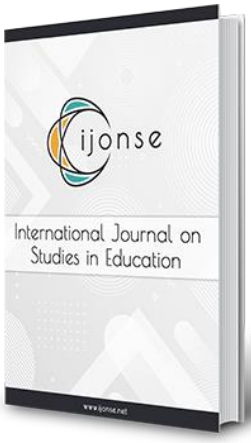

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Implementation of Augmented Reality Media in Physics Learning to Develop Students' Cognitive Abilities: A Systematic Literature Review

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Implementation of Augmented Reality Media in Physics Learning to Develop Students' Cognitive Abilities: A Systematic Literature Review

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Abstract

Augmented reality as a learning media has the ability to explain physics concepts contextually and concretely to students in three dimensions, so this study aims to identify the trend that influence the use of augmented reality Media in physics learning on the cognitive abilities of students. This research is composed of the results of a synthesis of the findings of previous research articles that are relevant in the 2017-2022 period. This study adapted systematic literature review method with Publish or Perish software, then filtered and extracted data according to the criteria for the research objectives to produce 47 relevant articles and compiled using PRISMA Protocol. From the results of several research syntheses, it was found that the use of augmented reality in physics learning can improve students' cognitive abilities which include self-efficacy, conceptual understanding, critical thinking, high order thinking, visual representation, abstract thinking, scientific literacy, creative thinking, computational thinking, reasoning and problem solving. In addition, the use of augmented reality media provides optimal learning outcomes for students and has a positive influence on affective abilities. Future research is expected to be able to present in depth the influence of augmented reality media in physics learning to develop students' affective abilities and attitudes.

Introduction

The development of today's world has entered an era of change called the era of the industrial revolution 4.0. This era is an implementation of the latest German technology modeling which is marked by technological developments and the emergence of robots, artificial intelligence, internet of things (IoT), big data, virtualization, cloud computing, and simulations that provide easy interaction between users (humans) and computers (Fauzan & Paulus, 2018; Ngalimun, 2023). This development provides easy access for users in searching for information and communication. As a result, the impact of globalization cannot be avoided so that technology becomes a basic need for today's society. This impact has an influence on all fields, one of which is in education (Liu & Zang, 2023). Education in the era of the industrial revolution 4.0 provides stimulation to the world of education in facing learning challenges through interactions between humans and technology to create opportunities creatively and innovatively (Lase, 2020; Ngalimun, 2023). With this progress, several learning technologies have emerged to facilitate the learning process. One of the technologies that is the impact of future educational developments is

augmented reality.

Augmented reality technology during the era of the industrial revolution 4.0 became an innovation that opened people's eyes. Augmented reality is a technology that combines the real world and the projection of virtual objects superimposed on real images (markers) into three dimensions on a device's camera in real time. (Aggarwal & Singhal, 2019; Oranç & Küntay, 2019). Augmented reality is a technology that can overlay computer-generated virtual visualization results either directly or indirectly on a real and real-time environment. (Baker, Abu Bakar, & Zulkifli, 2020; Chen, 2019). Augmented reality can be utilized in various fields such as: construction, economy, health, and education,

In the field of education, augmented reality is able to clarify pictures from 2-dimensional textbooks into 3-dimensional objects with variations of animation, audio and video that can blend into the environment through a computer or smartphone device so that the subject matter is clearer for students. studied and all the five senses of students interact optimally (Dargan, Bansal, Kumar, Mittal, & Kumar, 2023; Köse & Güner-Yildiz, 2021). Through a combination of real and virtual objects, AR enables the visualization of abstract concepts and complex spatial relationships or experiencing phenomena in ways that cannot be experienced in the real world, thereby strengthening students' interest in learning. (Liono, Amanda, Pratiwi, & Gunawan, 2021). So it can be concluded, augmented reality is a visualization technology to collaborate the real and virtual worlds to form 3-dimensional visualization of objects through marker scanning in real places and times. Augmented reality in the field of education is often used as a medium for learning students to interpret visualization of cases in 3 dimensions, one of which is its application in learning physics.

