Bibliometric analysis: Augmented Reality-Based Physics Laboratory with VOS Viewer Software

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Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software

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Abstract. Augmented reality (AR) is a breakthrough in future technology trends that combine information and virtual objects that draw the user's imagination into a real scene. The implementation of AR into the world of education will greatly affect the transformation of education, especially in the physics education laboratory. The purpose of this research was to analyze the application of the AR in the physics laboratory by providing bibliometric analysis so that the opportunities for further research can be presented. The data had been collected from the Scopus database. There were 80 articles found using the keywords "Augmented Reality and Physics", 21 articles were found using the keywords "Augmented Reality and Physics Education" and 10 articles were found using the keywords "Augmented Reality and Physics Laboratory". Then all data was classified according to the type of co-occurrence analysis based on the keywords of the author, co-authorship for unit countries, publication density, and year of publication using VOSviewer software. Based on the analysis, research on the augmented reality-based physics laboratory on the Higher-Order Thinking Skill (HOTS) aspect has never been studied. Previous research discussed physics laboratory experiments based on AR technology using Smart glasses to foster the concept of heat conduction and the effects of AR technology on students' cognitive in the physics laboratory. Thus, HOTS on AR-based physics laboratories can be opportunities for future research.

Keywords: Augmented reality, bibliometrics, physics education, physics laboratories

1. Introduction

Augmented Reality (AR) has gotten much attention from the researchers in the last two decades [1–3]. AR has become a breakthrough in future technology trends that combines information and virtual objects that caught the imagination of its users into a real scene [1,4,5]. The AR toolkit software was first discovered in the 2000s [4] to pave the way for AR development to be implemented into various elements, one of them in the world of education [6]

AR will greatly influence the system [4,7–9] and will have a significant impact on the future [1,4,5,10]. Implementing AR technology into physics learning helps students understand the phenomena and concepts of physics in a multidimensional manner [1,11]. Previous research also discussed how AR can provide interesting experiences in learning physics [11–15]. The use of AR technology also allows students to absorb information more ideally to develop reasoning skills [16], to improve higher-order thinking skills [17,18], problem-solving [17,19,20], and problem analysis on physics [10,17,19,21].

The ability of AR technology to visualize physics concepts into the virtual world brings further research to see how it can visualize physics phenomena taught at schools [22,23] using experiments in the laboratory. Previous research discussed physics laboratory experiments based on AR technology using Smart glasses to foster the concept of heat conduction [11] and the effects of AR technology on students' cognitive in the physics laboratory [11,12]. A review of bibliometric mapping analysis on the use of AR in science education has been conducted before [4,7]. However, there has been no bibliometric analysis that reviews the implementation of AR in physics education, especially its implementation in physics laboratories. So, it is important to know the extent to which AR has been involved in experiments in physics laboratories.

The purpose of this research was to analyze the extent to which AR research is involved in the physics laboratory by providing bibliometric analysis so that the opportunities for further research can be determined.

2. Research Method

All articles analyzed in this research were sourced from the Scopus database. The data collection was carried out in August 2020 by using 3 keywords, namely Augmented Reality and Physics, Augmented Reality and Physics Education, and Augmented Reality and Physics Laboratory. The literature search was devoted to journals and conference proceedings within 2015-2020.

The initial search on the first keyword found 149 articles in the Scopus database in the form of journals, books, and proceedings. After being selected according to the type of article for journals and proceedings and based on the year of publication, 80 articles were selected. The second keywords found 41 in which 21 articles were selected based on the types and year of publication. The third keyword found 13 articles in which 10 articles were selected based on the types and the year of publication. The search results were stored in CSV format to be input into VOSviewer software. The data were then classified based on the type of analysis, the analysis unit, and the number of keywords occurrence. The research consisted of five steps of bibliometric analysis as shown in Figure 1.

