education sciences

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Implications of Virtual Reality in Arts Education: Research Analysis in the Context of Higher Education

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Received: 26 July 2020; Accepted: 28 August 2020; Published: 29 August 2020

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Abstract: Technological advances have posed a challenge in university learning ecosystems in terms of the application of immersive technologies that offer an educational and innovative framework to the student. The evolution of global research on this topic during the period 1980 to 2019 was studied. For this purpose, a bibliometric analysis of 1296 articles was applied, obtaining results of the scientific productivity of the journals, authors, institutions, and countries that contribute to this research. The evidence shows a growing interest, especially in the last three years, in the study of the application of virtual reality in higher education. The main subject area is Social Science. The most productive research institution is the Complutense University of Madrid. The United States is the country with the most publications and citations. In addition, The United States, Spain and the United Kingdom are the countries with the most international collaborations in their publications. The study detected five new directions for future research. The growing worldwide trend of scientific production demonstrates the interest in developing aspects of the use of virtual reality in arts education in the context of higher education. This study contributes to the academic, scientific and institutional discussion around the improvement of decision making based on the available information.

Keywords: virtual reality; higher education; arts education; educational technologies; scientific research

1. Introduction

In recent decades, just as with other experimental technologies that are born to respond to scientific research, virtual reality (VR) has crossed the science barrier to access content developers and end consumers, making it more accessible.

In this digital context, VR and augmented reality (AR) are technologies that are awakening great interest due to their enormous strategic potential. Currently, VR and AR are setting trends with great impact on various studies and proposals applied to the field of education and its creative process [1,2]. In any case, innovation, creativity, immersion, fascination, technology, and information are words that define and accompany the concept of VR. In recent years, there has been a significant increase in scientific publications [3,4], echoing the impact of the world academic environment [5].

VR and AR are technological systems based on computers and devices that include the digitization of images. Their purpose is to produce a VR, where the user has the perception of being part of it, either through total or partial immersion. In this sense, there are notable differences between the two. VR is an immersive digital practice that replaces the real environment with a simulated one. Although there are various concepts about VR, we are interested in highlighting the one that derives from the combination of three perspectives: the philosophical, the technical and the psychological.

VR is the most advanced form of relationship between a person and a computer system; this relationship allows direct interaction between the user and the artificially generated environment;

an environment that is intended to stimulate some or all of the human senses, characterized mainly by the creation of experiences through images and thus direct participation in this virtual environment [6]. That is, the user is immersed in an artificial three-dimensional (3D) scenario, generated by the computer, and does not observe anything that is around him [7].

Sometimes, the terms are confused between VR and AR. In this sense, AR is a variant of the virtual experience, and is understood as a technology that facilitates the combination of digital information and physical information in real time, and that allows users to see and interact in real time with virtual images superimposed on the real world [8]. In this case, the subject coexists between the real and the virtual, complementing one environment with the other. That is, there is an overlay of virtual objects on the real physical environment. This implies the use of mobile devices, such as smartphones or tablets, which facilitate their incorporation into the educational environment and their predisposition towards students as a motivating tool [9]. In the case of art, the possibilities of the new digital technologies suppose a change of focus in the exchange between the objects of the cultural, heritage and educational spaces with the user in a dramatic way [10].

VR allows access to experiences in a 3D space in real time, being part of interactive environments which generate in the student the feeling of being in another space. Updates and new low-cost applications allow it to be linked in all areas of teaching and learning, combining with different methodologies, pedagogies and styles, where the student builds knowledge and is the main actor in their educational process. Hence, it has become an essential tool to be used in different fields—such as Science, Geography, Heritage, Art, and Culture, among others—since it constitutes an innovative space that generates interest and motivation [9,10].

The positive perception of VR is due to the possibilities offered by digital interfaces to penetrate the student's mind through attractive visual experiences, providing added value to education and to sometimes-complex subjects to tackle.

Among the conditions that define VR technology, the first is that the real environment must be integrated with the virtual one [11]. As a second condition, it must be done in real time and, finally, all of this must be able to be applied in a space with three dimensions, generating an accurate record of the real and virtual elements. Likewise, it could be said that VR is very similar to other digital interfaces, in the sense that it allows the creation, through a set of computer techniques, of simulated images and spaces in which a person, through a visual device, has the feeling of being—and being able to function—within them [12,13].

Hence, the purpose of this study is to analyse research trends in scientific publications related to the use of VR and its link with arts education and the technologies applied to higher education (HE).

It is of interest to know about the application of VR and the interest it arouses as a didactic tool to incorporate it into the educational field and teaching processes, in addition to discovering what are the future lines of research.

There are many improvements that can be included for consideration when betting on the technological change proposed by the European Higher Education Area (EHEA). Among all the possibilities that may arise when proposing an adequate teaching and learning method, the key is to combine a teaching model that enhances the use of information and communications technologies (ICTs), thus increasing the flexibility, self-regulation, adaptation and self-learning of the student [14].

In this sense, incorporating immersive technologies into HE has resulted in the acquisition of abilities and skills that are in accordance with the needs of the digital age, where information is fully available to everyone, and is immersed in different processes of learning. In this way, students can develop autonomy, discipline and motivation skills, in addition to increasing academic performance and results [15].

After reviewing the literature, the research question refers to determining whether the application of VR in HE has generated a growing academic production over the last few years.

Consequently, the main objective of this study is to analyse research trends on VR in arts education in the context of HE at a global level, during the period 1980–2019.

To obtain answers to the research questions, a sample of 1296 articles from scientific journals selected from the Scopus database was analysed. This study used the bibliometric method to synthesize the knowledge base on the implications of VR in university arts education. The results showed the contributions of this line of research, which has allowed the identification of the main driving agents, their future trends, and has revealed certain gaps in critical knowledge. In this regard, it can be concluded that VR has been established as a tool with numerous applications in university education, and has also become a field of research with exponential growth.

2. Literature Review

The study of VR management in art education in the context of HE is supported by the analysis of a series of theoretical foundations that—together with the basic concepts—define the framework in this field of research. In this way, these explanatory foundations define how a set of phenomena behave, to generalize and carry out a separate abstraction of the cases.

2.1. Backgrounds

The information and knowledge society is a phenomenon that has impacted human beings for a few decades. It is characterized by information technology, which enables its organization into networks and offers people the possibility of accessing, sharing and processing data, even remotely and in real time [16]. Furthermore, one of its characteristics is the relevance that ICTs have assumed [17,18], which affect every aspect of our lives and, above all, what we know and how we learn. Furthermore, they have brought about a pedagogical change that fosters and encourages true experiences and activities focused on deeper and interactive learning [19].

