# Research Trend of Augmented Reality in Chemistry Learning: Bibliometric Analysis

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**Abstract** Augmented Reality (AR) is a medium that can be used to help visualize abstract concepts so they are easy to understand. The purpose of this research is to find out research trends related to AR in Chemistry Learning. The method used is Systhematic Literatute Review. The data collection technique used was to conduct research studies for the last 5 years (2019-2023) according to the keywords. The inclusion and exclusion criteria for article search include AR, AR effectiveness, chemistry, chemistry education, chemistry learning, AR App, etc. The research data obtained were analyzed using a bibliometric approach with the help of the VOSviewer program. The results showed that the number of article documents for the keyword Augmented Reality in Chemistry Education obtained based on Google Scholar sources was 993 documents in 6 clusters with 70 keyword items. This shows that many research trends related to Augmented Reality in Chemistry Education have been carried out as learning media and measure its effectiveness in learning and training.

**Keywords:** Augmented Reality, Chemistry Learning, Bibliometric Analysis, Education Technology

## 1 Introduction

The development of information and communication technology influences globalization in almost all aspects of human life, including the world of education and especially the educational process. Consequently, there has been a paradigm shift in education, particularly in the concept of how people learn and how this subject matter is delivered. Responding to the consequences of globalization, the role of the teacher who is seen as the only source of learning, or the person who knows best in schools, must be changed to a source of learning. In addition, the teacher must be able to determine the media needed and which can be used directly by teachers and students both at school and outside of school without being limited by time [1].

Utilization of media, especially realia media around the student learning environment is able to create an effective and efficient learning atmosphere and is able to improve students' thinking and logic [2]. However, realia media also has limitations, such as being difficult to obtain, abstract in nature, or if it is brought into the class-


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room it can threaten student safety. therefore, in the future, the technology that will be developed to overcome these limitations will be increasingly complex. One of them is the development of augmented reality (AR) technology.

Augmented reality (AR) can be defined as a technology capable of integrating two or three-dimensional virtual objects into a real-world environment and then displaying or projecting them in real time. [6]. Augmented reality engages all the senses, including hearing, touch and smell [9]. In addition, it is used in fields such as health, military, manufacturing and education. This AR technology can bring certain information into the virtual world and display it in the real world using devices such as web cameras, computers, Android phones or special glasses.

Augmented reality (AR) can be used to visualize abstract concepts to understand and model the structure of an object. This can help in facilitating studying and studying chemistry. Where material science has the characteristic of containing concepts that are mostly abstract in nature [13]. One example of research related to Augmented reality (AR) is the development of mobile Augmented Reality (AR) as a learning medium on the theme of animal cells [11], or as an interactive learning media in chemical bonding learning [14]. Some AR applications are also designed to provide users with more detailed information than real objects. The potential of Augmented Reality (AR) is growing rapidly nowadays, especially since we are approaching the Metaverse era, where the virtual world is projected directly onto the real world.

Reality (AR) technology has become an important research area in education. This study examines AR to provide an understanding of research activities from a multidisciplinary perspective, trends, and predictions of future directions of the field using Bibliometric Analysis. Current educational developments, and predicting future development trends can help better guide educational practice and research. Therefore, it is very important to conduct research that describes the development and application of Augmented Reality (AR) in chemistry education.

The term 'Augment' according to the Oxford Dictionary is defined as making something bigger. It means enlarging, expanding, or adding to the characteristics of a physical component. Some experts define Augmented Reality (AR) in several definitions, among others [3] defines Augmented Reality (AR) as a technology that overlays computer-generated information onto the real world. Our environment is 'augmented' so that users can perform existing tasks with minimal effort. Augmented Reality (AR) technology is a technology that is able to combine real (real) and virtual (virtual) situations and is displayed in real time (real-time) [6]. This is in accordance with the opinion of [4] is a direct or indirect real-time view of the real-world physical environment that has been added with virtual information into it.

The method developed in Augmented Reality (AR) is currently divided into two methods, namely Marker based tracking and Markless augmented reality (AR) [10]. Marker Augmented Reality (Marker Based Tracking) is a black and white square image with a thick black border and a white background. The computer recognizes the position and orientation of the marker and creates a virtual 3D world, namely the point (0,0,0) and the three axes, namely X, Y and Z. The basic working principle of a marker-based system requires three main components: (1) a printed marker or visual

information, (2) handles for calling up digital content (e.g. cameras), and (3) additional digital content displayed on the screen.

Whereas in the Markerless Augmented Reality method, users no longer need to use markers to view digital assets. Qualcomm's mobile-based augmented reality development tools make it easy for developers to create common applications [17]. Markerless Augmented Reality (AR) uses the SLAM algorithm to localize users or objects in an unknown environment through simultaneous mapping.

The main components of AR [12] including as (1) real and virtual merging, (2) real-time interactivity, and (3) alignment of both real and virtual objects with each other. Systematic literature review by [18] especially categorizing the benefits of learning Augmented Reality (AR) in six ways. The first is that psychological outcomes are conceptualized as mental states to explain motivational benefits, interest, attention, and satisfaction. Second, they found that digital content representations allow access to detailed information in real time as they interact with each other. The second benefit leads to the third benefit, namely understanding content using spatial skills in Augmented Reality (AR) experiences; Thanks to improvements in the human brain's binary coding system, it has become easier to remember content. The fourth category of excellence relates to a faster learning curve and motivation for different learning styles. Student creativity is also greatly encouraged through Augmented Reality (AR) techniques. Fifth, through active participation and collaboration facilitated by the use of AR, it provides a student-centered education concept. Finally, Augmented Reality (AR) technology has the potential to reduce education costs.

