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AUGMENTED REALITY IN EDUCATION REVIEW: BIBLIOMETRIC COMPUTATIONAL MAPPING ANALYSIS USING VOSVIEWER

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Abstract

This study examines the development of research on the use of augmented reality (AR) in education with bibliometric mapping analysis using VOSviewer. This article was compiled from the Google Scholar database using the Publish or Perish application. Titles and articles are searched by entering the keywords "augmented reality, education". This study analysed the indexed database of Google Scholar for 10 years (2012-2021) which resulted in 756 articles. The results of research on the use of AR in education show an increase every year, except from 2020 to 2021 there is a decrease in total publications. There are two research themes, namely the AR theme which resulted in a total of 254 links, 4494 total link strength, and 772 occurrences. The education theme resulted in a total of 253 links, 3313 total link strength, and 552 occurrences. Research topics that are trending and frequently researched are AR, education, higher education, experience, teaching, learning, use, teachers, books, studies, applications, and development. This means that there are still many research topics that need to be researched and will continue to be developed. Therefore, this review can be a starting point for research related to other fields of study.

Keywords: Augmented reality, Bibliometric, Computational mapping analysis, Education, VOSviewer.

1. Introduction

The development of the 21st-century education pattern is marked by changes in the Industrial Revolution 4.0, including artificial intelligence (AI), Big data, the Internet of Things (IoT), and Robotics. This changes our lifestyle [1-4]. Technology has been integrated into the teaching and learning process, and as a consequence of the emergence of new technologies, teaching and learning methods have also developed [5]. However, the use of technology in learning has not been able to increase learning motivation and is not following student needs [6]. The use of digital media as technology is not fully effective in improving the quality of education. This is due to the limitations of learning tools and content that do not follow the needs of students, these problems cause learning to be not optimal [7-11].

Industrial Revolution 4.0 is described as merging the physical world and the virtual world, media combines the physical world and the virtual world, one of which is the Metaverse. The emergence of the metaverse represents the way humans will change the way of future development through science and technology [12]. Metaverse allows everyone to meet avatars in 3D video games by combining virtual reality (VR), augmented reality (AR), and the internet [13].

Based on An Overview of Twenty-Five Years of AR in Education put forward by Juan Garzón stated that AR from 1995 to 2022 had three generations of AR in education. The first generation (1995-2009) was defined as hardware AR. The second generation (2010-2019) is defined as application-based AR. The third generation (2020 and beyond) evolves turning AR into a mature technology to complement every educational context [14]. AR is defined as the integration of AR on mobile devices, in an educational context it can reduce costs and increase usability. The successful application of educational AR depends not only on technical issues but also on the pedagogical characteristics of the context in which it is used [14]. Many reports regarding AR and VR are available [15-18].

This research reviews the development of AR in education. VR, mobile learning, interactive learning environments, and e-learning were among the most studied concepts in AR research [19]. Specific research on the use of AR and VR is still at a very early stage [20]. VR, virtual worlds, AR, e-learning, and simulations are the top keywords used in the VR domain [21]. To support this review, bibliometric analysis was used. Scientific research is growing and collaborative [22] one of which is bibliometrics. Bibliometrics is increasingly being used as a tool for evaluating research performance [23]. The bibliometric method complements the meta-analysis and literature review to evaluate the scientific literature [24].

Table 1 shows current studies regarding bibliometric analysis. Bibliometric analysis is used to make decisions about continuing or stopping research in the future.

Some research has successfully found good performant adsorbents from some biomass particles, like calcium carbonate microparticles obtained from barred fish (*Scomberomorus spp*.) [9], carbon particle from Soursop (*AnnonaMuricata* L.) [10], carbon particle from Red Dragon Fruit (*Hylocereus undatus*) [11], carbon particle from Pumpkin (*Cucurbita maxima*) Seeds [12], proposed adsorbent biomass derived from bacteria, fungus, and algae for the removal of petroleum pollutants from water [13].

Table 1. Prior bibliometric analysis research.

