their cognitive performance and produced improvements in social relationships.

Table 5. Articles on virtual reality and augmented reality in physical education, along with their journals and the number of citations (TGCS).

Author (Year)	Article Title	Source	TGCS
Bunkler, L.K. (1994)	Virtual reality: Movement's Centrality	Quest	8
Haggerty, T.R. (1997)	Influence of Information Technologies on Kinesiology and physical education	Quest	3
Hsiao, K.F. (2013)	Using augmented reality for Students Health-Case of Combining Educational Learning with Standard Fitness	Multimedia Tools and Applications	14
Pasco, D. (2013) [34]	The Potential of Using Virtual Reality Technology in Physical Activity Settings	Quest	12
Castro, N. and Gómez I. (2016)	Incorporating QR Codes in physical education in Secondary	Retos	3
Davidson et al. (2016)	A Cybercycling Intervention to Improve Behavioral Regulation and Classroom Functioning among Children with Behavioral Health Disorders: Pragmatic Randomized Trial Design for Manville Moves	Contemporary Clinical Trials	2
Rincher, M. and Misner, S. (2017)	The Jig Experiment: Development and Evaluation of a Cultural Dance Active Video Game for Promoting Youth Fitness	Computers in the Schools	0
Wang, B. (2017)	Evaluation of Sports Visualization Based on Wearable Devices	International Journal of Emerging Technologies in Learning (iJET)	0
Sun, Y.L. (2017)	Research on the Application of Computer Simulation Technology in the Field of physical education	Agro Food Industry Hi-tech	0
Gallego-Lema, V., Alberto Muñoz-Cristobal, J., Francisco Arribas-Cubero, H. and Rubia-Avi, B. (2017)	Orienteering in the Natural Environment: Ubiquitous Learning through the use of Technology	Movimento	2
Muñoz-Cristóbal, J.A., Gallego-Lema, V., Arribas-Cubero, H.F., Martínez-Monés, A. and Asensio-Pérez, J.I. (2017)	Using Virtual Learning Environments in Bricolage Mode for Orchestrating Learning Situations across Physical and Virtual Spaces	Computers & Education	2
Tutak (2017)	Virtual Reality and Exercises for Paretic Upper Limb of Stroke Survivors	Tehnički Vjesnik-Technical Gazette	0
Huang, Y. and Reynoso, L.C. (2018).	Based on Physical Self-Concept to Discuss the Effect of Environmental Education on Health Related physical education	Ekoloji Dergisi	0
Yang, Y. (2018).	The Innovation of College Physical Training Based on Computer Virtual Reality Technology	Journal of Discrete Mathematical Sciences and Cryptography	0
Gómez-García, M., Trujillo-Torres, J.M., Aznar-Díaz, I. and Cáceres-Reche, M.P. (2018).	Augment Reality and Virtual Reality for the Improvement of Spatial Competences in physical education.	Journal of Human Sport and Exercise	2
Kim, H., Shin, H., Kim, H.S. and Kim, W.T. (2018)	VR-CPES: A Novel Cyber-Physical Education Systems for Interactive Virtual Reality Services Based on a Mobile Platform	Mobile Information Systems	0
Ruiz-Ariza, A., Casuso, R. A., Suarez-Manzano, S. and Martínez-López, E.J. (2018) [48]	Effect of Augmented Reality Game Pokémon GO on Cognitive Performance and Emotional Intelligence in Adolescent Young	Computers & Education	13
Yang, Y. and Meng, L. (2019).	Physical Education Motion Correction System Based on Virtual Reality Technology	International Journal of Emerging Technologies in Learning	0
Gómez-García, G., Rodríguez-Jiménez, C. and Ramos-Navas-Parejo, M. (2019). [37]	Virtual Reality in physical educationArea	Journal of Sport & Health Research	0
Kang, S. and Kang, S. (2019).	The Study on the Application of Virtual Reality in Adapted physical education	Cluster Computing	1
Chang, K.E., Zhang, J., Huang, Y.S., Liu, T.C. and Sung, Y.T. (2019).	Applying Augmented Reality in physical education on Motor Skills Learning	Interactive Learning Environments	0
Chambers, F. and Sandford, R. (2019).	Learning to be Human in a Digital World: A Model of Values Fluency Education for physical education	Sport, Education and Society	0

