

Bibliometric Analysis of Research Developments in the Field of Augmented Reality in Physics Education (2012-2021*)

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ABSTRACT

Augmented Reality (AR) is efficient in improving the quality of education, training and academics. There have been many studies discussing Augmented Reality, but not yet research on the development of Augmented Reality implementation using bibliometric analysis that maps (a) research developments, (b) core journals, (c) publishers by country and researcher productivity (d) top ten publishers by institution and subject (e) data and keyword maps (f) development maps by the author. This study indicates that the growth development in Augmented Reality in 2012-2021* with the highest Scopus index occurred in 2020, which reached 1381 publications. The Journal of Physics Conference Series published the most international publications in Augmented Reality with 388 publications. The Chinese Academy of Sciences has the most research publications in Augmented Reality, while the United States is the most significant contributor Zhang z is the most prolific writer in Augmented Reality in physics learning, and the subject of this research is Computer Science. The Augmented Reality field development map based on co-words is grouped into three clusters, and the co-author is grouped into 58 co-authors clusters. The research shows that augmented reality-based learning was developed to facilitate students in learning activities.

Keywords: *Bibliometric analysis, Research development, AR in physics education.*

1. INTRODUCTION

Starting from the declining birth rate and the increasing non-productive age population faced by the State of Japan, in 2019, Japan issued the idea of the era of society 5.0, which perfected the industrial era 4.0 [1]. This era was developed to anticipate the turmoil of disruption due to the industrial revolution 4.0, which caused uncertainty, ambiguity. It was feared to provoke an invasion that could eliminate human values. The digitalisation of artificial intelligence, big data, robotics and cyber has become part of society in the era of super-smart society [2], [3]. The era of society 5.0 is an idea of a human-centred and technology-based society that

directs how we (humans) use technology itself [4], [5]. Education is a conscious, planned effort to create an atmosphere and an active learning process in developing the potential of students to prepare human resources in realising their life goals that can compete globally [6], [7]. One of the factors that can affect the quality of education is the learning process that can adapt to the times [8]. In connection with the era of super-smart society, of course, human abilities are needed that can carry out activities that support the needs of that era, namely the ability to adapt, agility, mobility, and reactivity in facing the facts of change, mutation, and revolution every day [9]. From this description, it can be said that the learning model needed in the era of society

5.0 is in line with the skills of the 21st-century. 21st-century skills combine knowledge, skills, attitudes, and information and communication technology [10], [11]. 21st-century skills seek to promote students to think critically in solving problems, think creatively in forming an idea or idea, collaborate with others, adapt, take the initiative, analyse information, be imaginative, and

communicate [12]–[17]. 21st-century skills are developed into three categories, namely character quality, competence, and basic literacy. Each type of 21st-century skill has its purpose. Raymond de Villiers created three categories of 21st-century skills, as shown in Table 1 [18].

Table 1. 21st century skills

Foundational Literacies	Competencies	Character Qualities
How do students apply core skills to everyday tasks	How students approach complex challenges	How do students approach their changing environment
Literacy, numeracy, scientific literacy, ICT literacy, financial literacy, cultural and civic literacy	Critical thinking/problem-solving, creativity, communication and collaboration	Curiosity, initiative, persistence/grit, adaptability, leadership, social and cultural awareness

Rapid technological developments also affect the outcome of education in the world. For example, in the learning process in the classroom, the use of learning media is more concise, exciting and does not reduce the essence of the material [19]. One of the developments of teaching-learning media in this century is Augmented Reality, whose use is highly recommended to answer the challenges of the 21st-century [20], [21]. Augmented Reality is a learning media packaged in an application that combines the real and virtual worlds in two-dimensional or three-dimensional forms projected on a natural environment simultaneously [22]–[24]. [19] developed a working diagram of Augmented Reality, as shown in Figure 1.