No.	Topic Discussion	Ref.
1	This work presents the development of dental aerosol suction using VOSViewer and the dissemination of bibliometrics maps.	[25]
2	This study looks at how research has changed over the Covid-19 era using bibliometric methodology.	[26]
3	The literature review for this study discusses the benefits and drawbacks of using pure biodiesel on engine performance.	[27]
4	This study discusses the current state and future directions of bioenergy management research.	[28]
5	This study investigated the dissolution of empty palm oil fruit bunches using benzotriazole ionic salt solutions and VOSviewer, a tool for bibliometric analysis.	[29]
6	Information regarding decision-making is covered in this study.	[30]
7	This study covers the analysis of science and its integration. This paper also did mapping analysis using the VOSviewer application.	[31]
8	This study discusses the usage of VOSviewer in conjunction with mapping analysis.	[32]
9	The expansion of geotechnical engineering research was investigated in this work using VOSviewer and bibliometric distribution maps.	[33]
10	This paper describes recent developments in engineering research and scientific education.	[34]
11	This study investigates the "Special Needs of Chemical Engineering" by combining mapping analysis and the VOSviewer tool.	[35]
12	The present directions in materials research are discussed in this paper.	[36]
13	This study uses data from Scopus-indexed article databases to investigate the evolution of bibliometric analysis research in the domains of science and Islam.	[37]
14	This study uses bibliometric analysis to examine how resin matrix composition affects brake pad performance.	[38]
15	This article examines the trends in briquette research during the COVID-19 epidemic.	[39]
16	VOSviewer is utilized in this study's Publish or Perish program to evaluate bibliometrics.	[40]
17	This paper explains the current nanotechnology on animal science	[41]
18	This paper describes research on how particle technology involve in realistic life, incuding its impacts on computational fluid dynamics.	[42]
19	This paper describes how to improve students' understading during practicum based on bibliometric analysis	[43]
20	This paper describes how to improve students' understading in engineering based on bibliometric analysis	[44]

2. Methods

This article discusses the development of AR in education. This article is taken from publication data that has been published by indexed Google Scholar. This paper uses the Publish or Perish application to make it easier to find and filter publication data that has been published on Google Scholar and analysed using a VOS viewer. Detailed information for the use of bibliometric is explained in other papers [45, 46].

In this study, how to get the data using the Publish and Perish application, we wrote down the keywords AR and education. This paper was searched from 2019-2021 by journal publication type. The data was then collected and saved with the format (.ris) for research information system and format (.csv) comma-separated

value format. The format (.ris) is used to browse the paper using an advanced application, namely VOSviewer, and the format (.csv) is used to process data using Microsoft Excel. VOSviewer analysis can be visualized into 3 variations, namely network visualization, density visualization, and overlay visualization.

3. Results and Discussion

3.1. Publication data search results

Based on the data search using the publish or perish application from the Google Scholar database, 756 articles were obtained according to the research criteria. The data obtained is in the form of article metadata consisting of the author's name, title, year, journal name, publisher, number of citations, article links, and related URLs. Table 2 shows some examples of published data using the VOSviewer application based on this research. The data samples taken are the 10 best articles that have the highest number of citations. The number of citations from all articles obtained in this study is 41318, cites/year is 4132.50, cites/paper is 41.37, author/paper is 2.90, h-index is 99, and g-index is 164.

Tabel 2. AR in education publication data.

No.	Authors	Title	Year	Cites
1	Acosta *et al*.	Augmented reality trends in education: a systematic review of research and applications	2014	1290
2	Cheng *et al*.	Affordances of augmented reality in science learning: Suggestions for future research	2013	849
3	Hussin *et al*.	Education 4.0 made simple: Ideas for teaching	2018	786
4	Gutiérrez *et al*.	Virtual technologies trends in education	2017	708
5	Baran *et al*.	A review of research on mobile learning in teacher education	2014	647
6	Flavián *et al*.	The impact of virtual, augmented and mixed reality technologies on the customer experience	2019	638
7	Chiang *et al*.	An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities	2014	630
8	Yim *et al*.	Is augmented reality technology an effective tool for e-commerce? An interactivity and vividness perspective	2017	468
9	Wang *et al*.	A critical review of the use of virtual reality in construction engineering education and training	2018	444
10	Ally *et al*.	What is the future of mobile learning in education?	2014	409

3.2. Research development in the field of AR in education

Table 3 shows the development of AR research in education published in the Google Scholar-indexed journal. Based on the data shown in Table 3, it can be seen that the number of AR research in education is 756 articles from 2012-2021. In 2012 there were 21 articles, in 2013 there were 36 articles, in 2014 there were 46 articles, in 2015 there were 48 articles, in 2016 there were 56 articles, in 2017 there were 81 articles, in 2018 there were 109 articles, in 2019 there were 143 articles.