The transcendence that VR is acquiring today has meant that it is presented as an emerging technology with great possibilities for incorporation into the educational system. In the 1960s, pioneers emerged who, with their ingenuity and creativity, designed precedents for smart glasses or various collaborative virtual devices, such as glasses, that would later be developed with greater sophistication by companies such as Google [20,21].

Likewise, the proposal of the artist Krueger is also interesting; he developed interesting interactive works, considering himself one of the initial researchers of VR and AR. In 1969, he proposed a computer-controlled light sound interface, which responded to the people inside it. In the mid-1970s, he established an artificial reality laboratory (videoplace), where he made progress in creating an artificial reality that surrounded users, and responded to their movements and actions, without being hindered by the use of glasses or gloves. The work carried out in the laboratory would form the basis of the book published in 1983, Artificial Reality [22].

In 1965, Sutherland proposed creating a virtual world that appears on a device, feels real, with real sound, and responds realistically to the viewer´s actions [19]. In this way, it can be recognized that these examples and case studies served as inspiration to advance the development of the technical and conceptual solutions that have resulted in current VR.

In the early 1990s, development in the VR field became much more complex and varied, making the term VR very popular. That new, promising, and fascinating technology captured great interest in the public with computer graphics, such us two dimensional (2D), three dimensional (3D), and animated graphics. The consequence of that is that today, the border between 3D and VR graphics is blurred. Hence, some definitions of VR and virtual environments (VE) are used interchangeably in the computing community. These are the most popular and used terms, but there are many others: synthetic experience, virtual worlds, artificial worlds, or realities. All these concepts mean the same thing.

Similarly, VR can be defined as the combination of interactive graphics in real time with 3D models, ordered with a visualization technology that offers the user immersion in a world model, with direct manipulation [23].

On the other hand, VR consists of the illusion of participation in a synthetic environment, rather than the external observation of such an environment [24]. VR is based on something three-dimensional and stereoscopic, with the use of a head-tracker, hand/body tracking, and binaural sound. VR is an immersive multi-sensory experience.

Moreover, VR is also considered to be an immersive, interactive, multi-sensory, spectator-centred 3D environment, with the combination of the technologies necessary to build these environments [25], or that allow the navigation and seeing of a world in three dimensions and in real time, with six degrees of freedom. VR is a clone of physical reality [26].

Although there are some differences between these definitions, they are essentially equivalent. All refer to VR as an interactive and immersive experience with the sensation of physical presence in a simulated world, with this reference being used to determine the level of the technological advancement of VR systems.

For its part, and to differentiate VR from AR, the latter is understood as a direct or indirect view in real time of a real environment that has been improved by virtual computer-assisted technologies [27]. That is, a set of devices that add virtual information to existing physical information. It is not a substitute for physical reality, but overprints computer data to the real world.

2.2. Framework

Considering the relevance of VR as a creative resource and as a tool to channel creativity, we recognize the learning possibilities it provides without leaving the classroom. In this sense, it offers students the possibility of directly experiencing their stimuli, giving learning significant value [28].

On the other hand, throughout history, the term 'creativity' has been defined by numerous authors, artists, scientists, psychologists and professionals from different areas and disciplines. A creative individual is considered to be a person who solves problems regularly, produces products or defines new questions in a field in a way that, at first, is considered new, but in the end becomes accepted in a specific cultural context [29]. It also focuses on the creative person, and states that creativity is a human capacity that, to a greater or lesser extent, everyone has [30]. In this, creativity is understood to be a natural and basic characteristic of the human mind, which is potentially found in all people. Imagination is the engine of creativity [31]. It allows us to think things that we do not perceive through the senses [32].

The arts help students develop creativity, and therefore flexibility, expressiveness and adaptability in life situations. Thus, there is clear evidence that creative learning is not only an emotional discipline, but also one which requires deep reflection and intellectual rigor and, therefore, it is learned [33,34].

In this context, it is unavoidable to incorporate as an objective in educational centres the development of artistic thought as a free game of sensitivity, imagination, and creativity. It teaches us how to do, to create and to carry out, but not from mere technical training, because instead of emphasizing uniformity, what is sought is to accentuate the difference and individuality of people and their creations. Educating artistically is educating beyond a discipline of knowledge, since it seeks the sense of identity; that is, to identify with the different, the unique and the original.

In 1961, Lowenfeld, known as the father of Arts Education, defended the use of art in education and the development of creativity to empower people to learn new knowledge and discover new possibilities and experiences [35]. One must be creative from every particle of one's organism, and not take creativity as a trait that only some people have, as it is often considered. The power of artistic creation should be fostered as a force that can be translated into other areas. For this reason, curricula that encourage creative thinking allow students to communicate effectively with others and understand each other, empathize, and see social problems from a different perspective. As a result, we will be able to see students who are continually willing to take on new and more difficult challenges, learning from mistakes and advancing in successes.

In this scenario, VR favours creative thinking, posing the imagination as the engine of reality [36]. The impact of a VR system on student motivation for a visual art course was applied to biology in high school students [37]. The results show high levels of satisfaction in the four motivational factors analysed: attention, relevance, trust, and satisfaction. By performing the practices with an augmented reality module, regardless of the level of studies in question, they generated more attention from the students than a traditional one, they understood difficult processes to explain and imagine, and they created and manipulated objects and discovered processes and elements of the environment.

VR applications in education have made a significant contribution to the knowledge area for which they were designed, since it enables otherwise unviable didactic content. Therefore, it is key to include this technology in educational practices to achieve better quality standards [37].

Furthermore, although most of the research on the educational use of VR is of a recent nature, in recent years, there has been an increase in work that provides findings to justify its incorporation into educational practice.

In a creativity-based pedagogy, it would ensure that students could acquire, as a natural part of their experience, the skills necessary to understand deep learning, the value of critical thinking, the development of divergent and convergent thinking, and motivation.

The educator and philosopher, Dewey, in 1934, was an advocate of integrating the arts into education as a means of developing creativity [38]. The author stated that the arts should be a fundamental part of the curriculum because they develop creativity, self-expression, and appreciation of the expression of others. The importance of creative thinking in students lies in the fact that it involves two consecutive processes: divergence and convergence. Divergent thinking involves expanding thoughts and ideas, making new connections, and opening up multiple possible areas for exploration. It is when new thoughts and possibilities are generated.

Convergent thinking is when students can establish a connection with society and the reality that surrounds them by progressing this thinking, evaluating the possibilities offered by the environment and discarding weak ideas or those that do not bring them any benefits.

Creativity linked to learning can, therefore, provide an ideal platform to improve the general well-being of students, allowing children to contribute to innovation from their school circle, understanding creativity as the basis of their future [39,40]. Encouraging the development of creativity and imagination in children through regular creative practice is more beneficial than producing a satisfactory grade.