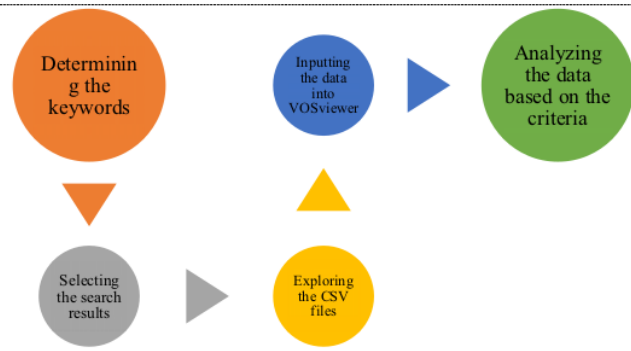


Figure 1. The Steps of Bibliometric Analysis

3. Research and Discussion

Based on the Scopus database, 380 articles were found using the first keywords, 21 articles were found using the second keywords, and 10 articles were found using the third keywords. Then the articles were processed using VOSviewer software to see the development of articles based on the co-occurrence analysis of author and index keywords. The first analysis was done by searching for a network of topics related to the AR and physics as shown in Figure 2.

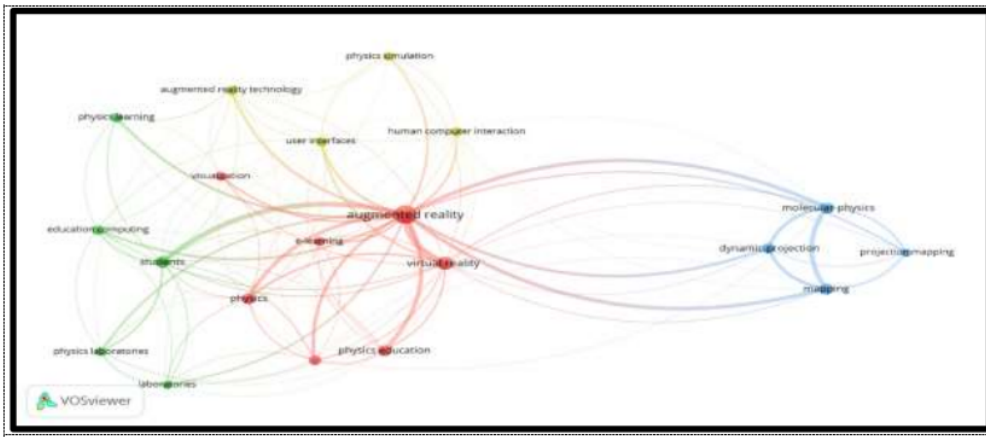


Figure 2. Network Vision of AR and Physics Keywords

Based on the data that had been downloaded and analyzed using the minimum number of occurrences of six times in a publication, 20 items, 4 clusters, and 105 links were defined. Each cluster is represented with different colors to indicate the relationship to keywords. However, not all terms in the cluster were directly related to each other. Each topic in the image is represented by a node where the size of the node shows the frequency of keywords and topics that appears in an article. The red cluster consists of augmented reality, virtual reality, physics education, e-learning, physics, and visualization. The green cluster consists of laboratories, physics laboratories, students, computing education, and physics learning. The yellow cluster consists of physics simulation, augmented reality technology, user interface, and human-computer interaction. The second analysis had been done by looking at the network of topics related to the AR keyword and physics education. The results are shown in Figure 3.