In 2020 there were 147 articles, and in 2021 there were 69. The data shows the trend of research developments on AR in education, the development continues to increase in 9 years but tends to decrease lately. Table 3 presents the development of AR research in education from 2012 to 2021.

Table 3. Development of AR in education research.

Year of Publication	Number of Publication
2012	21
2013	36
2014	46
2015	48
2016	56
2017	81
2018	109
2019	143
2020	147
2021	69
Total	**756**

The development of research on AR in education from 2012 to 2022 seems to be increasing. Figure 1 illustrates from 2012 to 2016 the trend of this research has gradually increased, from 2016 to 2020 the number of publications on AR in education has significantly increased drastically. However, in the last 1 year, from 2020 to 2021, it has decreased drastically.

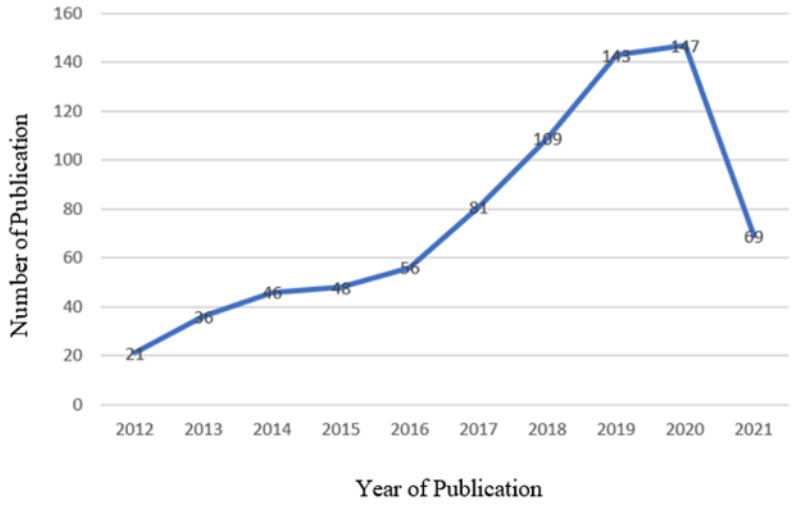

Fig. 1. Level of development in AR in education research.

3.3. Visualization of AR in education topic area using VOSviewer

Visualization of the mapping of related articles using the VOSviewer application. The results of the computational mapping found 245 items. For each item found related to AR in education, there are 7755 links and a total link strength of 20,969. 10 clusters describe the classification of the total items:

(i) Cluster 1 contains 38 items, cluster 1 is marked in red. The 38 items are area, augmented reality experience, augmented reality program, augmented reality technology, book, content, education, engineering education, environment, evaluation, experience, expert, feature, figure, future, image, interaction, mixed reality, mobile augmented reality, mobile device, order, overview, part, person, product, production, real world, reality, reality application, reality system, sense, term, type, user, virtual, virtual environment, virtual reality technology, and virtuality.

(ii) Cluster 2 contains 33 items, cluster 2 is marked in green. The 33 items are advance, anatomy, application, augmented reality simulation, augmented reality system, author, combination, dentistry, device, display, effort, enhancement, example, limitation, medical education, medical field, medicine, mobile technology, model, neurosurgery, patient, patient education, practice, reality technology, review, simulation, smartphone, spine surgery, surgery, surgical education, training, utilization, and virtual reality.

(iii) Cluster 3 contains 32 items, cluster 3 is marked in blue. The 32 items are activity, approach, augmented reality environment, augmented reality game, augmented reality sandbox, business, comparison, concept, context design education, framework, game, group, impact, importance, influence, issue, lab, language learning, learner, mobile learning, new technology, pilot study, problem, process, science education, strategy, student, student learning, topographic map, view, and virtual object.

(iv) Cluster 4 contains 31 items, cluster 4 is marked in yellow. The 31 items are android, assessment, augmented reality, augmented reality app, augmented reality book, augmented reality technique, augmented reality benefit, change, construction, early childhood education, educator, effectiveness, exploration, field, higher education, level, marker, mean, mobile application, mobile augmented reality, possibility, project, researcher, teaching tool, technique, thing, understanding, visualization, way, and world.

(v) Cluster 5 contains 28 items, cluster 5 is marked in purple. The 28 items are augmented reality medical, chemical education, chemistry, chemistry education, covid, development, element, implementation, insight, learning process, medium, ministry, mobile, motivation, online education, pandemic, physics, positive impact, quality, school, science, science learning, solar system, stem education, subject, teacher, and time.