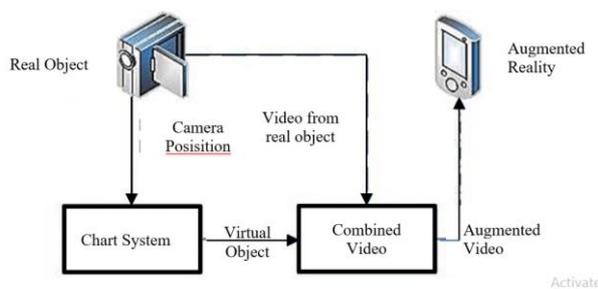


Figure 1. Augmented reality work diagram [19].

In the figure, it is explained that Augmented Reality has the working principle of tracking and reconstruction. Initially, the marker is detected using a camera. The data obtained is used to reconstruct the coordinate system in the real world and convert it into a virtual form. Physics is a science that studies natural phenomena and their interactions [25], [26]. Physics is fundamental which is the backbone for the development of science and technology [27]. The importance of mastering concepts in physics requires teachers to be able to abstract natural phenomena into learning materials. Thus, the use of augmented reality technology is indispensable in learning

physics. Augmented Reality-based learning is very suitable to be applied in physics learning, as evidenced by the existence of several relevant studies. Augmented Reality-based physics learning media development can improve students' critical thinking skills, science process skills, higher-order thinking skills (HOTS), etc. By applying Augmented Reality learning media in physics learning, it is known that it can make it easier for teachers to explain learning materials [28]. In addition, the use of Augmented Reality media can help teachers visualise the natural world in digital technology that increases the abstraction power of students in understanding learning materials. The use of Augmented Reality media in the classroom has higher learning outcomes than in other classes. Augmented Reality media can stimulate students in the thinking process to criticise problems [29]. With the benefits of Augmented Reality media that positively influence students' critical thinking skills in learning, many studies have discussed Augmented Reality-based education. Based on sources in Scopus and Google Scholar on August 5, 2021, it is known that there are 35,591 research documents on Scopus and 93,000 papers on Google Scholar. With many kinds of research on Augmented Reality in several sources, the authors find no bibliometric analysis of the implementation of augmented-based learning. With this background, the researchers took the initiative to conduct bibliometric analysis research on the development of Augmented Reality in Physics Learning from 2012-2021*. It aims to provide an overview to readers regarding the development of Augmented Reality-based in physics learning implementation that maps (a) research developments, (b) core journals, (c) publishers by country and researcher productivity (d) top ten publishers by institution and subject (e) data and keyword maps (f) development maps by the author.

2. METHODS

This study uses data from international publications in Augmented Reality sourced from the Scopus database (www.scopus.com). The data was collected in April 2021*. Initially, the authors found 5,448 document results using keywords in searching metadata: "ALL (Augmented AND Reality AND Physics AND Learning)", with the categories all fields. Then, the limitation process of the time-spent of publication (2012-2021*) resulted in 4,978 documents, with the following keywords: "ALL (augmented AND Reality AND in AND physics AND learning) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012))". Two kinds of metadata were saved into .csv and .ris for further data analysis. Microsoft Excel and VOSviewer were used in visualising raw data into tables, graphs, and maps.

3. RESULTS AND DISCUSSION

3.1 Research Developments in the Field of Augmented Reality

Table 2. Development of augmented reality in physics learning on 2012-2021

Year of Publication	Total	Percentage
2012	152	3.05%
2013	168	3.34%
2014	227	4.57%
2015	237	4.76%
2016	314	6.30%
2017	385	7.75%
2018	590	11.85%
2019	931	18.70%
2020	1381	27.74%
2021	593	11.91%
Total	4978	100%

The development of Augmented Reality in physics learning in 2012 - 2021 experienced a significant increase in 2020. The highest growth development of publications in Augmented Reality indexed by Scopus occurred in 2020, reaching 1381 publications (27.74%). More details about the growth of international journals in Augmented Reality show in Table 2.

3.2 The Core Journals on Augmented Reality Learning Model

There are 4978 publications based on the search results with the Scopus database's Augmented Reality in Physics Learning system. From this number, it is known that the most international publications in augmented

Reality are published in the Journal of Physics Conference Series (388 publications). Table 3 shows the top ten core journals that publish developments in Augmented Reality.