In this sense, VR is being considered for its creative possibilities in the educational process [41–43], recognizing among its advantages being a mixed reality that integrates in real time and incorporates information from various digital sources. This endows it with a high level of interactivity, which enriches and distinguishes it from other virtual environments, connecting positively with students [44] and their motivation [45].

Most studies on VR in education are based on learning theories, especially constructivist theory and situated learning [46,47]. It should be noted that the constructivist approach encourages students to understand and build their knowledge using information they perceive from the outside world [48,49]. For its part, this theory of learning refers to sociocultural context as a key element for the acquisition of skills and competences, always seeking the solution of daily challenges with a collective vision [50,51]. Knowledge is actively developed by students through social processes in an improved environment. In this context, VR applications employ real and virtual environments, encouraging students to develop and build knowledge in collaboration with other peers.

Thanks to these technologies, it is possible to navigate through works of art; that is, they allow us to understand and value them simply by looking at their surface or studying them in detail. An example of a VR experience applied to art is the case where students can walk through different rooms. In this virtual museum, you can see different pieces represented in the most realistic way possible, achieved using photogrammetry. Later, students can choose one of the works and begin to draw live what they are seeing in virtual space. In this way, the pieces can be manipulated, and details imperceptible to the human eye can be accessed. In this way, the arts teach children to make good decisions about qualitative relationships, that problems can have more than one solution, and that questions can have more than one answer [52]. The arts show multiple perspectives. Any of the lessons justifies the integration of the arts into other subjects.

This has meant that, in recent years, and mainly in developed countries, VR has gained a presence in educational settings as an alternative approach to traditional learning experiences [53], because, unlike other computer applications, VR provides the student with a highly interactive 3D visual environment, much like that which the real world offers. This also allows students to experience not only the feeling of being present within the environment, with the possibility of interacting with the objects within it, but also the potential for something to happen within said environment without this necessarily being the result of an action that he performed [54], all through its two key components: immersion and interaction [55].

There is a large volume of research that has focused on analysing the beneficial results of using VR in educational settings. It is necessary to point out as advantages the highest levels of academic performance, motivation to learn, interest in the subject and participation in the content [56,57].

The retention of content and greater ease in acquiring content are other advantages offered by VR experiences [58]. Because of this, VR applications can help attract the interests of the female gender and other disadvantaged groups to science and engineering issues [59].

In short, each year, the quality and quantity of VR publications in educational settings has been increasing. This suggests that the interest in this subject for educational researchers, especially regarding practical tests carried out in the classroom, is of great interest. The opportunities offered by virtual technologies allow us to break the limits of formal education [60]. In this way, VR has broken the barriers of formal education, making it possible to access quality education, informally and through ubiquitous technologies accessible to all [61].

3. Materials and Methods

'Scientometrics' refers to the scientific and empirical study of science, which studies scientific production to measure and analyse its evolution and impact. In practice, there is a clear overlap between scientometrics and other scientific fields, such as bibliometrics, the information system, information science, and science policy [62,63].

On the other hand, bibliometrics applies mathematical and statistical methods to scientific literature and the authors who produce it, in order to examine and analyse scientific production. The instruments used to measure the aspects of scientific activity are bibliometric indicators, which are measures that provide information on the results of scientific activity in any of its manifestations [64]. It was introduced by Garfield in the mid-20th century, has since become widespread in scientific research, and has contributed for decades to revising knowledge across multiple disciplines [65]. Therefore, scientometrics, together with bibliometrics, has evolved from reflection on scientific development and the availability of numerous databases for the researcher [66].

The objective of this study is to show a vision of the general research dynamics regarding the implications of VR in arts education in the context of HE. To achieve the proposed objective, a quantitative analysis was performed using bibliometrics. Likewise, the explicit objective of this methodology is to analyse trends in the research topic. In recent decades, it has contributed to the revision of scientific knowledge, and has been used successfully in different scientific fields [67–69].

The method used was to perform a complete search in the Scopus database, using a search string, with the terms that constitute this research: "artistic", "virtual reality", "higher education", and "education". The purpose was to examine the subfields of the title, abstract and keywords in a period from 1980 to 2019, as they have been reflected in other bibliometric works [70,71]. The sample of analysed articles only included scientific articles, both in open and non-open access. Thus, the final sample included a total of 1296 documents. The variables analysed were the year of publication, subject area, journal, author, country of author's affiliation, institution where the author is affiliated, and keywords that define the publication.

In this study, the indicators of the scientific production analysed were the distribution by years of the published documents, and the productivity of the authors, countries and institutions. Regarding the quality indicators used—referring to the impact of the different agents in this research area—were the h-index, the total number of citations and the indicator that measures the quality of the scientific journals included in Scopus, SCImago Journal Rank (SJR) and the quartile (Q), in which the journal is positioned [72,73].

Collaborative structure indicators, which measure links between authors and countries, were been analysed using processing tools and network maps due to their reliability in bibliometric analysis [74,75]. Thus, the VOSviewer software tool (version 1.6.15, Leiden University, Leiden, The Netherlands) was used for mapping. It allowed keyword processing and grouping analysis, with the purpose of displaying maps of co-authorship and co-occurrence. Furthermore, this tool revealed collaborative structure indicators, which measure network links between authors, research institutions, and countries, as well as the analysis of research trends based on the use of keywords [76].

4. Results and Discussion

4.1. Evolution of Scientific Activity

Figure 1 shows the articles published on the implications of VR in Arts Education (1980–2019) in the context of HE. In this period, interest in VR research and its involvement in arts education increased, especially in the last 3 years (2017–2019). In the first 20 years analysed (1980–1999), only 75 articles were published on this topic (5.79%); in the following decade (2000–2009), the number of articles rose to 235 (18.13%). The increase in the number of articles was accentuated, especially in the last decade analysed (2010–2019), where 76.08% of the total articles were published, totalling 986. The year with the most articles published was 2019, with 182 (14.04%).