(vi) Cluster 6 contains 26 items, and cluster 6 is marked with turquoise colon. The 26 items are ability, attention, attitude, augmented reality application, autism, autism spectrum disorder, child, disability, effect, geometry, individual, instruction, intellectual disability, investigation, journal, location, mathematics, meta-analysis, need, opportunity, postsecondary education, programs, special education, studies, tools, and videos.

(vii) Cluster 7 contains 20 items, cluster 7 is marked in orange. The 20 items are addition, adoption, advantage, augmented reality trend, challenge, classroom, computers & education, educational application, factor, information, interest, performance, perspective, potential, systematic literature review, systematic review, university student, usability, value, and works.

(viii) Cluster 8 contains 19 items, and cluster 8 is marked in brown. The 19 items are AR technology, case, computer, data, education system, efficacy, era, industry, integration, mobile augmented reality, role, system, teaching, technology, tourism, usage, virtual world, vocational education, and the web.

(ix) Cluster 9 contains 11 items, cluster 9 is marked in pink. The 11 items are case study, formal education, gamification, history, history education, knowledge, object, participant, perception, primary education, and state.
(x) Cluster 10 contains 7 items, and cluster 10 is marked with a beige colon. The 7 items are education field, engineering, entertainment, feasibility, survey, teaching material, and use.

10 clusters describe the relationship between AR and education, cluster 1 has 38 items, meaning that cluster 1 shows the most complex and complex linkages between AR and other studies, and the least correlation between AR and education is cluster 10, which has 7 items. The relationship between one term and another is shown in each existing cluster. Labels are assigned to each term with coloured circles. The size of the circle for each term varies depending on the frequency of occurrence of the term [47]. The size of the label circle shows a positive correlation with the occurrence of terms in the title and abstract [48]. The more often the term is found, the larger the label size [49]. AR in education is related to various fields of study and other research. From the results of the analysis using the VOSviewer application, there are 3 views of mapping visualization namely network visualization (see Fig. 2), density visualization (see Fig. 3), and overlay visualization (see Fig. 4).

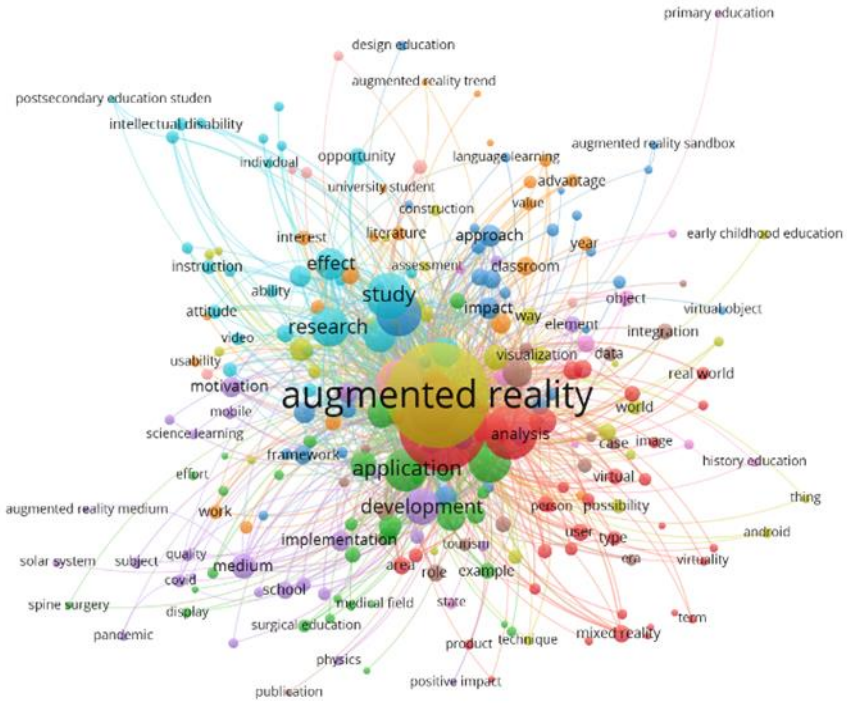

Fig. 2. Network visualization of AR in education keyword.

Figure 2 is a network visualization that shows the relationship between terms. The relationship between AR with education and other study topics. Various collars describe the identity of each cluster [49, 50]. There are various kinds of terms,

meaning that these terms are often used in research and related to AR in education. However, when one term does not have a connecting line to another term, it means that the topic has not been studied further by researchers.