Table 3. The core journal of the augmented reality in physics learning model at Scopus database

The Core Journals	Total
Journal of Physics Conference Series	388
Lecture Notes in Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	146
AIP Conference Proceedings	91
Ion Conference Series Materials Science and Engineering	81
IEEE Access	70
Ceur Workshop Proceedings	68
ACM International Conference Proceeding Series	58
Sensors Switzerland	56
Applied Sciences Switzerland	50
Computers And Education	47

3.3 Researcher Productivity and Publisher Country

The top 10 researchers in the development of Augmented Reality media in 2012-2021 indexed by Scopus shows that the productivity is almost different, but the difference is not significant, ranging from 13-24 studies. Table 4 shows that Mulyati, D. and Navab, N. have the highest research in the field of Augmented Reality.

Table 4. Researcher productivity on augmented reality in physics learning

Author	Total
Mulyati, D	24
Navab, N	24
Ramadhani, M.A	23
Bakri, F	22
Lindgren	19
Tsai	17
Enyedy	15
Kuhn, J	15
Lee, C	14
Heldal, I	13

Based on Table 5, we can see that the countries that have developed Augmented Reality publications include Spain, Italy, Germany, Ireland, Canada, United States of America, United Kingdom, China, Russian Federation, and Indonesia. The most significant contributor to the Scopus indexed Augmented Reality research results is the United States, followed by China, Indonesia, England, and Germany. Contributors of research results in the field of Augmented Reality show in Table 5.

Table 5. Publisher country on augmented reality in physics learning publication

Country	Total
United States	341
China	290
Indonesia	284
United Kingdom	123
Germany	115
Spain	102
Italy	77
Malaysia	74
Canada	68
Russian Federation	59
France	59
India	53
Taiwan	50
Brazil	40
Japan	38
Hong Kong	25
Portugal	24
Ireland	18

Indonesia is the third-largest contributor in the world in the field of Augmented Reality research. Researchers and education practitioners should think about the benefits of learning media development in the form of Augmented Reality to be implemented in learning. Especially in the conditions of the COVID-19 pandemic in Indonesia, which requires distance learning like this.

3.4 Top Ten Institution Publisher and Subject of publication on Augmented Reality in Physics Learning

The results of data searches in Scopus show that the Chinese Academy of Sciences is the institution that publishes the most research on AR with a record publication of 61 journals then followed by the Technical University of Munich, Johns Hopkins University, and Johns Hopkins University.

Table 6. Publisher of publication on augmented reality in physics learning

Publisher	Total
Chinese Academy of Sciences	61
Technical University of Munich	48
Johns Hopkins University	44
Universitas Negeri Malang	44
Universitas Negeri Jakarta	43
Universitas Pendidikan Indonesia	41
CNRS Centre National de la Recherche Scientifique	40
Stanford University	40
Imperial College London	40
National University of Singapore	40

Table 6 shows the top ten institutions that publish research in AR. The following data is the number of publications of research results in Augmented Reality based on Scopus indexed subjects in 2012 - 2021 shows that Computer Science is the highest subject, followed by Engineering, Social Sciences and Social Sciences. Table 7 shows the issue of most publications in the field of Augmented Reality in 2012 - 2021.

Table 7. Augmented reality in physics learning publication subjects

Subject	Total
Computer Science	2,660
Engineering	1,801
Social Sciences	1,225
Physics and Astronomy	905
Medicine	616
Mathematics	588
Materials Science	406
Biochemistry, Genetics and Molecular Biology	304
Psychology	177
Chemistry	176

3.5 Data and Keywords Maps

Figure 2 shows that based on keywords (co-words), the map of the development of research publications in the field of Augmented Reality indexed by Scopus in 2012 - 2021 forms into 3 clusters, namely red, blue and green, as shown below. Based on the author's observations, it can be seen that the research in green groups is based on the topic of education. It is known that many research topics are based on research subjects, such as students, university, etc. While the red cluster is based on the development of science-based on AR, for example, on anatomy objects, physics objects, etc., and groups blue based on augmented reality implementation. The larger the point in the cluster, the more research that discusses the subject. Cluster 1 is blue, consisting of a cyber-physical system, digital twin, industry, keywords, IoT, the industrial revolution, management, government, web, systematic review, collection. Cluster 2 is red. It consists of future direction, artificial intelligence, review, prediction, advance, state, set, search, algorithm, property, physical object, localisation, patient, scene, procedure, pilot study, segmentation, image, calculation, user study, and projection. While in Cluster 3, it is green. It consists of the fields of educational process science, competency, per, university, stem, education, attitude, game, topic, skill, student, research design, effectiveness, Indonesia, critical thinking skill, stage, book, week, test, medium, high school, validation, fun, feasibility, average, average value, learning medium and media expert.