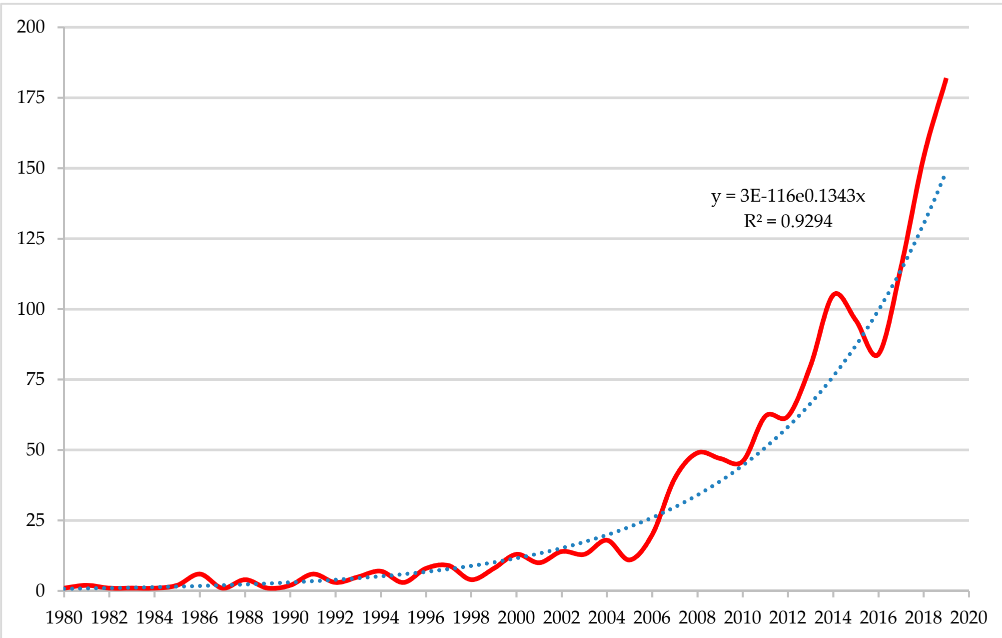

Figure 1. Evolution of scientific production (1980–2019).

It is noteworthy that, in the last three years, 34.80% of the articles (451) were published, while in the last five years, this variable reached 48.69% (631).

The exponential trend line denotes the number of articles about this research on the implications of VR in Arts Education increasing rapidly over time, in the last 40 years. This line shows its goodness with an R^2 of 0.9294.

This evolution is related, mainly, to the fact that during the first years of the period studied, the basic articles, both theoretical and conceptual of VR in art education, were published, while in the following periods the contributions were mainly oriented to the analysis of particular cases [77–80].

4.2. Distribution of Articles by Subject Area and Journal

During the time horizon analysed, 1980–2019, there are various categories where articles related to the implications of VR in arts education in the context of the HE were found. According to the Scopus database classification, there are a total of two thematic areas in which the 1296 articles analysed are classified. It should be noted that an article may be classified in more than one category, depending on the publisher's interest.

Regarding the thematic classification of the articles on the implications of VR in arts education in the context of HE during the period 1980–2019, two thematic areas were considered: Arts and Humanities, and Social Sciences. Therefore, the 1296 articles are classified into these two subject areas, according to the Scopus database. In this sense, an article could be classified in more than one subject area, or in a single area. There is a correlation between the subject areas and the journals, with the editor being the journal that ends up cataloguing each article in a subject area. In this way, other subject areas were excluded, such as: Agricultural and Biological Sciences; Biochemistry, Genetics and Molecular Biology; Business, Management and Accounting: Chemical Engineering: Chemistry: Computer Science; Decision Sciences; Dentistry; Earth and Planetary Sciences; Economics, Econometrics and Finance; Energy; Engineering; Environmental Science; Health Professions; Immunology and Microbiology; Materials Science; Mathematics; Medicine; Multidisciplinary; Neuroscience; Nursing; Pharmacology, Toxicology and Pharmaceutics; Physics and Astronomy; Psychology; and Veterinary, in order to avoid erroneous results.

The Social Sciences category is the one that stands out throughout the period studied, with 1088 articles published, representing 67.24% of the articles about study, followed by the Arts and Humanities category, with 646 articles and 37.25%.

The association of publications in these research fields, especially, to the categories of Social Sciences and Arts and Humanities makes sense, since this research analyses the trends in the contributions related to VR and its link with arts education in the context of HE, in the sense of generating a motivating and quality education together with technological advances [81].

The 1296 articles were published by 541 journals. Regarding the characteristics of the articles in the main journals of the publication on the implications of VR in arts education in the context of HE, in the selection of the 10 journals with the highest number of articles published on the research topic, the high percentage (70%) of journals belong to the first quartile of the SJR factor, SCImago Journal Rank of 2019, which stands out. For years, the topic of management between VR and HE has been of interest to a growing number of journals and authors, as evidenced by the growth in the number of published articles and the variety of interested journals.

By country, among the 10 most important journals in the publication on this subject, those of European origin stand out: the United Kingdom (6), Spain (1), and Lithuania (1). The rest are of Australian origin (1) and of Latin American, Venezuelan orgin (1).

The journal that has published the most articles on VR in art education in the context of HE was the International Journal of Art and Design Education, with 53 articles. It also stands out because it concentrates a great interest in the scientific community, with the highest number of citations (206). On the other hand, it is also the journal with the highest h-index for articles published on this research topic: 7. Its CiteScore indicator is 0.7, and it is the journal with the highest SJR impact factor: 0.293. On the other hand, Figure 2 shows the grouping of the journals in five clusters according to the co-citation method, using the VOSviewer tool.

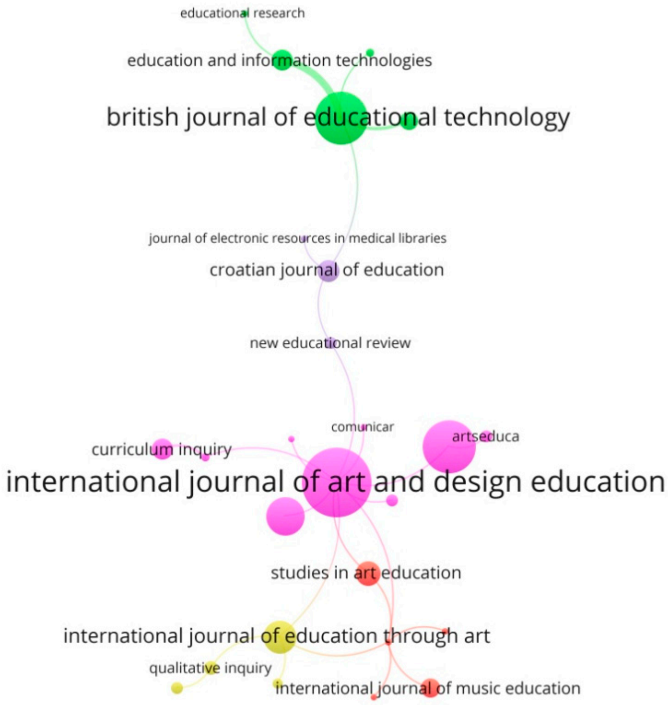

Figure 2. Network of Journals based on co-citation method (1980–2019).

4.3. Productivity of Authors, Research Institutions and Countries

Table 1 shows the main variables of the articles by the 10 most productive authors of the publications on VR in arts education in the context of HE during the period 1980–2019. The author who published the most articles on the research topic is Duh, M., who is affiliated with the University of Maribor (Slovenia), with 10 articles. They are followed by Ellaway, R. (University of Calgary, Canada) and Čagran, B. (University of Maribor, Slovenia), with four articles each. In this case, the author with the highest number of citations per article on VR in Art Education in the context of HE is Ellaway, R., with a total of 350 citations.