The article with the third-highest number of citations (TGCS = 12) was the one from Pasco [34], which analyzed the current state of the literature focused on the role of VR in physical activity environments, and discussed the potential application of the use of virtual reality technology to improve learning in PE. It described the main characteristics of VR technology, and then focused on reviewing and critiquing studies on the use of VR in physical activity environments, and finally, some future directions for the use of VR technology in PE were proposed. Therefore, it was concluded that under certain conditions and with specific students, VR technology can be a useful tool to enhance learning in physical activity environments

3.2.1. Basic Bibliometric Indicators

Years

In relation to the number of articles published on AR and VR in PE, it can be observed that since the first article was published in 1994, the number of these rose to the present. However, articles on this topic published in WoS were still scarce. In relation to the TGCS, it can be observed that there were two peaks, one of them for the articles published in 2013 (26), and the other peak corresponded to the articles published in 2018 (16). These results can be observed in Figure 6.
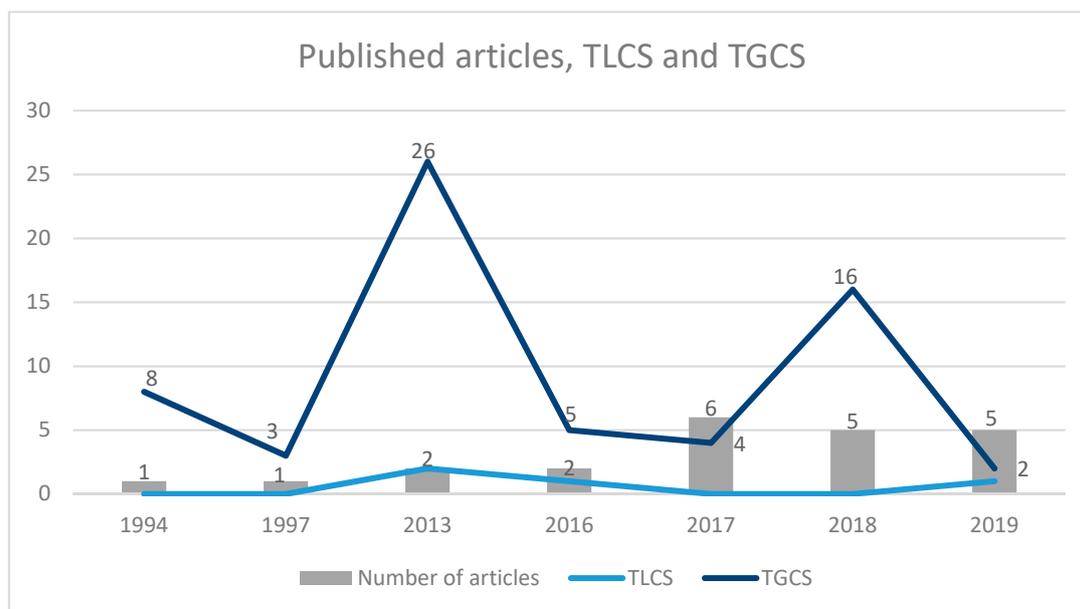

Figure 6. Evolution of the number of articles published on AR and VR in PE in the Web of Science.

Authors

A total of 55 researchers published at least one article on this more specific subject of AR and VR in PE. Within this specific search, H.F. Arribas-Cubero, V. Gallego-Lema, J.A. Muñoz-Cristóbal, and S. Kang were the ones with the highest number of articles published in this database. Specifically, they were the only researchers who published more than one article (two each). Of the authors given in Table 6, it was the first three that received the highest number of citations throughout the WoS (TGCS = 4). The remaining 51 authors published only one article each on this subject, with K.F. Hsiao as the one with the highest number of citations (TGCS = 14). The results can be seen in Table 6.

Table 6. Most productive authors (≥2 papers), with affiliations, TLCS, and TGCS.