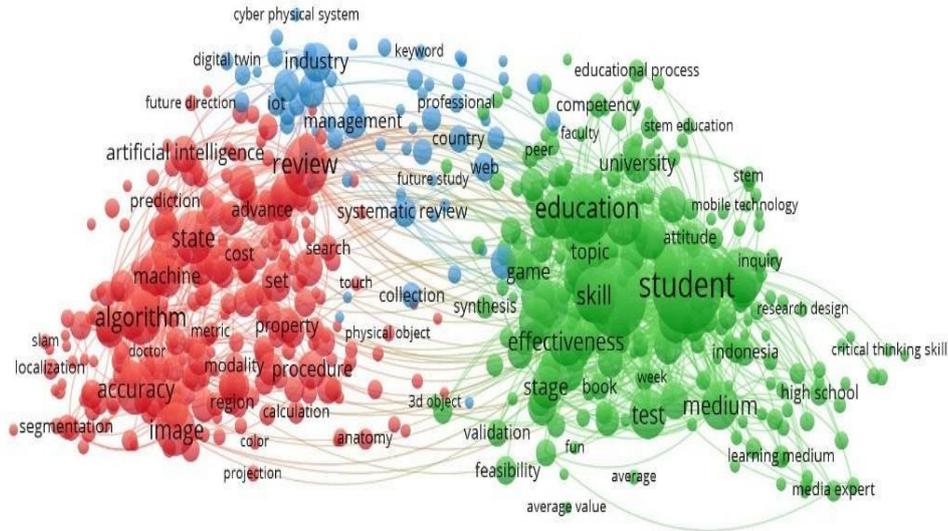
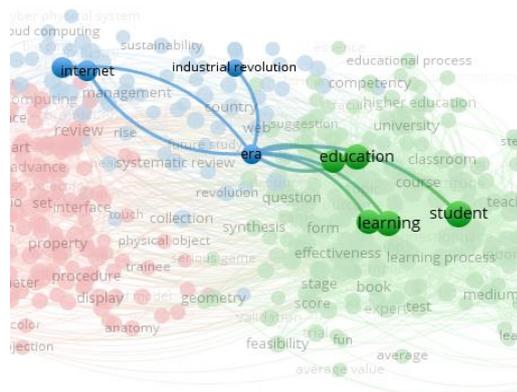
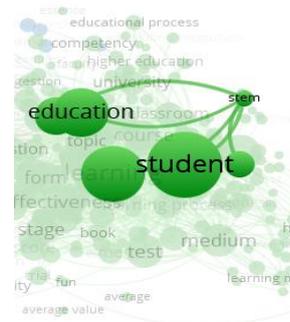


Figure 2 Visualization augmented reality in physics learning field publication co-word map in circles.

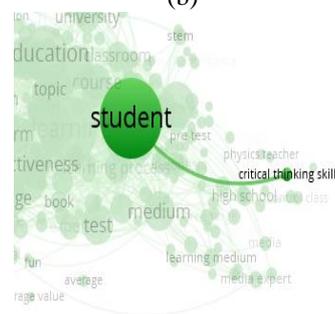
Based on the cluster in blue in Figure 3, it is known that there is an era subject that shows a relationship with the internet subject, industrial revolution, education, learning, and student. The visualisation illustrates that Augmented Reality is closely related to education and the times. The existence of augmented reality technology is used to facilitate students in learning activities. In addition, Augmented Reality is also associated with STEM-based learning. STEM is a learning approach that combines science, technology, engineering, and mathematics to train 21st-century skills in students. Augmented Reality-based learning development is also known to teach students critical thinking skills. In this era, essential thinking skills are needed to train students in how to approach complex challenges.