Table 1. Top 10 authors (1980–2019).

Author	A	TC	TC/A	Institution	Country	1st A *	Last A *	h-index *
Duh, M	10	38	3.80	University of Maribor	Slovenia	2006	2018	4
Ellaway, R	4	350	87.50	University of Calgary	Canada	2003	2008	3
Čagran, B.	4	20	5.00	University of Maribor	Slovenia	2012	2015	3
Bennett, D.	3	35	11.66	Victoria University	Australia	2011	2016	3
De Mesa, C.G.G.	3	2	0.66	University of Oviedo	Spain	2014	2014	1
Huzjak, M.	3	9	3.00	University of Zagreb	Croatia	2012	2016	1
Mikropoulos, T.A.	3	48	16.00	University of Ioannina	Greece	1998	2018	3
Orman, E.K.	3	53	17.66	The University of North Carolina at Charlotte	United States	2002	2017	3
Springgay, S	3	48	16.00	University of Toronto	Canada	2008	2019	1
Yavgildina, Z.M	3	3	1.00	Kazan State University of Culture and Arts	Russia	2015	2015	1

A: number of articles; TC: number of citations for all articles; TC/A: number of citations by article; 1st A: First article; Last A: Last article; h-index: Hirsch index; (*): in this research topic.

The rest of the authors, in this Table 1, have published three articles each: Bennett, D.; De Mesa, C.G.G.; Huzjak, M.; Mikropoulos, T.A.; Orman, E.K.; Springgay, S; and Yavgildina, Z.M.

On the other hand, Duh, M. also stands out, with the highest h-index (4), while Mikropoulos T.A is the author in this ranking to publish his first article on this subject in 1998.

It is noteworthy that, of the ten most prolific authors in the publication of articles on this research topic, six are of European origin: Slovenia (2), Spain (1), Greece (1), Croatia (1) and Russia (1); and three from North America: (United States (2) and Canada (1)) and Australia (1) [82,83].

Figure 3 shows the collaboration map between the main authors who published on the research topic, based on co-authorship. The different colours represent the different clusters formed by the working groups in the production of articles, and the size of the circle varies depending on the number of articles of each author.

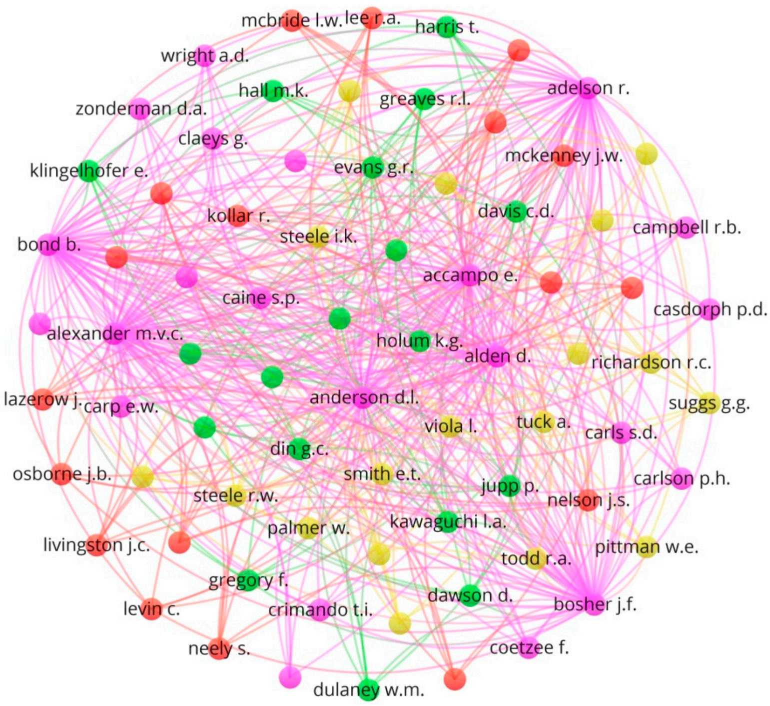

Figure 3. Network of authors based on the co-authorship method (1980–2019).

The 1296 articles were written by 2415 authors. The grouping followed by the lead authors into four groups is shown below. Group 1 (pink) presents the collaboration between Accampo, E.; Adelson, R.; Alden, D.; Alexander, M.V.C.; Anderson, D.L.; Bond, B.; Bosher, J.F.; Burke, P.; Caine, S.P.; Campbell, R.B.; Carls, S.D.; Carlson, P.H.; Carp, E.W.; Carroll, J.M.; Casdorph, P.D.; Claeys, G.; Coetzee, F.; Crimando, T.I.; and Willis, K., among others. Group 2 (green) consists of the authors Davis, C.D.; Dawson, D.; Din, G.C.; Douglas, D.M.; Dulaney, W.M.; Evans, G.R.; Foster, G.M.; Greaves, R.L.; Greever, W.S.; Gregory, F.; Hall, M.K.; Harris, F.W.; Harris, T.; and Hause, S.C., among others. Group 3 (red) contains several authors, including Kollar, R.; Krammer, A.; Lauber, J.M.; Lawrence, J.D.; Lazerow, J.; Lee, R.A.; Leupp, G.P.; Levin, C.; Livingston, J.C.; Lunenfeld, M.; Mcbride, L.W.; Mckenney, J.W.; Miller, J.E.; Milligan, J.D.; Neely, S.; and Nelson, J.S., among others. Finally, Cluster 4 (yellow), is composed—among others—of Palliser, D.M.; Palmer. W.; Pittman, W.E.; Richardson, R.C.; Sharfman, G.; Small, M.; Smith, E.T.; Steele, I.K.; Steele, R.W.; Suggs, G.G.; Thomas, P.D.; Todd, R.A.; Torbenson, C.L.; Tuck, A.; Van Hartesveldt, F.R.; Veseth, M.; Viola, L.; and Williams, B.D.

The analysis based on co-authorship shows wide variety, highlighting Asian authorship in line with the affiliation of these authors, who contribute to the relationship between VR in arts education in the context of HE [84,85].

The 1296 articles were published by 1814 research institutions. Table 2 shows the five most productive research institutions in the publication of articles related to VR in arts education in the context of HE during the period examined.

Table 2. Main institutions (1980–2019).

Institution	Country	A	TC	TC/A	h-index *	1st A *	Last A *
University Complutense of Madrid	Spain	13	34	2.62	1	2009	2019
Vytautas Magnus University	Lithuania	13	4	0.31	1	2014	2018
University of Granada	Spain	12	7	0.58	1	2008	2019
University of Maribor	Slovenia	11	41	3.73	4	2006	2016
University of Barcelona	Spain	10	12	1.20	2	2013	2019

A: number of articles; TC: number of citations for all articles; TC/A: number of citations by article; h-index: Hirsch index; 1st A: First article; Last A: Last article; (*) in this research topic.