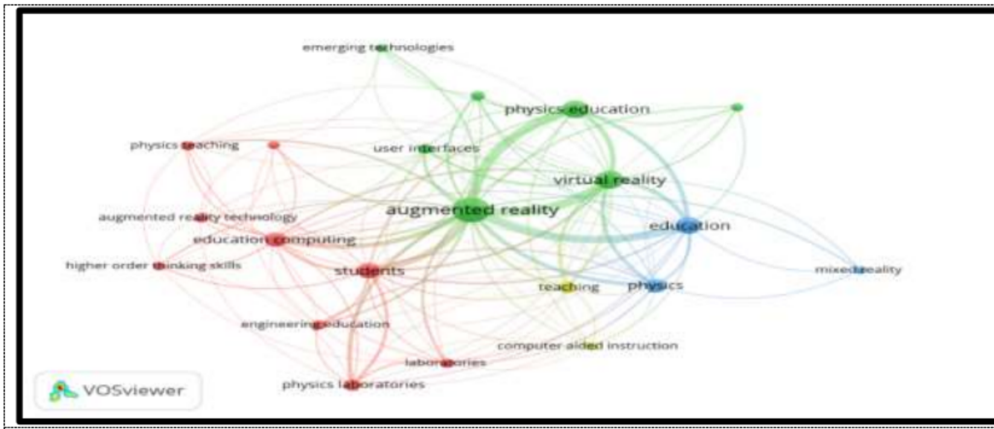


Figure 3. Network Visualization of the AR and Physics Education

The downloaded and analyzed data on the AR and physics education keywords were then searched using a minimum of 3 occurrences in a publication that resulted in 21 items, 4 clusters, and 125 links. The red cluster consists of physics teaching, augmented reality technology, educational computing, higher-order thinking, engineering education, physics laboratories, laboratories, and student. The green cluster consists of emerging technologies, user interfaces, and virtual reality. The blue cluster consists of mixed reality, education, and physics. The yellow cluster consists of teaching and computer-aided instruction. The third analysis had been continued by looking at the network of topics related to the AR and physics laboratory keywords. The results are shown in Figure 4.

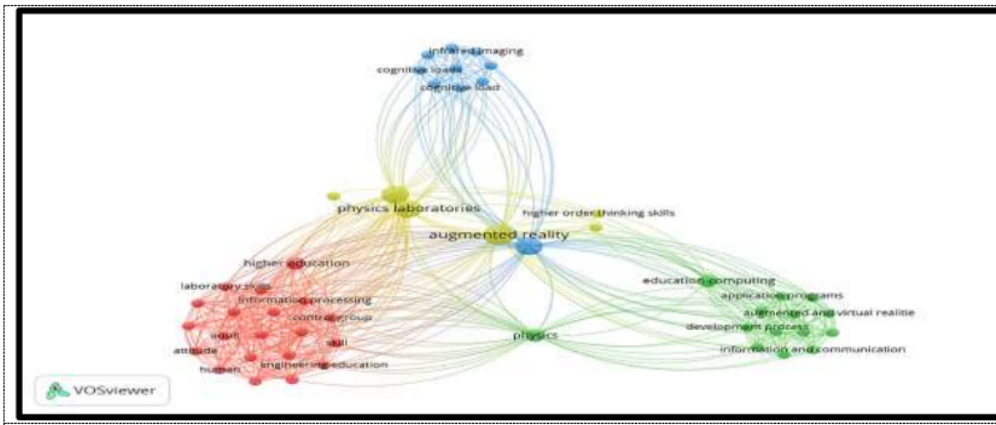
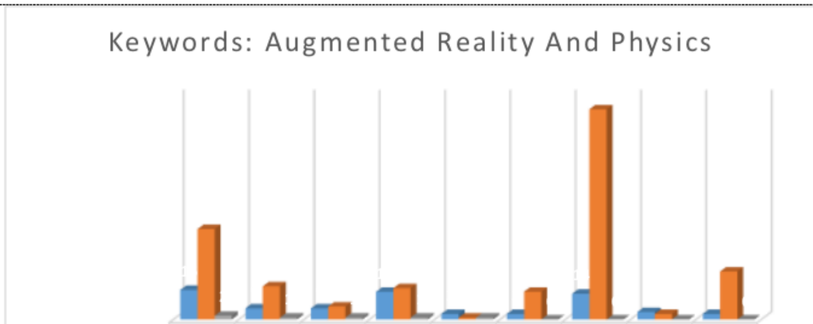


Figure 4. The Network Visualization of the AR and Physics Laboratory Keywords

The downloaded and analyzed data on the AR and physics education keywords were then searched using a minimum of 1 occurrence in a publication resulted in 49 items, 4 clusters, and 502 links. The red cluster consists of higher-education, laboratory skills, and information processing, control group, adult, and attitude, human, civil, and engineering education. The green cluster consists of physics, education computing, application programs, augmented and virtual reality, development process, and information and communication. The blue cluster consists of infrared imaging and cognitive content. The yellow cluster consists of higher-order thinking skills.

Based on the network visualization shown by each keyword, the first and second keywords in the green cluster contains the physics laboratory term. This shows that articles with the keyword physics laboratory appeared together in an article with the keywords augmented reality, physics, and physics education. In the network visualization of the third keywords, the terms related to the AR keywords and physics laboratory can be found. Several terms arise from various clusters, however, possible topics to be researched related to physics laboratory are higher-order thinking skills, control groups, cognitive, higher education, and laboratory skills.