Figure 3 is a density visualization that shows the relationship between terms. The relationship between AR with education and other study topics. Density visualization describes which research trends are most frequently studied and which are the least frequent if the colon is brighter. Then, the research topic is often studied, and vice versa if the colon is darker then the research topic is less researched [51, 52]. Figure 3 shows research with topics of AR, education, higher education, experience, teaching, learning, use, teacher, book, study, application, and development are often researched. On the other hand, such as primary education, design education, and post-secondary education students have been little researched. Therefore, the theme of AR and education allows it to be developed with other research topics.

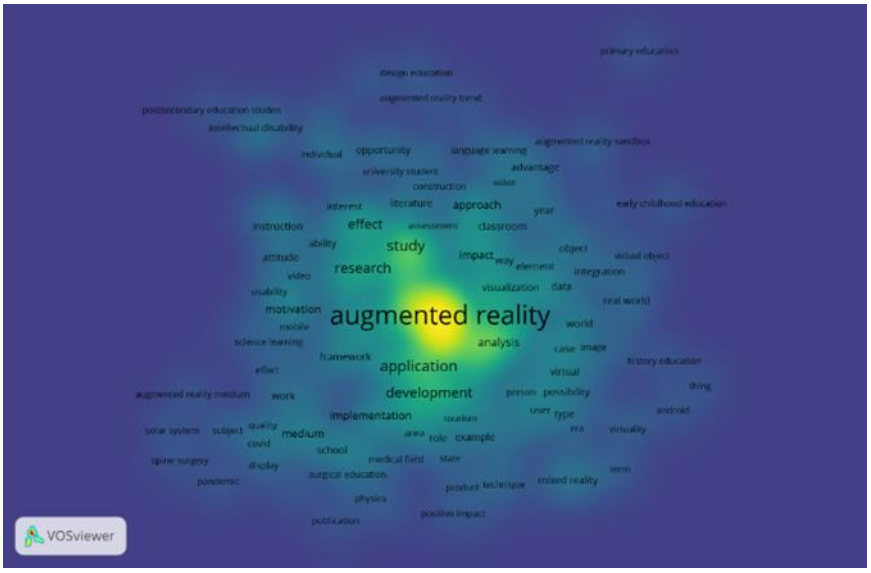

Fig. 3. Density visualization of AR in education keyword.

Figure 4 is an overlay visualization that shows the relationship between terms and the novelty of the research being studied [53]. The relationship between AR and education and other study topics, overlay visualization shows the development of study topics by year with colon indicators, dark blue colon shows study topics that have been published in 2012-2017, green colon shows study topics that have been published in 2018- 2019, and the yellow colon shows the research topics that have been published in 2019-2021.

From the clusters contained in the network visualization, the focus of research on AR in education can be classified into 2 aspects, namely the terms AR and education. AR is included in cluster 4 with a total link of 254, a total link strength of 4494, and occurrences of 772 (see Fig. 5). Furthermore, the term education is included in cluster 1 with a total link of 253, a total link strength of 3313, and occurrences of 552 (see Fig. 6).

From the data obtained, the AR term has 254 links and is related to 31 terms, and education has 253 links and is related to 38 terms. AR and education tend to be related; therefore, AR and education are still very likely to be investigated further for new research. Based on the results of the analysis of the data that has been collected, the topic of AR research in education is still rarely used in research.

