Trends of Augmented Reality in Science Learning: A Review of the Literature

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Abstract. This study provides a literature review on the trend of using Augmented Reality (AR) in science learning. A relative literature review was carried out by collecting 30 journals from the Science Direct and Google Scholar databases in the period 2012 to 2021. This paper examines the research that has been done on the use of AR in science learning and classifies it into 11 topics, namely about inquiry skills, critical thinking, conceptual knowledge, misconception, conceptual understanding, knowledge construction, learning outcomes, attention, attitude, achievement, motivation, collaborative and autonomous learning. A review of the research results shows that the overall use of AR technology in recent years has increased, especially on the topic of attitude and achievement which has a positive impact on science learning. While on the topic of misconceptions, inquiry skills, attention, collaborative and autonomous learning has not been widely studied by researchers. In addition, the use of AR in science learning has challenged such as students, teachers, and technical. This is interesting for further research.

1. Introduction
Science is a science that contains systematic, rational, and objective theories about the universe. Science can be claimed as scientific knowledge, namely science that has been tested for truth through systematics or scientific methods [1]. Science contains abstract concepts so that it requires the use of learning media to visualize abstract concepts. The integration of technology in developing appropriate learning media can make it easier for students to understand abstract concepts in their entirety. One of the uses of technology in education is the use of Augmented Reality technology in learning science.

Augmented reality is a technology that visually augments the real world environment by projecting computer-generated information into the eye [2]. Augmented Reality is a rapidly growing field of research that aims to fully integrate the virtual with the real environment [3]. This AR can be interpreted that real objects in real time are added to virtual objects that appear when using a tool or device on the real object. So that there is a relationship between the virtual world and the real world with the help of the camera. The resulting content can be in the form of three-dimensional (3D) models, videos, images, sound and text [4].

Research on augmented reality has been widely carried out, based on published journals reporting the advantages, limitations, effectiveness challenges, etc. of the use of augmented reality in education. However, since augmented reality is an emerging technology, it is important to get an idea of the progress and real impact of its use in education especially on science learning.
Previous studies on augmented reality in science learning can be used to guide future studies. Therefore, a systematic review is very important to present the current situation and to shed light on future studies. Reviewing previous studies helps researchers to make decisions about issues such as topics, methods and sampling. It is possible to find many systematic reviews in the literature on the use of technology in education [5, 6]. However, there have only been a few systematic reviews examining augmented reality studies. This augmented reality study, therefore, aims to bridge the existing gap in the literature by analyzing all educational studies found in various databases (ScienceDirect and Google Scholar). From the identification results,
1) What journals are used in this literature study?
2) How will augmented reality research trends in science learning be from 2012 to 2021?
What are the challenges of implementing augmented reality in science learning?

2. Method
This study analyzed and synthesized articles about the use of Augmented Reality media in science learning from 2012 to May 2021. Articles were collected using Publish or Perish software using the keyword “Augmented Reality Science Education” in the Science Direct and Google Scholar databases. There are several criteria used to select the articles to be analyzed which are shown in table 1.

| Criteria          | Inclusion                  | Exclusion                                      |
|-------------------|----------------------------|------------------------------------------------|
| Article type      | Indexed journal            | Journal not indexed                           |
| Types of research | Empirical research         | Meta analysis, literature review              |
| Research field    | Science Learning           | Non-science learning                          |
| language          | English                    | Non-English                                   |
| Timeline          | 2012- May 2021             | Less than 2012                                |

3. Result and Discussion
3.1 Number of Journal Publications
Among the 30 studies augmented reality were analyzed from 15 journal and 3 conference, consisting of dairy journal Interactive Learning Environments (2), Advances in Human-Computer Interaction (1), British Journal of Educational Technology (2), Computers & Education (4), Computers in Human Behavior (6), Computer Applications in Engineering Education (1), Contemporary Educational Technology (1), Education and Information Technologies, European Journal of Physics, International Journal of Computer Supported Collaborative Learning (1), Journal of Computer Assisted Learning (1), Journal of Research in Education and Teaching (1), Journal of Science Education and Technology (1), Science Educational International (1), Human Interaction Conference (1), International Conference on Advanced Learning Technologies (1), International Symposium on Mixed and Augmented Reality Adjunct (1). The distribution of articles from 2012- Mei 2021 is shown in table 2.

| Publication Type | Journals and Conference Selected                  | Number of Articles Selected | % of Articles Selected |
|------------------|--------------------------------------------------|----------------------------|------------------------|
| Conference       | Human Interaction Conference                     | 1                          | 3,3%                   |
| Conference       | International Conference on Advanced Learning Technologies | 1 | 3,3% |
| Conference       | International Symposium on Mixed and Augmented Reality Adjunct | 1 | 3,3% |
| Journal          | Interactive Learning Environments                | 2                          | 6,6%                   |
| Journal          | Advances in Human-Computer Interaction           | 1                          | 3,3%                   |
| Journal          | British Journal of Educational Technology       | 2                          | 6,6%                   |
3.2 Augmented Reality trends in Science Learning

The use of AR in the educational environment is a research topic that has recently become popular. In this study, 30 articles were used regarding research on the use of augmented reality in science learning which were grouped into 11 topics, namely about inquiry skills, critical thinking, conceptual knowledge, misconceptions, conceptual understanding, construction knowledge, learning outcomes, attention, attitude, achievement, motivation, collaborative and autonomous learning. In addition, the use of augmented reality is mostly applied in universities. This is because the student's learning independence factor is quite good compared to students at middle and elementary school levels.