Spain, with three research institutions, is the country with the greatest presence in this ranking. The Complutense University of Madrid occupies the first place, with 13 articles, sharing the first position with the Vytautas Magnus University, which has the same number of articles (13). It is followed by the University of Granada (12 articles), the University of Maribor (11) and the University of Barcelona (10).

Regarding the highest average of articles cited per year, the Complutense University of Madrid presents the highest average (2.62).

On the other hand, it is also interesting to note that four of the five most productive institutions made contributions to the research topic during 2018–2019, which confirms the interest in VR in the field of university education [86].

Furthermore, with the exception of the University of Maribor (Lithuania), which published its first article on this subject in 2006, and the University of Granada, which did so in 2008, the rest of the institutions in this ranking contributed their first article in the last decade. This confirms the evolution of this research area, since numerous institutions added the contribution of articles to the development of this technology and its link with university education and training [15,87].

Regarding the countries with the greatest scientific production in the field of research during the period 1980–2019, the 1296 articles were published by 80 countries. In this ranking, in first place is the United States, with a total of 273 articles, with the highest total number of citations, 3443; that is, an average of 12.61 citations for each article on the research topic, and with the highest h-index (26).

The second country with the highest number of articles is Spain, with a total of 127, although it ranks third in citations and h-index (221, 6). In third place is the United Kingdom, with 111 articles, which rises to number two in total citations (1846) and the second highest h-index, with 19. After these three countries is Canada (66) and Russia (65). This circumstance indicates the interest of American, Spanish and English publications for the application of VR in arts education in the context of HE [88].

Likewise, 49.54% of the contributions on VR in arts education in the context of HE worldwide—that is, 642 articles—were developed by five countries: the United States, Spain, the United Kingdom, Canada and Russia. The remaining five countries (Australia, Brazil, Turkey, China and Germany) promoted 15% of the articles on this topic. Among these, only Australia (56) exceeds the 50 articles published during this period.

Figure 4 shows a collaboration map between the main countries based on the co-authorship of their authors. The different colours represent the different clusters formed by the country groups, while the size of the circle varies depending on the number of articles in each country. In this way, the larger the circle of each country, the greater the number of articles it represents. The countries were grouped into six clusters.

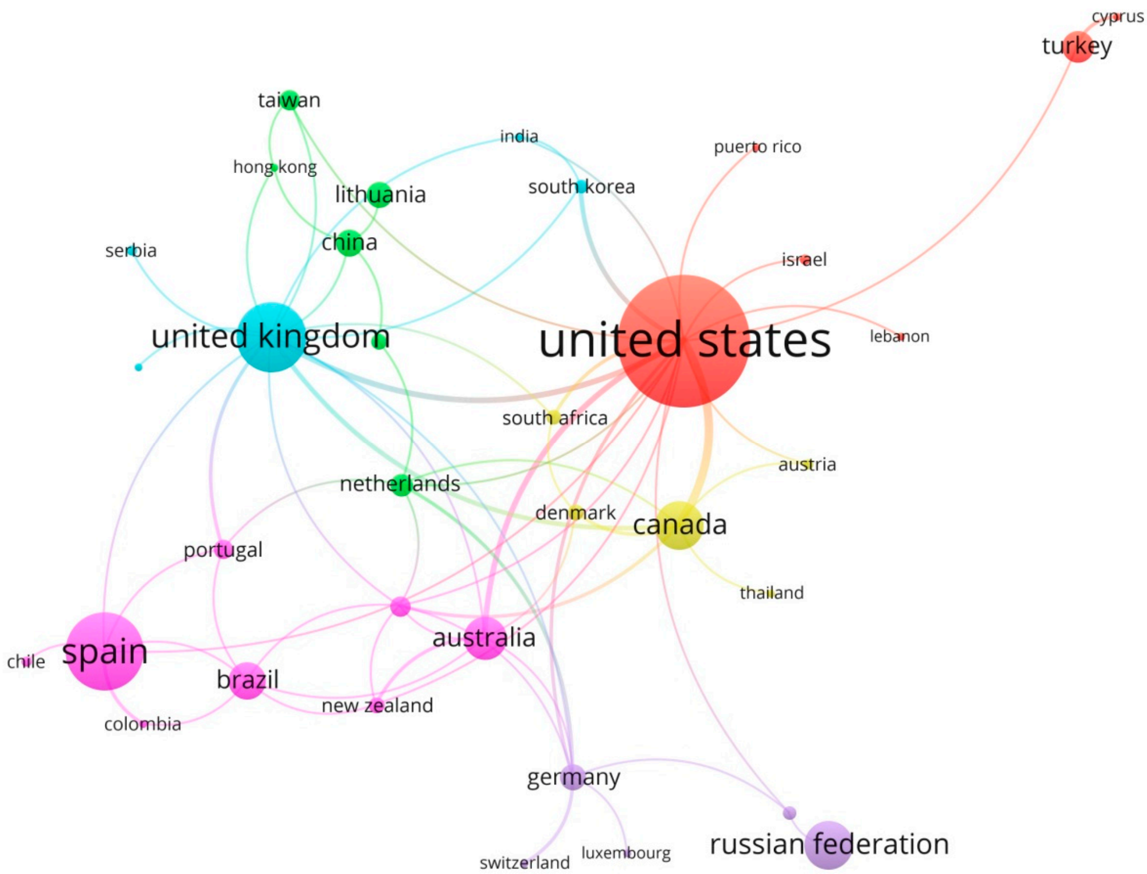

Figure 4. Network of countries based on co-authorship (1980–2019).

Cluster 1 (pink), the largest, is led by Spain, and is associated with Australia, Brazil, Chile, Colombia, New Zealand, Portugal, and Sweden. Cluster 2 (green), led by China, is made up of Belgium, Hong Kong, Lithuania, Netherlands, and Taiwan. Cluster 3 (red) is headed by the United States, and includes Cyprus, Israel, Lebanon, Puerto Rico, and Turkey. Cluster 4 (yellow) is headed by Canada and includes Austria, Denmark, Thailand, and South Africa. The fifth cluster (violet), led by Russia, includes Germany, Poland, Luxembourg, and Switzerland. Finally, Cluster 5 (purple), led by the United Kingdom, includes India, Japan, Serbia, and South Korea.

4.4. Keyword Analysis

The 1296 articles contain 4222 keywords. Likewise, Figure 5 displays the network map for the keywords of the research articles on VR in arts education in the context of HE for the period 1980–2019. The colour of the nodes is used to differentiate the different groups based on the number of co-occurrences, while their size varies according to the number of repetitions. Thus, four lines of research developed by the different communities were detected. These are grouped under the terms “Art education”, “Virtual reality”, “Computer simulation” and “Painting”.