Author	Affiliation	Articles	TLCS	TGCS
H.F. Arribas-Cubero	Universidad de Valladolid	2	0	4
V. Gallego-Lema	Universidad de Valladolid	2	0	4
J.A. Muñoz-Cristobal	Universidad de Valladolid	2	0	4
S. Yang	University of Science and Technology Liaoning	2	2	2
51 authors	-	1 each	-	-

Journals

A total of 18 journals published articles on this specific topic. In relation to the journals that published the most articles on this subject, *Quest* (Taylor and Francis) stood out with three articles published, followed by *Computers & Education* (Elsevier) and the *International Journal of Emerging Technologies in Learning* with two. Of these three, the *Quest* journal received the highest number of citations in the WoS (TGCS = 23). With respect to the remaining 15 journals, they only published one article each. These results are presented in Table 7.

Table 7. Journals with the highest number of publications (≥2 articles), citations (TLCS and TGCS), and impact factor.

Journal	Articles	TLCS	TGCS	IF (2018)
Quest	3	0	23	1.82 (Q3)
Computers & Education	2	0	15	5.63 (Q1)
International Journal of Emerging Technologies in Learning	2	0	0	-
15 journals with one paper each	15	-	-	-

Quest is the official journal of the National Association for Kinesiology in Higher Education and it aims to understand how digital technology can enhance education. *Computers & Education* focuses on the practical experiences using technology to enhance learning to extend theory and practice. Finally, the *International Journal of Emerging Technologies in Learning* is an interdisciplinary journal that focuses on trends and results, and presents practical experiences and testing elements of technology that can improve learning.

Countries

In relation to the country of origin of the authors (Table 8) who published articles on VR and AR in PE, there were 11 countries. The largest number of authors were from Spain with a total of six, followed by China with five, and the USA with three. With respect to the rest of the countries, there were two (South Korea and Taiwan) that published two articles and six that published one article each (Canada, France, Ireland, Philippines, Poland, and the UK). Among all of them, Spain was the one that received more citations in all the WoS (TGCS = 22).

Table 8. Countries with the highest number of published articles (≥3 articles) and citations (TLCS and TGCS).

Country	Articles	TLCS	TGCS	TGCS/Article
Spain	6	1	22	3.67
China	5	0	1	0.20
USA	3	0	10	3.33
2 countries	2	-	-	-
6 countries	1	-	-	-

Institutions

Researchers from 27 different institutions published at least one article on this subject. In relation to the institution of origin of the researchers, three of them were from the University of Granada (TGCS = 15) and two of them were from the University of Valladolid (TGCS = 4). The remaining 25 institutions had only one researcher each who published on this topic (Table 9).

Table 9. Institutions with the highest number of published articles (≥2 articles) and citations (TLCS and TGCS).

Institution	Articles	TLCS	TGCS
University of Granada	3	0	15
University of Valladolid	2	0	4
25 institutions	1	-	-

3.2.2. Co-Author and Co-Word Analysis

Co-Author Networks

The co-authoring networks were analyzed and 14 small main networks were found: one of ten researchers, one of six researchers, one of five researchers, three of four researchers, two of three researchers, and six of two researchers. However, most of the authors only published one joint publication; therefore, they were still not very consolidated research networks. Despite that, among all the networks, the relations between V. Gallego-Lema, J. Muñoz-Cristobal, and H. Arribas Cubero should be highlighted as they were the only ones that presented more than one collaboration, and therefore, it can be said that they were the most consolidated network of co-authors. Figure 7 shows the different co-authoring networks:
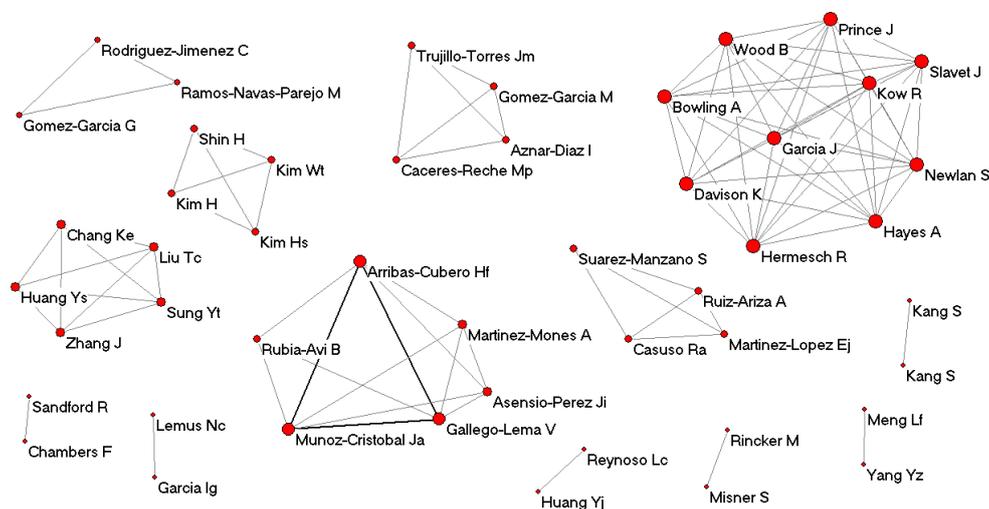