Physics basically studies natural phenomena or phenomena. The relationship of natural phenomena observed in the concept of physics is the result of an experiment through the scientific method in proving it in reality. Physics learning is inseparable from facts, principles, laws, postulates, and scientific methods, so experimental activities are often carried out. Physics learning basically discovers the truth of facts, laws and concepts that exist in the natural surroundings using the scientific method (Galili, 2021; Park, Yang, & Song, 2019; Raissi, Perdikaris, & Karniadakis, 2019). Based on this, learning physics must be emphasized with the experiences and daily lives of students so that they provide direct experience and students can easily understand natural phenomena scientifically. (Yanto & Andriani, 2018). In addition, contextual physics learning requires teachers to always innovate in designing learning media so that it is easy to convey physics concepts to students. Thus, learning physics using augmented reality can help students to convey physics concepts in three dimensions.

The application of augmented reality makes it easy for students to visualize physics concepts so that they can see in real terms and in 3 dimensions. In addition, augmented reality can improve students' cognitive, affective and psychomotor skills. Projection of virtual objects and real environments using AR enables students to visualize complex spatial relationships, apply practically, and conceptually and inquiry-based understanding of abstract physics (İbili, Çat, Resnyansky, Şahin, & Billinghurst, 2020; Kaur et al., 2018; Lin et al., 2023; Wen et al., 2023). augmented reality-based learning influences students to learn more deeply to increase students' attention and motivation by providing different perspectives on systems or objects that are difficult to learn (Arici, Yilmaz, &

Yilmaz, 2021; Boboc, Chiriac, & Antonya, 2021). AR enables natural sensory interaction with virtual content through actions that mirror real-world interactions such as gestures, body language, sound, glances, touch, and so on. AR can provide dynamic images of 3D shapes and intuitive and natural interactions with users to interact with 3D shapes through hand movements thereby developing their awareness of interacting with shapes and making knowledge memorable or permanent. (Le & Kim, 2017). Thus, the use of augmented reality in learning supports students to improve cognitive abilities (concept understanding, investigation, spatial visualization), affective (motivation, attitudes, interests), and psychomotor (sensory movement, sound and three-dimensional touch) of students. so that competency achievement and potential cultivation are achieved. However, this research focuses on reviewing the cognitive abilities of students in using augmented reality.

Cognitive abilities can be defined as very general mental abilities which, among other things, involve the ability to reason, plan, solve problems, think abstractly, understand complex ideas, learn quickly and learn from experience (Gottfredson, 1997; Gustafsson, 1984; Sternberg & Grigorenko, 2002). Cognitive function is essential for distraction during complex tasks (Conway, Cowan, & Bunting, 2001; Unsworth, Redick, Heitz, Broadway, & Engle, 2009). There are two types of epistemic curiosity that affect cognitive level abilities, including the type of interest and the type of deprivation, predicted positively by cognitive flexibility but reflected negatively in students' non-scientific beliefs whose results imply that if a higher level of cognitive flexibility is achieved, so that the practitioner's gap scientists can be reduced (Hong, Lee, & Ye, 2021). Students who have a good level of cognitive reflection skills and knowledge plan orientation produce students with good quality in learning, where students are able to answer questions with a strong level of intuition, recognize the need to justify their answers and reason more consistently (Gette & Kryjevskaia, 2019; Magana, Fennell, Vieira, & Falk, 2019). With regard to the intuition of physics (scientific knowledge) which is currently still underdeveloped in learning and most students are still operating at the action level so that only a small number operate at the process and understanding level, causing students difficulties in solving counterintuitive problems and cognitive abilities (Balta, Japashov, Abdulbakioglu, & Oliveira, 2020; Mutambara & Tsakeni, 2022).Therefore, based on the description and presentation related to the urgency of using augmented reality in learning physics, this study aims to identify the trend that influence the use of augmented reality Media in physics learning on the cognitive abilities of students.

Method

This study uses the systematic literature review method to identify research topics related to augmented reality technology in learning physics and the impact of using augmented reality on cognitive abilities in learning physics. In systematic literature review research it is necessary to identify as much as possible of previous research that has been conducted in the field to be studied and which is most relevant to the research topic area, which is very important for direction and methodology, so that systematic screening is needed.