The first line of research, associated with the term “Art education” (pink), includes keywords such as creativity, arts education, artistic education, arts, higher education, culture, music education, visual culture, performance, photography, visual arts, cultural heritage, communication, technology, perception, contemporary art, theatre, visual arts education, art appreciation, artistic expression, critical thinking, fine arts, imagination, leadership, lifelong learning, modernity, emotion, art therapy, artistic skills, constructivism, craft, creation, creative process, cultural capital, cultural participation, deconstruction, visual art, visual art education, visual literacy, and visualization.

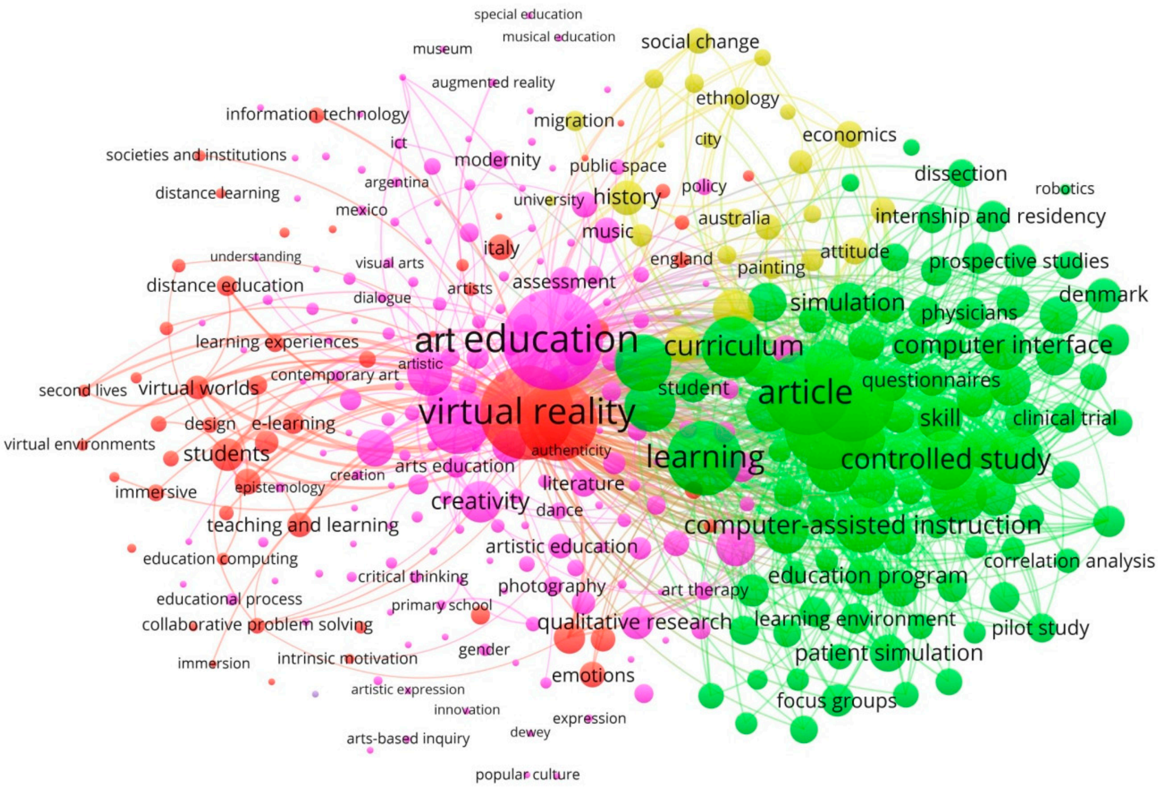

Figure 5. Keywords network based on co-occurrence (1980–2019).

The second line of research, associated with the term "Computer Simulation" (green), groups keywords such as educational technology, user-computer interface, controlled study, internet, computer-assisted instruction, computer interface, simulation, computer graphics, computer interface, computer program, simulator, simulation training, performance and task analysis, video recording, robotics, computer system, sensitivity and specificity, software, video recording, image quality, scoring system, statistical significance, surgical training, and validation study.

On the other hand, the third line of research, linked to the term "Virtual Reality" (red), includes keywords such as virtual worlds, teaching and learning, distance education, e-learning, interactive computer graphics, design, distance learning, virtual community, virtual classroom, virtual learning, artificial intelligence, immersive, virtual learning environments, user interfaces, mixed reality, 3D, interactivity, virtual laboratory, simulations, intelligent tutoring system, virtual and augmented reality, display devices, flow visualization, gesture recognition, image enhancement, real time system, user experience, user interfaces, object recognition, information technology, learning algorithms, machine learning, learning performance, real time, computer vision, decision making, visualization, data visualization, and three dimensional.

Finally, the fourth line of research, led by the term "Painting" (yellow) is associated with keywords such as social change, decision making, ethnology, personality, attitude, behaviour, university, arts education policy, cultural anthropology, social work education, and sociology.

These four lines of research bring together all the concepts related to the implications of VR in arts education in the context of HE, since it includes various aspects related to technologies [89,90], their applications in different sectors of virtuality [36,41,91], their application in HE [25,92], and with the use of technologies in the educational sector [93,94].

Figure 6 shows the evolution of each keyword cluster by differentiating the period in which they were incorporated into the research. Furthermore, this allows us to understand the importance of keywords according to the time in which they appeared, because the most pioneering ones have had the greatest influence, and were a reference for those that emerged later. The presence of four differentiated clusters allows us to understand how research on the implications of VR in education covers various topics of study in research activities.