The second analysis was had been done on the same 3 keywords to see the authors' productivity based on country of origin using co-authorship analysis for unit countries. The first analysis was carried out to see the author's productivity and affiliation by country using AR and physics keywords. The results are shown in Figure 5.



	United States	China	Germany	Indonesia	South Korea	France	Japan	Kazakhstan	Ukraine
Document	16	6	6	15	3	3	14	4	3
Citation	49	18	7	17	1	15	114	3	26
Total links	2	1	1	1	1	0	0	0	0

Figure 5. Productivity and Author's Affiliations on AR and Physics Keywords

Based on the downloaded and analyzed data on the AR and physics education keywords searched using a minimum of 3 citation occurrences, 9 countries with the most publications were found as defined in this data. In the graph, it can be seen that the most number of articles had been published by the United States with 16 articles, Indonesia with 15 articles, and Japan with 14 articles. Meanwhile, the most cited articles came from Japan with 114 citations, the United States with 49 citations, and Ukraine with 26 citations. The calculated total links define the author's network with other authors; the United States has more total links than any other country for the AR and Physics keywords. The second analysis had been done to see the author's productivity and affiliation by country using the AR keyword and physics education. The results are as shown in Figure 6.

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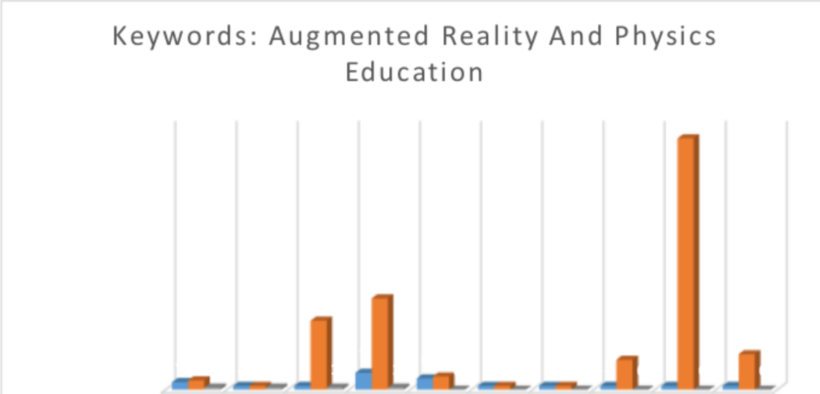

	Germany	Mexico	Spain	United States	Indonesia	Japan	Kazakhstan	South Korea	Turkey	Ukraine
Document	4	2	2	9	6	2	2	2	2	2
Citation	5	2	37	49	7	2	2	16	135	19
Total links	1	1	1	1	0	0	0	0	0	0

Figure 6. The Productivity and Author's Affiliation on AR and Physics Education Keywords

Based on data that had been downloaded and analyzed on the AR and physics education keywords using the VOSviewer software, the search carried out using co-authorship analysis in the units of countries with a minimum limit of 2 citations found that 10 countries with the most publications were found as defined in figure 6. It can be seen that most articles had been published by the United States with 9 articles, Indonesia with 6 articles, and Germany with 4 articles. Meanwhile, the most cited articles came from Turkey with 135 citations, the United States with 49 citations, and Spain with 37 citations. The highest total links counted on the AR and physics education keywords came from Germany, Mexico, Spain, and the United States. The third analysis had been done to see the author's productivity and affiliation by country using the AR and physics laboratory keywords. The results are as shown in Figure 7.

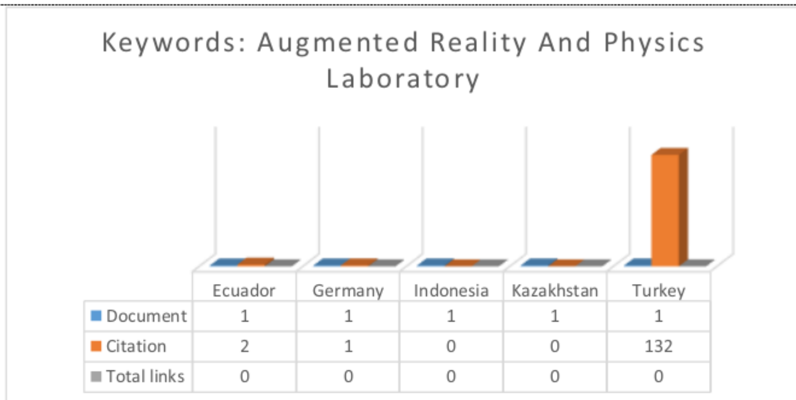

Figure 7. The Author's Productivity and Affiliation on AR and Physics Laboratory Keywords