Search Strategy

Screening of journal articles in this SLR research uses the help of PoP (Publish or Perish) software with data sources on Google Scholar. Filtered articles have a range of 2017-2022 (last 6 years) with the selection of

keywords augmented reality and Physics Learning.

Publication Selection & Data Extraction

Based on the PRISMA Protocol chart in Figure 1, showing the presentation of articles through a search for Publish or Perish identified as many as 2989 articles. In the identification process, screening was carried out by eliminating articles that had never been cited so that there were 135 articles reduced. In the screening process, screening was carried out with criteria taken specifically for journal articles so as to exclude as many as 1320 articles that were not included in the journal. Next, in the sought for retrieval process, the criteria for articles that use English (International Language) are taken, so that as many as 62 articles that do not use English are filtered. Then entering the assessed for eligibility stage there are two reasons, the first reason is to filter articles by specifying the title physics or physics material so that the articles that are specifically filtered for physics learning are reduced by 1364 articles. This was done because in the data base obtained by Publish or Perish, learning was found other than physics. In the second reason, filtering was carried out with special criteria in the title of the article there was the word augmented reality so that there were 61 articles reduced. The second reason is done because it is more specific on the use of augmented reality technology.

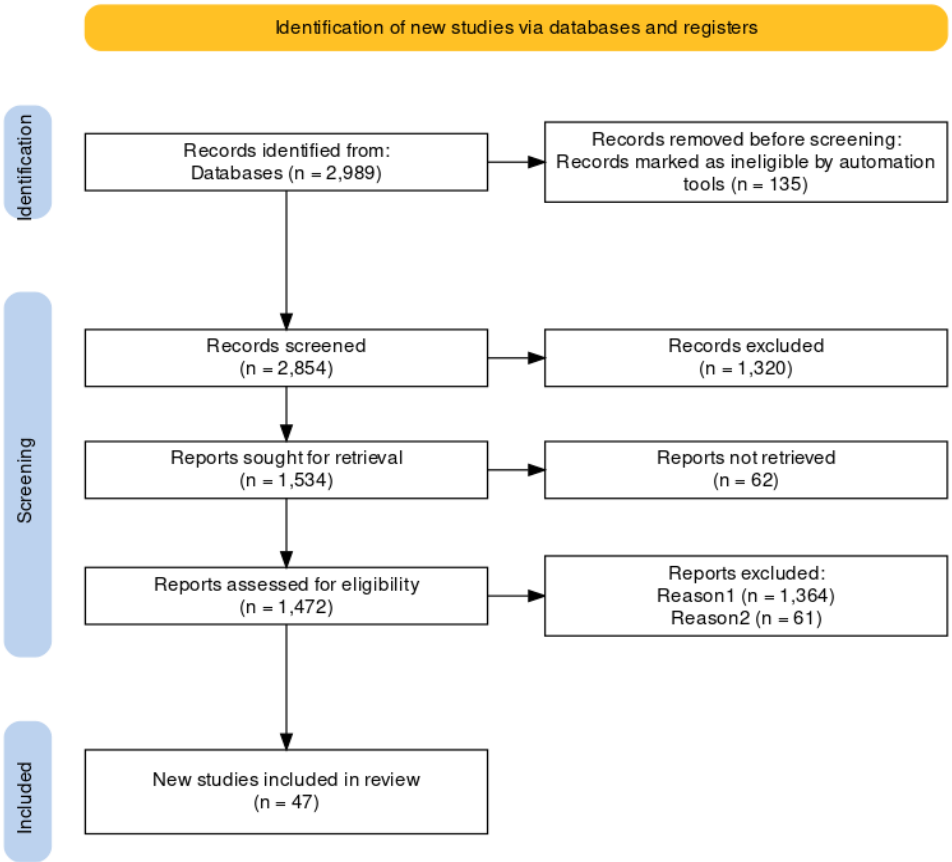

Figure 1. PRISMA Diagram Flow

Based on the entire screening series as shown in the PRISMA Protocol Chart, a final number of 47 articles was obtained relating to the topic of using augmented reality to impact cognitive abilities in physics learning. Thus

this research is directed to provide research results in which augmented reality technology can provide development of cognitive abilities in students in learning physics and in the future they can better develop augmented reality technology in learning physics.