Figure 7. Co-author networks.

Co-Word Networks

In relation to keyword networks, we found that there were five main networks, with one of them being large (49 keywords). Within this larger network, PE and VR stood out, followed by AR, as the keywords that appeared most in the searched articles. The strongest relationships were found between the terms PE and VR, and then between public spaces and computing.

In relation to the second-largest network (five keywords), this was related to the introduction of simulation in schools using the Markov process, where the terms Markov process, visualization management, school sports, and sports simulation stand out. Another of the larger networks (four

keywords) referred to the use of technology in orientation at a university level, highlighting the terms motor activity education technology, orientation, and higher education.

Another four-keyword network was related to interventions with the aim of improving sport habits, where the terms classroom behavior, exercise, intervention development, and childhood behavioral health disorders stood out. Finally, the smallest network (three keywords) referred to aspects related to health and physical self-concept, and was composed of the terms environmental education, physical self-concept, and health-related physical fitness. These networks can be observed in Figure 8.

Figure 8. Co-word networks and AR and VR.

4. Discussion

The study of technologies in education is one of the themes that has experienced the greatest growth in the last decade [49,50]. In general, research shows that the integration of technology is a complex process of educational change, and the scope of technological applications in schools continues to be very varied [51]. The status of this research in the field of PE is presented below, answering each of the research questions posed in this study.

4.1. Discussion Regarding Research Questions

RQ1: How Did the Articles Published on Technology (and Specifically AR and VR) in PE Evolve Over Time?

With regard to technological integration in PE and the digital competence of its teaching staff, Sanmarco et al. [44] revealed the existence of less scientific production in comparison with other areas of knowledge. In fact, the use of technology within PE classes has been scarce [1] up until the last few years, when it has increased; this growth was observed in the large number of articles published from 2015 onward. These data were in accordance with Cabrera-Ramos [40], who also showed that the first articles were published from the 1990s onward and that there was a large growth in 2015, although unlike the data presented in this research, it showed a decrease in 2016, to again show a large growth in 2017.

However, in relation to AR and VR, although the first article published was also in the early 1990s, the growth was slower, being two years later, from 2017, when the largest number of articles were published. These data were in line with those found by Gómez-García et al. [37], who also highlighted this same year as the peak in this area. However, in comparison with the introduction of these two

technologies in the field of education in general, it also began somewhat later, since according to the literature review conducted by Aznar Díaz et al. [27], there was an increase in interest from 2015 onward in VR.

RQ2: Which Authors Have Published the Highest Number of Articles on Technology in PE in General and Specifically on AR and VR, and Which Ones were Most Cited?

In relation to the most important authors within the field of study of technologies and PE, it is worth highlighting Goodyear as the author with the greatest number of publications and citations in this field, followed by Casey, both from English institutions. These data coincided with those of the bibliometrics carried out on ICT in PE by Cabrera-Ramos [40] using different databases. Moreover, as a result of this, England was one of the most influential countries in this field of study.

However, in relation to the most influential authors in the study of AR and VR, we can highlight Arribas-Cubero, Gallego-Lema, and Muñoz-Cristobal, all of whom worked within Spanish institutions. This last author was also found in the bibliometrics carried out by Aznar Díaz et al. [27] on VR in education as one of the most influential in this field, mainly due to the high number of articles published. These three authors worked within Spanish institutions, specifically the University of Valladolid, and this has led to Spain being the country with the greatest number of publications on this specific subject. Furthermore, these three researchers also appeared in the list of the most influential in the general search.