Based on downloaded and analyzed data on the AR and physics laboratory keywords on the VOSviewer software, the search had been carried out using co-authorship analysis in the unit countries with a minimum limit of 1 citation occurrence. Five countries with the most publications were found as defined in this data. In the graph above, it can be seen that each country had the same number of publications. The articles with the most citations came from Turkey with 132 citations. There were no total links calculated for each country which indicated that there were no affiliations between authors.

The third analysis had been done with the same keywords and data to see the opportunity of publication in the future using co-occurrence analysis. The first analysis to see the publication density on the AR and physics keywords is shown in Figure 8.

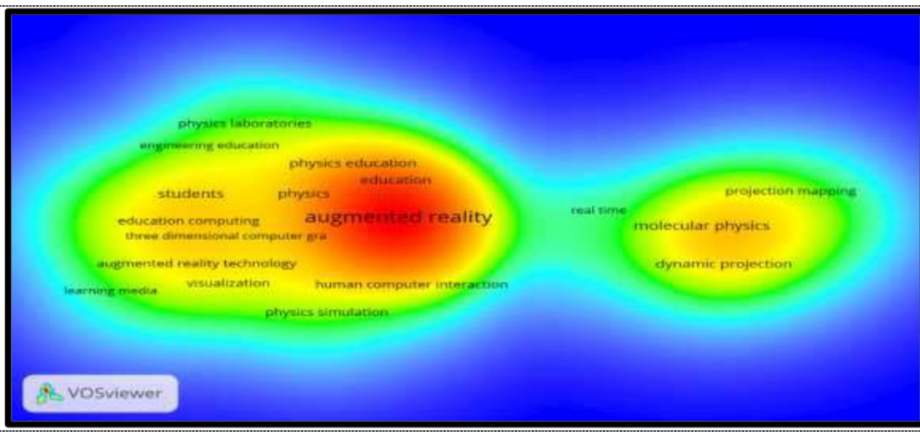

Figure 8. Visualization of AR Publication Trends in Physics

Based on downloaded and analyzed data on the AR and physics laboratory keywords on the VOSviewer software, the search had been carried out to see the publication density using a minimum of 6 occurrences in a publication that resulted in 20 items, 4 clusters, and 105 links defined in this data. The

AR and physics laboratory keywords were divided into 4 different colors. The numbers of research are visualized in red while the faded colors show the rarely found terms. The research on AR and physics keywords that are rarely studied includes the physics laboratory, engineering education, learning media, and physics simulation. The second analysis had been done to see the density of publications on the AR and physics education keywords. The results are as shown in Figure 9.