Results

Article Characteristics

In this SLR research, the final results of screening as many as 47 articles on the topic of augmented reality in physics learning have been obtained. The research articles were analyzed using VoSviewer software to find out the article keywords that often appear and the associations of other keywords. Analysis using VoSviewer can be seen through the keyword mapping shown in Figure 2.

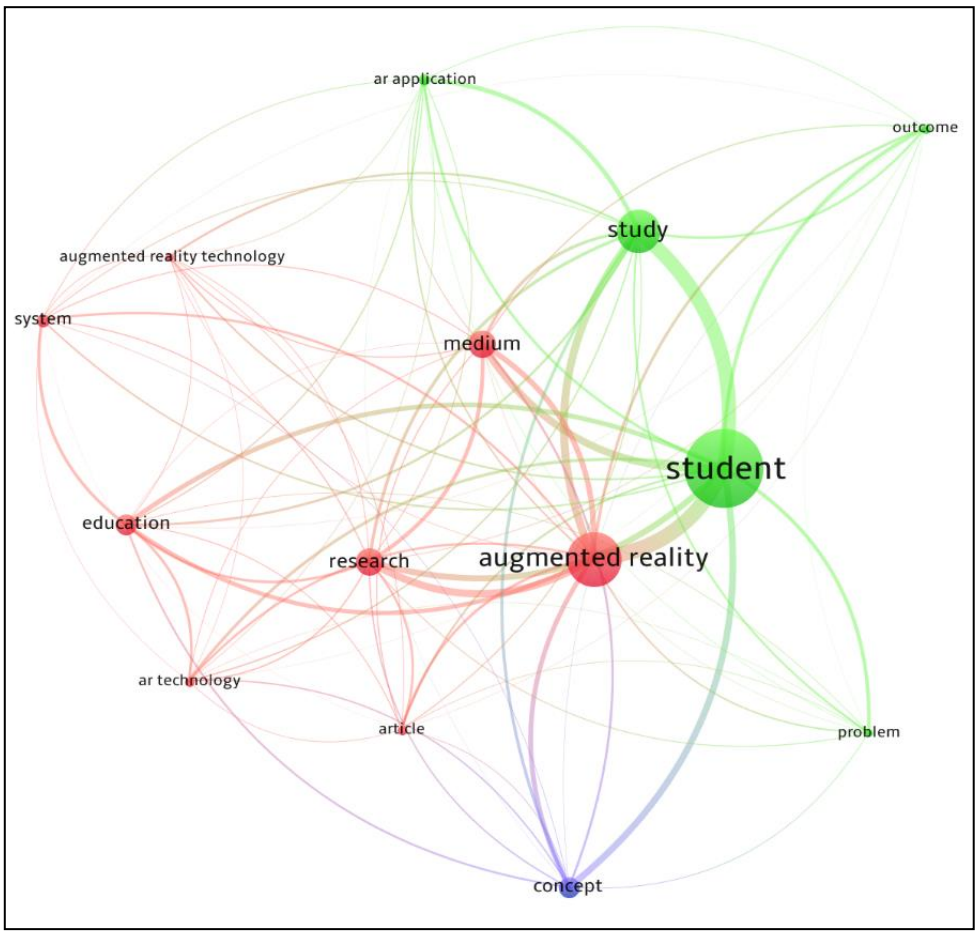

Figure 2. Obtained Article Keyword Mapping

In Figure 2 it shows that the keywords about Student and augmented reality are the most dominant in the articles obtained because they have a large circle, so that it can be said that Student and augmented reality are often discussed in articles and have a relationship shown through connected curved lines. Based on the dominant article keywords, it can be concluded that the articles that have been filtered discuss learning using AR media that has an impact on students. In the research articles obtained the distribution each year can be shown through the graph in Figure 3.