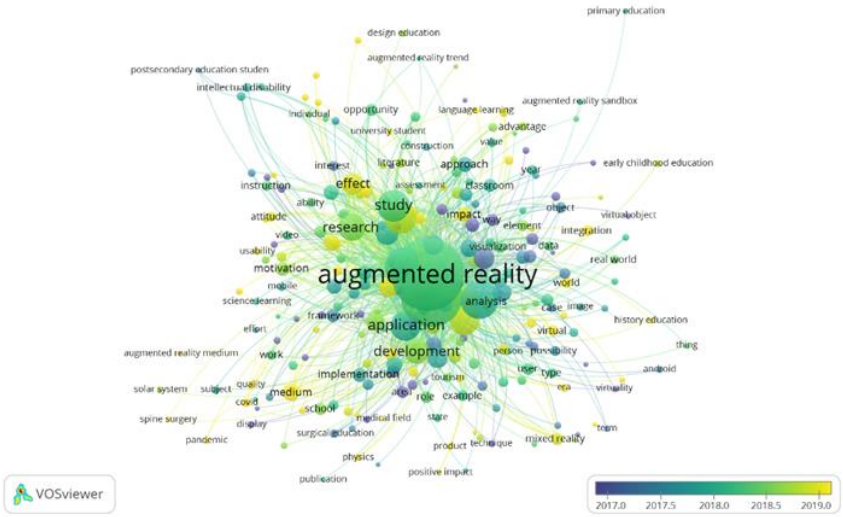

Fig. 4. Overlay visualization of AR in education keyword

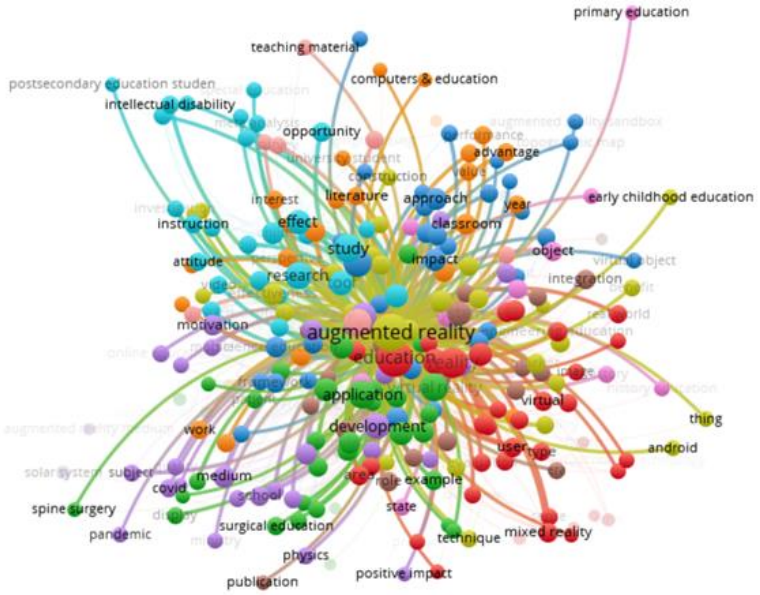

Fig. 5. Network visualization of AR term.

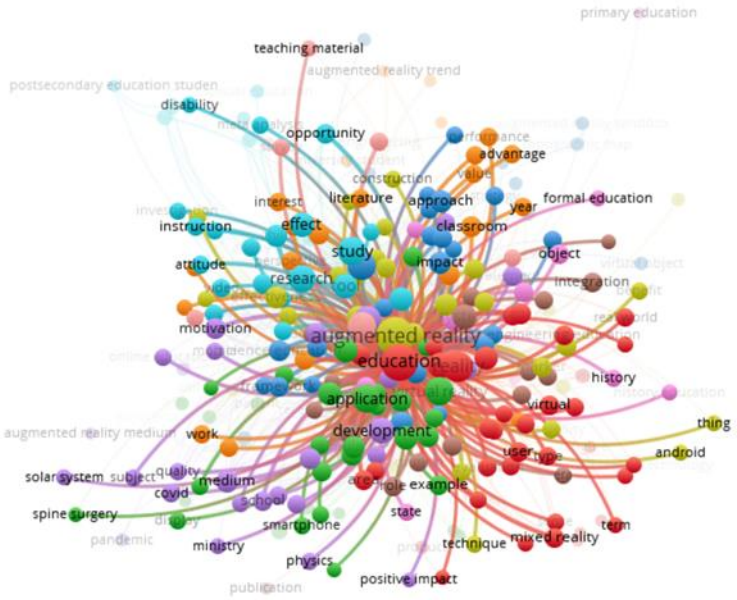

Fig. 6. Network visualization of education term.

4. Conclusion

This study aims to analyse the development of AR and education using bibliometric techniques. The publication theme studied is AR in Education. This article looks at developments from 2012 to 2021 by taking the Google Scholar database using Publish or Perish and analysing it using VOSviewer. From the search results as many as 756 articles. The results showed that research with the theme of AR in Education continued to increase from 2012 to 2020, but in 2021 this theme fell significantly. Thus, research with the theme of AR in Education has the opportunity to develop because many other topics still need to be studied and developed in research. AR in Education also has the opportunity to develop because it is a simple metaverse technology that students can use to increase learning motivation and satisfaction in 21st-century education.

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