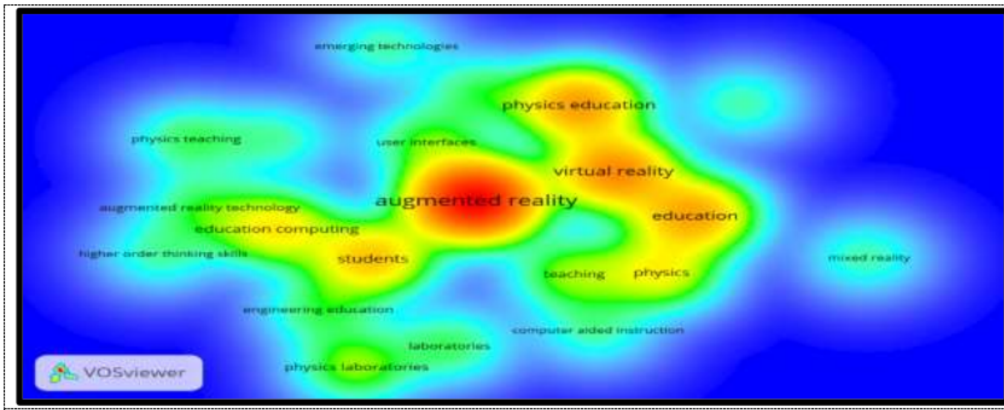

Figure 9. The Visualization of AR Publication Trends in Physics Education

Based on the downloaded and analyzed data using VOSviewer software, a search had been carried out to see the density of publications using a minimum of 3 occurrences in a publication. It was found that 21 items, 4 clusters, 125 links were defined in this data. The extent of AR involvement in physics education had been researched by looking at the level of color in the image. The AR and physics education keywords had been widely researched in terms of physics education, virtual reality, education, computing education, students, physics, and teaching. Meanwhile, in terms of mixed reality, new technology, physics teaching, higher-order thinking skills, technical education, computer-assisted instruction, and physics laboratories showed very few publications. The third analysis had been done to see the density of publications on the AR and physics laboratory keyword. The results are as shown in Figure 10.

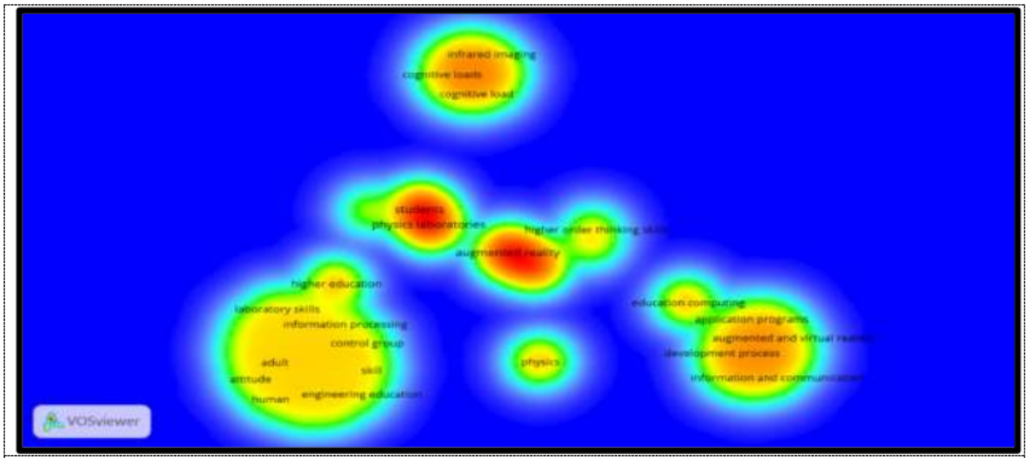

Figure 10. The Visualization of AR Publication Trends in Physics Laboratories

Based on the downloaded and analyzed data using VOSviewer software, a search had been carried out to see the density of publications by using a minimum of 1 appearance in a publication that resulted in 49 items, 4 clusters, and 502 links as defined in this data. In the AR and physics laboratory keywords, most research had been done related to the keywords, namely in terms of cognitive content, infrared imaging, application programs, development processes, and information and communication. Meanwhile, the least research was in the terms of higher-order thinking skills, computation education, physics, higher education, and laboratory skills. However, the possible topics to be researched related to the physics laboratory are higher-order thinking skills, higher education, and laboratory skills.

Based on AR and physics laboratory keywords, a search had been carried out to find out which articles were most frequently cited during the 2015-2016 period using the type of citation analysis for document types with the limitation of 1 quotes. The 3 most frequently cited documents are presented in Table 1.

Table 1. The Most Frequently Cited Articles AR and Physics Laboratories keywords

Author	Number of Citations	Article Title	Source	Affiliation	Country
Thees.M (2020)	1	Effects of augmented reality on learning and cognitive load in university physics laboratory courses	Computers in Human Behavior 108, 106316	Kaiserslautern Technical University	Germany
Ullon. H (2017)	2	Smart objects for engineering labs: Boosting	12th Latin American Conference on Learning	Escuela Superior Politécnica Del	Ecuador

Author	Number of Citations	Article Title	Source	Affiliation	Country
		exploratory learning in higher education	Technologies	Litoral (espol)	
Akcayir. M (2016)	133	Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories.	Computers in Human Behavior 57, pp. 334-342	Kirikkale Üniversitesi	Turkey

The fourth analysis had been done with the same keywords and data to see the publication year period of each keyword. This analysis used the co-occurrence analysis for author keywords and index keyword on the overlay visualization display. The results are shown in Figure 11.