RQ3: Which Countries, Academic Journals, and Institutions were Focusing the Most Attention on Technology in PE in General and Specifically on AR and VR in PE?

As for the countries that published the greatest number of articles, the USA stood out in first place, followed by China and Spain. However, taking into account the most productive countries article-wise in terms of the number of citations received, the USA stood out in first place, followed by the UK and Australia. These data were in line with those found in a previous study [40], which also highlighted China, USA, and Spain as the countries with the highest amount of scientific production on this topic. In the same vein, one Spanish university, the University of Granada, and one USA university, West Virginia University, were the most productive in terms of the number of publications.

In relation to the journals that published the largest number of articles to date, the journal *Sport Education and Society* stood out in first place, followed in second position by *Agro Food Industry Hi-Tech*, and in third-equal position were the journals *International Journal of Emerging Technologies in Learning*, *Pedagogics Psychology Medical-Biological Problems of Physical Training and Sports*, *Quest*, and *Science and Education*. Some of these journals also coincided with the bibliometrics carried out by Cabrera-Ramos et al. [40], although they were not in the first positions because other databases apart from the WoS were considered in this study.

On the other hand, in relation to the specific field of AR and VR, the same countries as for the general search were also the most productive, but with Spain in first place, China in second, and the USA in third. As can be seen, the countries were the same for the specific and general searches, although the order was different, and in this case, Spain stood out as the most productive country. Therefore, it seems that this country was a pioneer in terms of this specific issue within the field of technology and PE. In relation to the most productive institutions, the University of Granada stood out, as it did in the specific search, followed by the University of Valladolid, which had the most productive authors in this subject area (Arribas-Cubero, Gallego-Lema, and Muñoz-Cristobal). Therefore, the University of Granada can be considered as one of the most important institutions within this field of study due to its scientific production.

In relation to the journals that have published the greatest number of articles to date, the journal *Quest* stood out in first place, followed in second place by *Computers & Education* and the *International Journal of Emerging Technologies in Learning*, where *Quest* is one of the journals that has also published the greatest number of articles on technology and PE in general. This is the official journal of the

National Association for Kinesiology in Higher Education and it aims to understand how digital technology can enhance education.

RQ4: What Networks of Co-Authorship, Co-Words, and Thematic Analysis Reflect Studies on Technology in PE and Specifically on AR and VR?

On the one hand, information about the author networks that published two or more articles together about technology in PE was limited, and the majority of the groups were small, with the majority of them composed of two researchers. Among all of them, the one formed by Gallego-Lema, Muñoz Cristobal, Arribas-Cubero, and Rubia-Avi should be highlighted as they presented several publications among them, therefore making them a consolidated group. The second-strongest collaboration relationship was between Casey and Goodyear. Some other consolidated relationships were found, but the majority of networks were not consolidated yet.

According to the co-word analysis, there was only one co-word network. The relations between the keywords "physical education" and "technology" was the one that appeared together the most times. There was also a strong relationship between the terms "physical education" and "Foucault," and between "physical education" and "students." Furthermore, there were different terms in this big network that were related to evaluation, fitness, motivation, and health, among others. Therefore, it can be seen how the themes within this field of study were very varied.

Finally, the thematic analysis showed three different lines within this field of study: (a) training and implementation of technologies in the educational context more related to fitness and training evaluation; (b) the motivation of the use of technologies and gamification in PE classes, and their role in combating obesity; and (c) the training of PE teachers in the use of new technologies in the classroom. The first topic found was in line with Liu et al. [12], who stressed the need to apply technology in youth fitness testing to improve the accuracy of test results. The second theme was in line with the creation of healthy habits that last throughout life, which is another of the main objectives sought with the introduction of technologies in the subject of PE [22]. Finally, the third of these was one of the trends that also appeared in education in general, which was the training of teachers to be able to use new technologies, as can be seen in the meta-analysis done by Scherer et al. [52].

On the other hand, the co-authoring networks of the specific field of the use of AR and VR in PE were analyzed, and a very small number of networks were found. Moreover, most of them were not very consolidated research networks since they shared only one common publication. Despite that, among all the networks, the relations between Gallego-Lema, Muñoz-Cristobal, and Arribas Cubero should be highlighted as they were the only ones that presented more than one collaboration. This may be because this is a young, growing field of study, as the data from this study has shown.