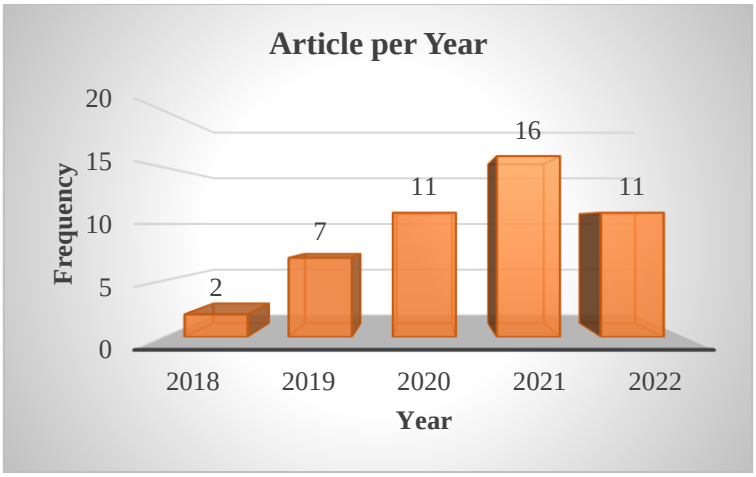

Figure 3. Distribution of Article Every Year

Based on Figure 3, it can be seen that most of the research articles obtained were published in 2021 and in 2017 no augmented reality articles in physics learning were found that matched the criteria that had been carried out in the screening process. In addition, it can be concluded that research on AR in physics learning is popular in 2021. The number of citations to the articles obtained can be shown using the diagram in Figure 4.

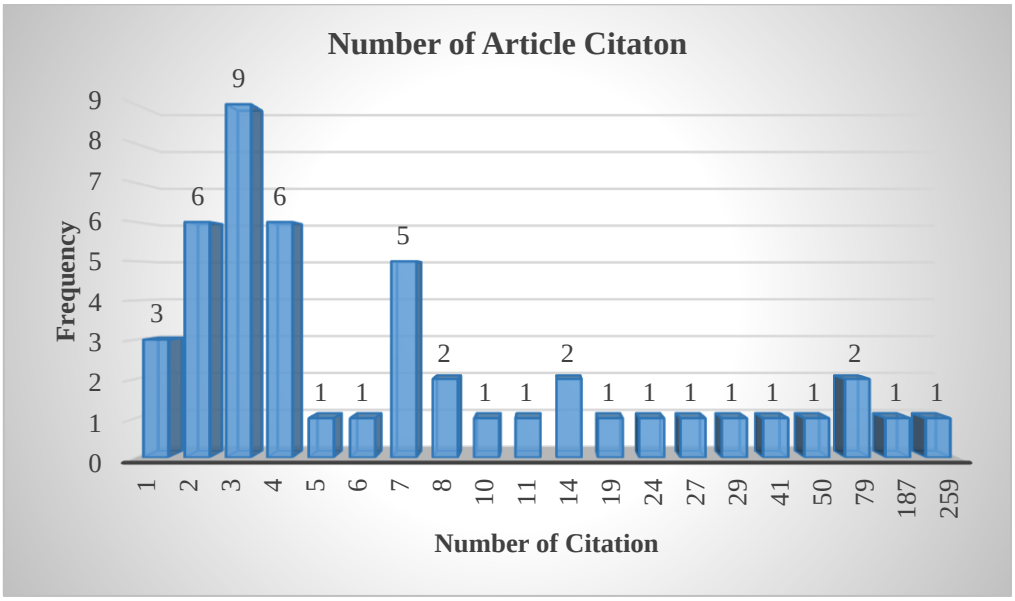

Figure 4. Number of Article Citations Obtained

Based on Figure 4, it shows the distribution of the number of citations of the filtered articles, with the article having the highest number of citations namely 259 times. In the filtering process we did not take articles that have not been cited with the aim of obtaining articles that are already trusted and well-known. As for the distribution of journal publication sources, the research articles obtained can be shown in the diagram below Figure 5.

Based on Figure 5, it shows that the distribution of article sources obtained mostly from Journal of Physics: Conference Series sources as many as 15 articles. In addition, a total of 30 international journals were screened for articles. The distribution of the article publications obtained can be illustrated by diagram shown in Figure 6.