## 2 Method

The research method used is systhematic literatire review. Systematic Literature Review or what is called SLR is a systematic literature review aimed at identifying, evaluating, and interpreting the findings of primary studies [19]. This research was conducted on June 5-11, 2023. The data collection technique was carried out by conducting research studies according to the keywords in the research titles for the last 5 years (2019-2023) based on the Google Schooler database. The data obtained were analyzed using a bibliometric analysis approach, namely an approach that can determine technology patterns or research orientation using keywords, title keywords, and plus keywords [15][16]. The inclusion and exclusion criteria for article search include AR, AR effectiveness, chemistry, chemistry education, chemistry learning, AR App, etc. Bibliometric analysis was carried out using the VOSviewer program. Based on the author's search, 993 documents were found that matched the keywords.

## 3 Result And Discussion

This section presents findings and discussion of findings to reflect developments and research trends in Augmented Reality (AR) in chemistry education.

**Table 1.** Citations Metrics

| | |
|---|---|
| Publication years: | 2019-2023 |
| Citation years: | 4 (2019-2023) |
| Papers: | 993 |
| Citations: | 16083 |
| Cites/year: | 4020.75 |
| Cites/paper: | 16.20 |
| Authors/paper: | 3.02 |
| h-index: | 60 |
| g-index: | 94 |
| hI,norm: | 34 |
| hI,annual: | 8.50 |
| hA-index: | 29 |
| Papers with ACC >= 1,2,5,10,20: | 733,566,346,183,68 |

The data in Table 1 can be seen that based on search results on the Google Scholar database, it shows that the development of Augmented Reality (AR) research in chemistry education over a period of 5 years (2019-2023) totaled 993 articles that match the related research title keywords. Based on the number of citations for the last 5 years, there were 16,083 with an average annual citation of 4,020.75. Citation is a reference or quote that allows us to acknowledge the sources that have been cited. Citations are useful for verifying the data obtained so that our writing can be accounted for and has accountability. This shows that research related to Augmented Reality (AR) in chemistry education is still a trend and has been widely studied.

Based on the results of the analysis using VOSViewer, which is a software used to visualize bibliometric maps or data sets that contain bibliographical fields such as title, author, author, journal, etc., the number of clusters and keywords can be identified [7]. The results of the analysis of the Augmented Reality (AR) research area in chemistry education show that there are 6 clusters with 70 keywords, this can be seen in the table. 2 below.

**Table 2.** Clusters and Frequently Appearing Keywords

| Clusters | Number of Items | Keywords |
|---|---|---|
| 1 | 17 | Advantage, analysis, benefit, case study, challenge, chemistry course, computer, educational setting, evaluation, industry, interest, opportunity, performance, reality application, STEM education, support, systematic review. |
| 2 | 17 | Abstract, addition, augmented reality app, chemistry education, chemistry teaching, covid form, geography, journal, mobile augmented reality, order, organic chemistry, quality, role, simulation, time, work |
| 3 | 11 | Achievement, ar application, attitude, biology, course, effect, impact, mathematic, motivation, physics, subject |
| 4 | 9 | Android, AR technology, chemistry learning, chemistry teaching, medium, part, problem, user, world |
| 5 | 8 | Education process, education resources, element, implementation, perception, possibility, teacher, training. |
| 6 | 8 | Article, literature, metaanalysis, mixed reality, physical model, proceeding, trend, virtual. |

Based on Table 2 it can be seen that the number of clusters that appear is 6 clusters with a total of 70 keyword items. Cluster 1 (17 items), cluster 2 (17 items), cluster 3 (11 items), cluster 4 (9 items), cluster 5 (8 items), and cluster 6 (6 items). Based on the keywords that match the related research titles, it is known that the number of Augmented Reality (AR) keywords appears 3 times and the keywords Chemistry education or chemistry learning 5 times. This shows that there is still an opportunity to examine the Augmented Reality (AR) research theme in chemistry education.

A map of the development of publications and the relationship between terms based on search keywords on Google Scholar is illustrated in Figure 1. In the visualization of inter-network linkages, the relationship between terms is represented by networks or lines that connect one term to another [5]. Several research results examine how the Effectiveness of AR, Functions of AR, and Characteristics of AR in chemistry learning.

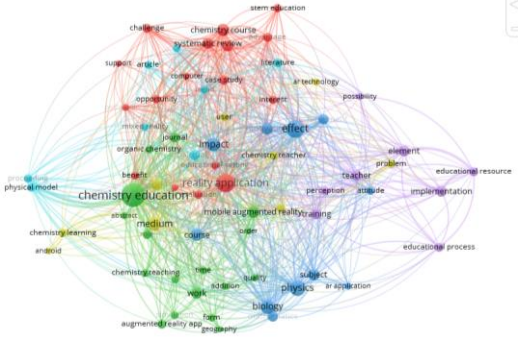


**Fig. 1.** Visualization Network

## 4 Conclusion

The results showed that the number of article documents for the keywords Augmented Reality in Chemistry Education obtained based on Google Scholar sources from 2019-2023 was 993 documents in 6 clusters with 70 keyword items. This shows that many research trends related to Augmented Reality in Chemistry Education have been carried out as learning media and measure its effectiveness in learning and training.

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