In relation to keyword networks, this research suggests that there were five different main networks between the keywords "PE" and "virtual reality." The second-largest network was related to the introduction of simulation in schools using the Markov process. Another of the larger networks referred to the use of technology in orientation at a university level, which was in line with the bibliometric analysis of Salmerón-Manzano and Manzano-Agugliaro [39] that focused on the use of technology at a university level. Another network was related to the interventions with the aim of improving sport habits, which was in line with the second line of the general search. Finally, the smallest network referred to aspects related to health and physical self-concept, as well as health-related physical fitness, which are related to the benefits that the use of these technologies have, as previous studies have highlighted [14,18].

Finally, as a thematic analysis was not performed due to the small number of articles on this subject, it was decided that an analysis of the content of the three most frequently cited articles should be done to find out the subject matter of these three. The most cited article considered the better use of information technology through the integration of AR in the educational process. The second one analyzed the effect of playing Pokémon GO for 8 weeks on cognitive performance (memory, selective attention, concentration, mathematical calculation, and linguistic reasoning) and emotional intelligence

(well-being, self-control, emotionality, and sociability) in adolescents. The third one analyzed the current state of literature that focused on the role of VR in physical activity environments and discussed the potential application of the use of VR technology toward improving learning in PE. Thus, these studies are currently the basis of this field: (a) how to introduce AR in PE, (b) a practical experience of one app for improving cognitive performance and emotional intelligence in adolescents, and (c) an analysis of the current state of literature about VR in PE.

4.2. Discussion about the Concerns and Potential of Applying VR/AR in PE

The results of this study showed that there was a lack of research on the use of VR and AR in PE. Among the main barriers and difficulties that exist for PE teachers toward integrating technology in the PE classroom, there is a lack of confidence of teachers regarding using more ICT in the classroom [53] due to their low expectations of the improvement of the integration of technologies in the subject [54]. In addition, another obstacle is teachers' uncertainty about the potential benefits of using ICT in the classroom [55], as well as the belief that it entails a greater workload concerning organizational aspects [56]. Likewise, class size and the classroom itself are also factors that inhibit the use of these technologies in the teaching of PE and make it difficult for teachers to integrate them [7,57].

In the same vein, other frequently perceived obstacles are the loss of time dedicated to physical activity, lack of resources, investment in time and training, inappropriate use, lack of knowledge, and technical problems [58]. In terms of the age of the teachers, these same obstacles were perceived, but in a different order, and it was the older teachers (over 50) who had the highest percentages in most of the obstacles considered. However, these obstacles presented by teachers need to be overcome, as many articles have highlighted the benefits that the use of VR or AR has in physical education. In fact, evidence supports the idea that, under certain conditions and with specific students, these technologies can be useful learning tools in physical activity environments [34].

Among the benefits of the use of these technologies in the classroom (VR and AR), the motivational element stands out, which is very important in education since according to Reinoso [59], where numerous investigations indicate that these technologies reinforce learning and increase the motivation to learn. Furthermore, literature has shown the importance of motivation with the continuity of physical sports [60], which is one of the great objectives perceived by this subject. A plausible example of this is that students can use technology to learn motor skills in a new way by imitating the movement of an expert avatar [34], and thus learn new movements or improve their technique, as well as abilities, such as reaction, coordination, and spatial skills [35], along with developing some offensive skills [36]. They can also receive indications for learning that are simultaneously developed through an intelligent real-time tutoring system [61] that is based on the real-time analysis of the student's previous knowledge, their current responses to the environment, and their movement solutions in a wide range of conditions. Furthermore, in addition to the health benefits of physical activity, these technological tools allow for the work of transversal themes that can vary depending on the theme of the game, which makes this proposal an interesting option where VR or AR becomes a co-protagonist along with the PE [37].

In addition, these tools can help to bring environments closer, such as facilities that are not available at educational centers, to generate new physical activity environments that can attract students' attention and stimulate their interest in physical sports practice, thus improving the students' sports level in a relaxed and pleasant environment for them [38]. Furthermore, with these technologies, the integration of people with functional diversity in the classroom can be promoted, as well as teamwork and cooperation [35].