(a)



(b)



(c)

Figure 3 Visualization subject (a) era, (b) STEM and (c) critical thinking skill in circle.

3.6 Research Development Map by Authors

Figure 4 shows that based on the co-authors, based on the data on the VosViewer visualisation, 58 co-authors meet the criteria. These criteria include publishing a minimum number of documents of an author as many as three documents. Co-authors Zhang z is the most active co-author with 19 publication documents and 48 link strengths. Based on Figure 8, it is known that the yellow color indicator, the more research documents published by co-authors and the blue indicator shows less research is being done.

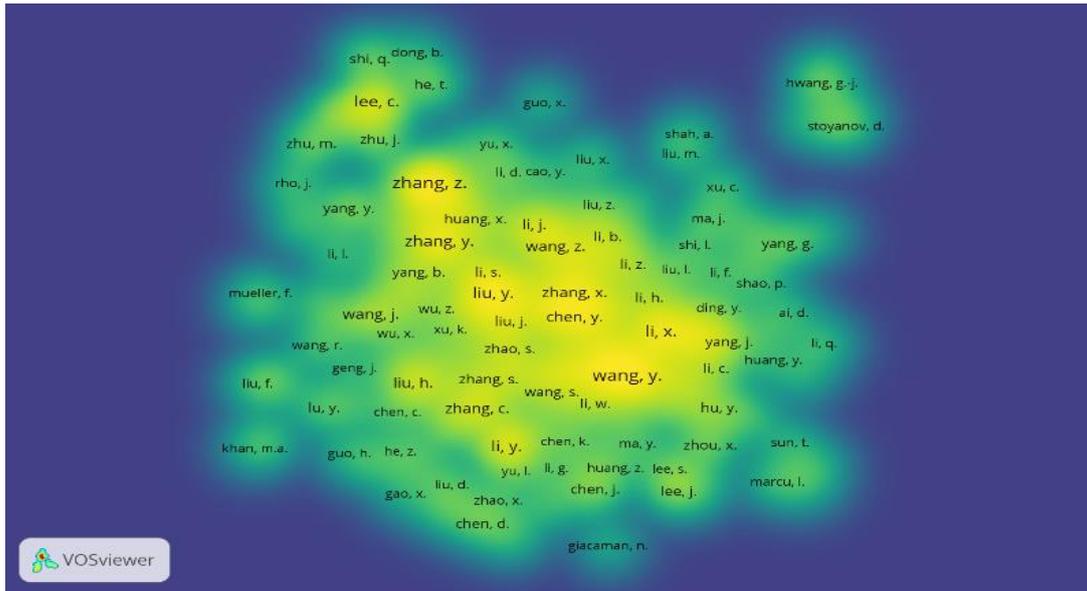


Figure 4 Visualization map of co-authors of augmented reality in physics learning field publications in circles appearance.

4. CONCLUSION

This study reviews all articles related to Augmented Reality in physics learning keywords. After searching for journals and conference proceedings on the Scopus database for 2012-2021, the keyword Augmented Reality obtained 1,156 articles. All data were analysed using the VOSviewer application. The development of growth in Augmented Reality in 2012-2021 with the highest Scopus index occurred in 2020, which reached 1381 publications (31.1%); this value tends to increase in recent years. The Journal of Physics Conference Series publishes the most international publications in Augmented Reality with 388 publications. The Chinese Academy of Sciences has the most research publications in Augmented Reality, while the United States is the most significant contributor. Co-authors Zhang z are the most prolific writers in Augmented Reality in physics learning, with the most subject being Computer Science. The Augmented Reality field development map based on co-words is grouped into three clusters, and the co-author is grouped into 58 co-authors clusters. In the development of research, it is known that augmented reality-based learning was developed to facilitate students in learning activities.

AUTHORS' CONTRIBUTIONS

Irda, Abib, Naba: conceptualization, method, data visualization, and drafting manuscript. Niswati: Review and editing of manuscript; Binar: data curation, Nur Shabrina & Husni: Review and suggestion.

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