Table 3. The Study on the use AR in Science Learning

| Study | Subject | School Level | Topic |
|-------|---------|--------------|-------|
| [7]   | Physics (Electromagnetic) | University | Critical Thinking |
| [8]   | Biology (Anatomy) | Secondary School | Attitude, Achievement |
| [9]   | Chemistry (Molecular Geometry) | University | Motivation |
| [10]  | Physics (Electric circuit) | University | Conceptual Understanding |
| [11]  | Chemistry (Chemical Elements) | Junior high school | Conceptual knowledge |
| [12]  | Physics (Heat Transfer) | University | Knowledge Construction |
| [13]  | Physics (Electric circuit) | Middle school | Attitude |
| [14]  | Biology (Cell) | University | Motivation, Achievement |
| [15]  | Physics (Force and energy) | Junior high school | Achievement, Attitude |
| [16]  | Physics (Electric circuit) | Junior high school | Conceptual knowledge, Inquiry Skill |
| [17]  | Biology (Anatomy) | University | Motivation |
| [18]  | Natural Science | Elementary School | Achievement, Motivation, Critical Thinking |
| [19]  | Physics (Heat Transfer) | Senior High School | Conceptual Understanding |
| [20]  | Physics (Solar system) | Junior high school | Achievement, Misconception |
| [21]  | Physics (Heat Transfer) | University | Conceptual Understanding |
| [22]  | Physics (Magnetic Field) | University | Motivation, Learning Outcomes |
| [23]  | Physics (Electricity) | University | Attitude |
| Study | Subject                             | School level     | Topic                                |
|-------|-------------------------------------|------------------|--------------------------------------|
| [24]  | Physics (Magnetic Field)            | University       | Attitude, Learning Outcomes          |
| [25]  | Biology (Ecology)                   | Elementary School| Achievement, Attitude                |
| [26]  | Biology                             | Secondary School | Motivation                           |
| [27]  | Physics (Electrical Machines)       | University       | Collaborative, Autonomous Learning   |
| [28]  | Chemistry (Atoms)                   | Junior high school| Attitude                             |
| [29]  | Natural Science                     | Elementary School| Achievement, Motivation              |
| [30]  | Physics (Electromagnetics)          | High school      | Attitude                             |
| [31]  | Physics (Elastic collision)         | University       | Learning outcomes                    |
| [32]  | Astronomical                        | Elementary School| Conceptual knowledge                 |
| [33]  | Physics (Lens)                      | High school      | Attitude, motivation, attention      |
| [34]  | Physics (Space)                     | University       | Knowledge Construction               |
| [35]  | Physics (Electromagnetics)          | High school      | Achievement, motivation              |
| [36]  | Physics (Newtonian force and motion)| Primary school   | Learning outcomes                    |

**Figure 1.** Trends of Research Subject in Science Learning

![Diagram showing trends of research subjects](image)

**Figure 2.** Trend of Research Articles on the use of AR for Several Variables in Science Learning from 2012 – 2021

![Diagram showing trends of research variables](image)
Based on Figure 1 and 2, it can be concluded that the research trend of using AR in science learning from 2012-2019 is on the subject of electricity and electromagnetic. Whereas for the topic of attitude and achievement which can have a positive impact on science learning. While on the topic of inquiry skills, misconceptions, and attention have not been studied by many researchers. This is interesting for further research.

3.3 Challenges of Using Augmented Reality in Science Learning

Based on the results of the analysis that has been done, there are several studies that do not write about the difficulties in using augmented reality in science learning and only focus on the benefits of its implementation. However, there are also some limitations to using AR for educational purposes. The technical problems experienced when using AR is the main and most important limitation [39]. The use of location-based AR is generally limited by the technical problems experienced with GPS [38]. The use of marker-based AR is limited by the technical problems experienced with perceiving the markers [31]. Other limitations include the lack of adequate information from teachers to develop AR materials [37]. In addition, there are challenges faced by students regarding students who are not accustomed to using augmented reality media in learning [32, 34]. Based on the results of the analysis that has been made the use of augmented reality in science learning is grouped into three categories, namely student difficulties, teacher difficulties, and technical difficulties as shown in table 4.

| Table 4. Challenges of Application of Augmented Reality in Science Learning |
|-----------------------------|-------------------------------|-------------------------------|
| Challenge | Challenge | Article Example |
| Student | Unaccustomed to using and difficulty in using it | [32, 34, 37] |
| Teacher | Lack of information in developing AR | [37] |
| Technical | GPS and markers | [37-39] |

4. Conclusion

This study examines 30 articles on augmented reality on science learning indexed in the ScienceDirect and Google Scholar databases using content analysis methods. Data analysis set out to establish trends in augmented reality studies of science learning. The number of educational AR studies has increased over the years. The importance of using Augmented reality for educational purposes and the increasing number of AR studies will continue in the years to come. It can be said that the results of this systematic review are important to guide future studies.

The results show that the research trend of using AR in science learning from 2012-2019 is on the topic of attitude and achievement that can have a positive impact on science learning. Apart from the advantages of using augmented reality in science learning, there are challenges for students, teachers, and technical challenges.

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