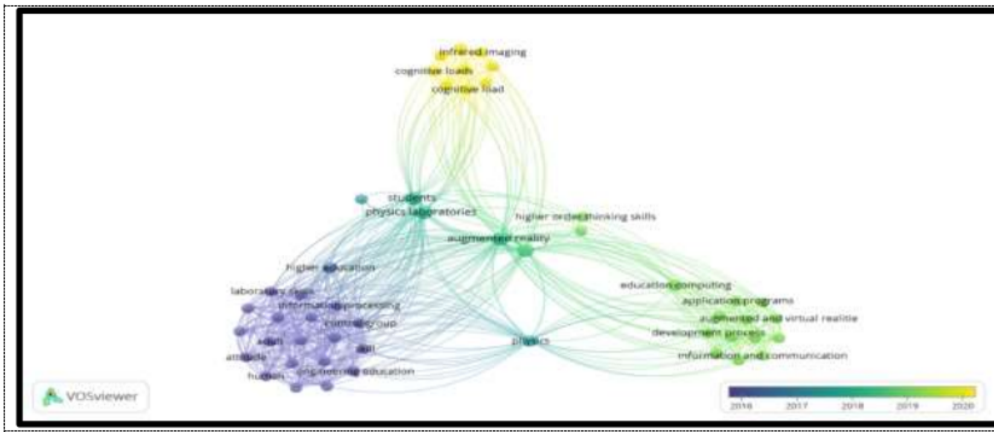

Figure 11. The Visualization of Keywords Based on the Year of Publication

Based on the downloaded and analyzed data using VOSviewer software, a search had been carried out to see the year of publication using the minimum of 1 occurrence in a publication that resulted in 49 items, 4 clusters, and 502 links. The color clusters were divided into 4 clusters. The purple color shows the 2016 publications, namely higher education, laboratory skills, information processing, control groups, adults, attitude, human, and engineering education. The blue color shows the 2017 publications, namely students and physics. Tosca green color shows the publication in 2018, namely augmented reality and physics laboratory. The light green color shows publications in 2019, namely higher-order thinking skills, education computing, application programs, augmented and virtual reality, development processes, and information and communication. The yellow color shows the latest publications in 2020, namely infrared imaging and cognitive factors.

Based on the connected network, the publication density, and the publication period, the keywords were then narrowed down to one keyword, namely AR and physics laboratory. The topics that should be researched are AR-based physics laboratory, specifically the higher-order thinking skills, control groups, cognitive factors, higher education, and laboratory skills.

However, based on the publication density analysis, further research opportunities are higher-order thinking skills, laboratory skills, and higher education. Based on the results of the analysis of the publication period, the least and most recent research is on the topic of higher-order thinking skills (HOTS).

This research is relevant to previous research on the application of AR in the laboratory. Previous research investigated the low use of HOTS in physics laboratories and the low achievement of HOTS so that the results of previous studies suggested involving the use of AR in physics laboratories as one of the new activities [24]. This research suggests that further research should be focused on HOTS as a topic of discussion in an AR-based physics laboratory.

4. Conclusion

This research reviewed all articles related to the predetermined keywords, namely augmented reality and physics, augmented reality and physics education, and augmented reality and physics laboratory. The search had been carried out on the Scopus database on the 2015-2016 period on journal and conference proceedings. The first keywords obtained 80 articles, the second keywords obtained 21 articles, and the third keywords obtained 10 articles. All data were analyzed using VOSviewer software based on the type of analysis.

In the network analysis between topics, it was possible to research AR-based laboratories, specifically on HOTS, control groups, cognitive factors, higher education, and laboratory skills. At the level of publication density, the least researched topics are HOTS, computational education, physics, higher education, and laboratory skills. The most commonly done research related to the keywords is on the topics of cognitive content, infrared imaging, application programs, development processes, and information and communication. The latest research had been analyzed based on the journal's period which resulted in HOTS as the only topic related to the AR and physics laboratory keywords. Due to the absence of publications regarding HOTS research in AR-based laboratories, the findings of this research becomes a suggestion for future research.

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