However, it is necessary to emphasize that VR and AR experiences should not consider the acquisition of knowledge as their singular objective; it is necessary to design these learning environments from a constructivist approach to obtain full learning benefits [62]. In addition, according to Gómez-García et al. [37], it is important to continue in-depth investigations of the advantages and possible applications that are different from those carried out so far in PE to solve the possible resistance

or difficulties that this trend may generate in its implementation by PE teachers. Educational policies should invest in providing schools with the necessary technologies to make the introduction of these tools in the classroom a reality. In this way, educational institutions will benefit from better accessibility to virtual technologies, which will make it possible to teach in virtual environments that are impossible to visualize in physical classrooms, thus breaking the limits of formal education [62]. In this way, more meaningful and autonomous learning for students will be generated, increasing their levels of motivation, and with it, finally increasing the levels of the student´s physical activity practice.

4.3. Strengths and Limitations

Finally, it should be noted that this study was not without its limitations. First, this study focused only on the analysis of studies published in the WOS; therefore, future studies should extend their search to other databases. In addition, this study was done from a quantitative point of view, analyzing both the productivity and the impact of the publications; therefore, future studies should focus on carrying out a content analysis of the articles on the different topics indicated in this search.

Therefore, this research was intended to be motivation for the development of this field of research, by presenting the different themes within technology in PE in general, and AR and VR in PE in particular. Specifically, to the best of our knowledge, this is the first study that analyzed not only the number of articles published, authors who have published them, and countries and institutions within them, but went beyond this through the creation of bibliometric maps. In this way, it provided more extensive information in this field, such as the collaboration networks between authors, as well as the different keyword networks and different research themes. All this provided more in-depth information about the reality of these two fields of study, and what the main lines of research may be at present and how they may evolve.

5. Conclusions

Bibliometric analysis is a tool that allows researchers to know the current state of research on a specific topic, along with its trends, which is very useful for establishing future lines of research. As a result of this analysis, it was observed that the number of articles published on technology and PE has dramatically increased in recent years. This has led, little by little, to the consolidation of co-authoring networks, although these are still scarce and need to be further consolidated. Of all the countries, the United States is the leading country in this subject area in terms of publishing the greatest number of articles. As for the topics, three different lines were identified: one referring to the training and implementation of technologies in the educational context, another referring to the motivation of the use of technologies and gamification in PE classes, and the third was related to the teaching of PE teachers through the use of different technological instruments. However, it is still a novel field of study, but it is currently in full growth and development, and new studies within this field are needed to contribute to its advancement.

On the other hand, in relation to the specific field of study of AR and VR in PE, it is an emerging field of study, of which few articles have been published to date, although their number has increased in recent years. Co-authoring networks are poorly consolidated, and few researchers have published more than one article. It should be noted that Spain is the country that has published the greatest number of articles, with the Universities of Granada and Valladolid being the pioneers. In relation to co-word networks, five themes were identified: the first was related to PE and the use AR and VR in relation with different specific topics, the second one related to the introduction of simulation in schools using the Markov process, the third referred to the use of technology in orientation at a university level, the fourth was related to the interventions with the aim of improving sport habits, and the last one referred to aspects related to health and physical self-concept in the educational environment. Thus, studies that contribute to these lines should be sought, as well as new lines of study within this field.

Therefore, both fields of study are currently in full development, although the specific field of VR and AR in PE is only a small line of study within this field. Hence, more studies are needed

to contribute to the scarce literature on this subject. In addition, it would be beneficial to promote collaborations between researchers of different countries. Thus, in a few years, this new field of study, which arose as a result of the introduction of new technologies into society, will be a consolidated field of research.

It is important to know the current stage of this research field to achieve this consolidation because the use of technologies in PE classes can improve the quality of them, as has been previously exposed, enriching the experiences that students have with them by generating experiences of enjoyment, always with the ultimate goal of generating habits of physical sports practice that will last a lifetime. That is why this is a field of study with great potential for sports practice because it will help teachers to improve the quality of PE classes by presenting practical experiences and new ways of using these technologies in the classroom, as well as reporting the benefits they present for students and establishing guidelines and advice for their proper use within the classroom. This will help to encourage more PE teachers to introduce these technologies into their classes, as well as to ensure that they are used in the right way by PE teachers, generating the expected benefits outlined throughout this research.

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