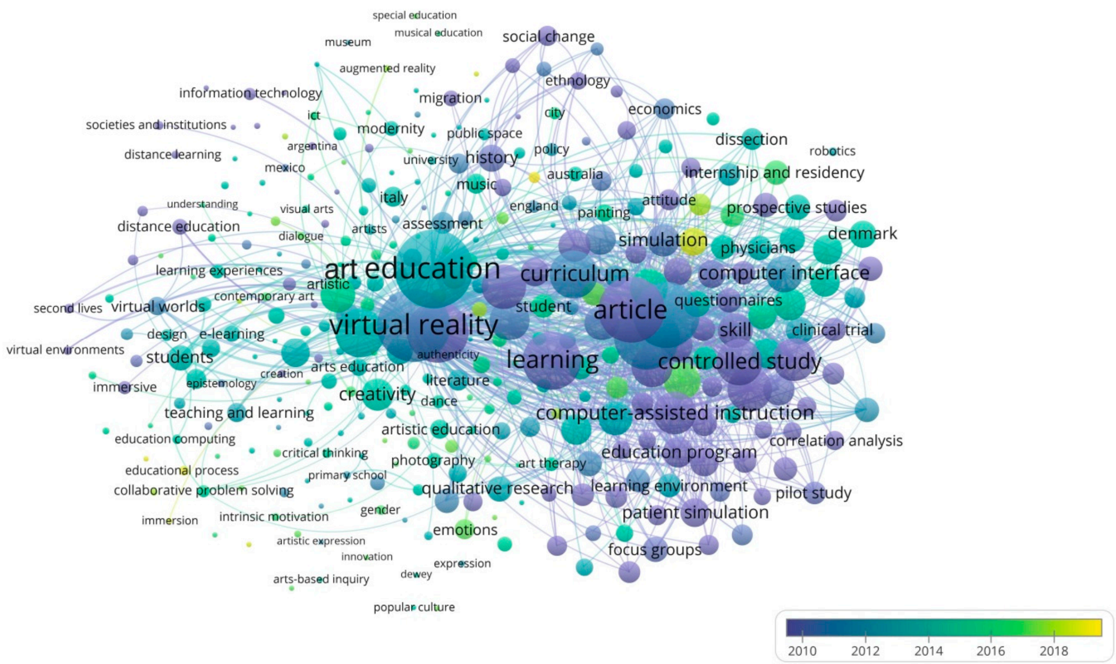

Figure 6. Evolution of keywords network based on co-occurrence (1980–2019).

Along these lines, higher education institutions are making a great effort to include new technologies in various areas, especially those related to culture and art; although sometimes the efforts are not reflected on campus, research works such as the one presented act as an antecedent that provides new research tools.

Moreover, others terms were added, such as “3D Virtual Reality”, “Digital Art”, “Interactive Learning Environment”, “Game-based learning”, “Mixed Reality”, “Internet Of Things” (IoT)”, “Ubicomp”, “Ambient Intelligence”, “Augmented Virtuality”, “Calm Technology”, “Things That Think”, “Everyware IoT”, “Tactile Feedback”, and “Image Segmentation”.

We observed that research on this topic continues to advance at a global level, so that—from the relevance of the last terms associated with this topic according to VOSviewer—the concepts and related technologies, HE and artistic education were detected. Thereby, we identified new directions in research and different issues associated with them: (i) Ubiquitous Computing, (ii) Pervasive Computing, (iii) Virtuality Continuum, (iv) Ambient Intelligence, and (v) Wearable Computing.

5. Conclusions

The objective of this study was to analyse the evolution of scientific production and research trends worldwide, during the period 1980–2019, on VR in arts education in the context of HE. For this, a bibliometric analysis of a sample of 1296 articles obtained from the Scopus database was developed.

Fundamentally, the evolution of the number of articles, the subject areas where they are classified, the journals where they are published, the authors, the research institutions and the most productive countries were identified. In addition, the main current and future lines of research were detected. Scientific production has increased, especially in the last triennium (2017–2019), where 451 articles were published, which represents 34.80% of the total VR topic in arts education in the context of HE, confirming its relevance to the global level and the impact of this research topic. In the same way, the authors, the research institutions and the most productive countries link their articles to the schools of knowledge of education and technology. Furthermore, the most prolific countries in this research topic are the United States, Spain, the United Kingdom, Canada and Russia. On the other hand, this study also identified the most influential areas of knowledge where publications are classified, being first the area of Social Sciences, followed by Arts and Humanities, which responds to the multidisciplinary nature of the research that this subject acquires, such that there is a link with education, art and technology. Social Sciences account for 62.74% of the total (1088 articles), and Arts and Humanities account for 37.25% (646).

The most productive journal on the topic of research on VR in arts education in the context of HE was the International Journal of Art and Design Education, with 53 articles published in the period of analysis. It is also the journal with the highest number of citations, the one with the best average number of citations per article, and the one with the highest h-index for articles published on this subject area. It should be noted that 70% of the ten journals that contribute the most to this topic are positioned in the first Scopus quartile.

The author who has published the most on this topic is Duh, M., who is affiliated with the University of Maribor (Slovenia). On the other hand, Ellaway, R. is the author with the highest number of citations and the best average number of citations per article. Furthermore, the most productive institutions in this research area are the University Complutense of Madrid (Spain), Vytautas Magnus University (Lithuania), and the University of Granada (Spain).

The countries that have made the greatest effort in this area of research, in order of importance, are the United States, Spain, the United Kingdom, Canada and Russia. Hence, the United States has the highest number of published articles (273), citations (3443), and the highest average number of citations per article (12.61). As for the countries that have made a greater international collaboration in their articles, they were the United States, Spain, and the United Kingdom.

This study has some limitations, which could be the basis for future research. Mainly, these come from the intrinsic characteristics of the quantitative analysis of the bibliometric method. One of these limitations is that some authors publish few articles with high influence in a certain field of research. In addition, this methodology could be extended with other databases or quantitative or qualitative tools, which would facilitate a different perspective of the study. In addition, other types of documents, in addition to scientific articles, could also be included in the search.

In addition, five lines of research developed by the different communities were detected. These are grouped under the terms “Art education”, “Virtual reality”, “Computer simulation” and “Painting”.

On the other hand, this study has identified new directions in research, and different issues associated with them: (i) Ubiquitous Computing, (ii) Pervasive Computing, (iii) Virtuality Continuum, (iv) Ambient Intelligence, and (v) Wearable Computing. For this, future lines of research on this topic will focus their efforts on analysing VR environments in university learning contexts related to digital art, historical and artistic heritage, immersive art, and interactive and 3D experiences of space.

Likewise, in addition to the potential for students and faculty in arts education, VR research is multidisciplinary, expanding the vision of applications within the environment of architecture, mathematics, engineering, advertising, marketing, psychology and languages, and also the initial training of university and postgraduate teachers.

On the other hand, contributions must be developed to support VR mobile applications for the services of the university libraries and for the welcome to the university campus; in developing the relationship between VR and inclusive education in HE, as well as connecting m-learning and VR in order to optimize the performance and motivation of students in HE. Consequently, these are the new challenges that must be studied to develop a research topic that involves VR and its link with HE.

The application of VR in arts education is appropriate to be applied for its great potential to bring the student closer to the possibility of making use of virtual 3D objects and models, based on innovative systems of the representation of reality through digital software technology. VR offers an innovative technological framework adapting the digital world that surrounds the student outside the classrooms within them, as a didactic and educational resource.

The results obtained are useful for researchers, academics, managers of HEIs and other stakeholders, since scientific activity in this field of research was evaluated. Finally, it was observed that research on

VR in arts education in the context of HE worldwide has followed an upward trend, with optimal publication rates in recent years, favouring the use of VR as a complement to teaching.

Author Contributions: Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, E.A.-S. and M.-D.G.-Z.; project administration, M.-D.G.-Z.; resources, E.A.-S. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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