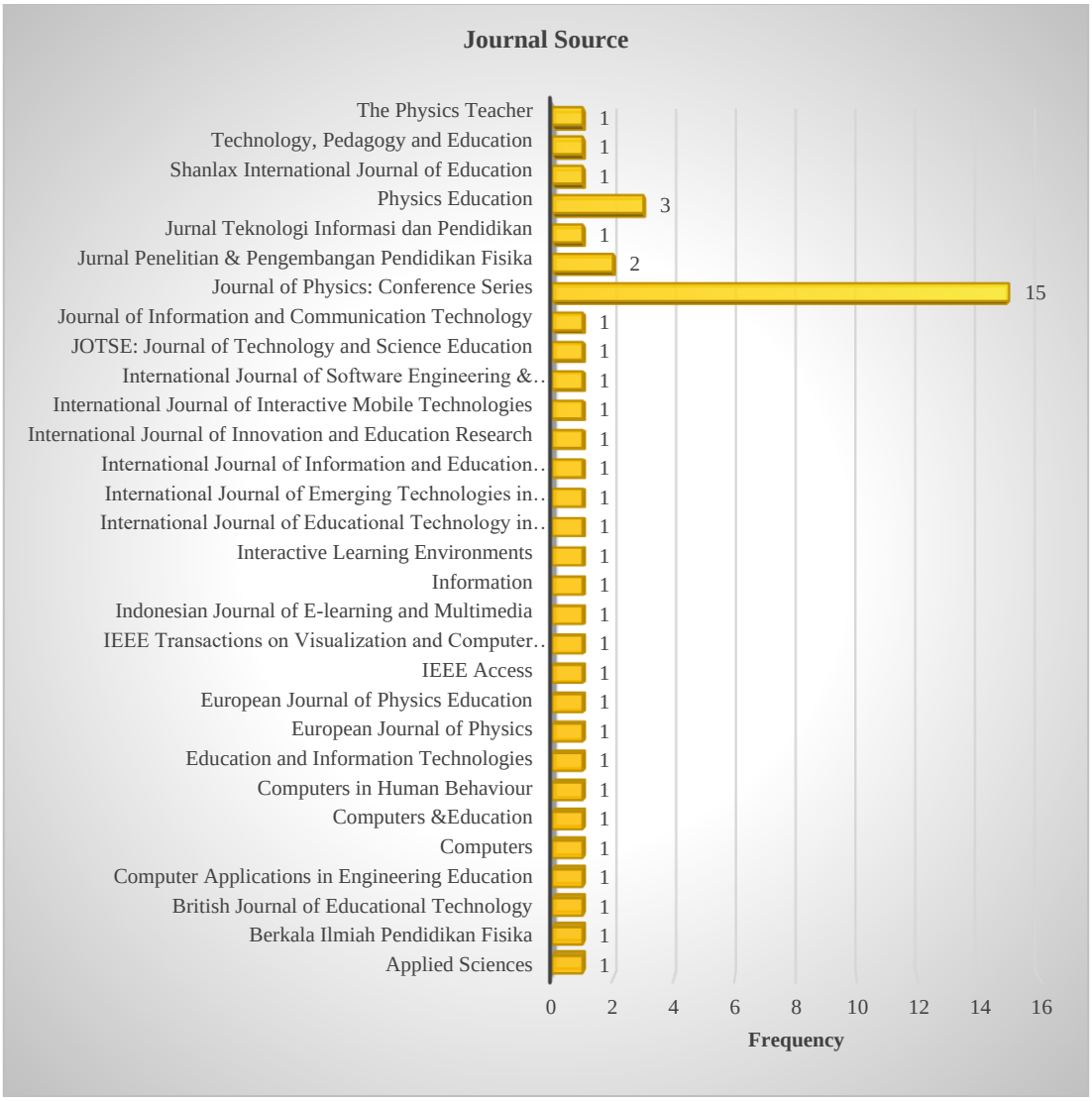

Figure 5. Distribution of Sources Articles Obtained

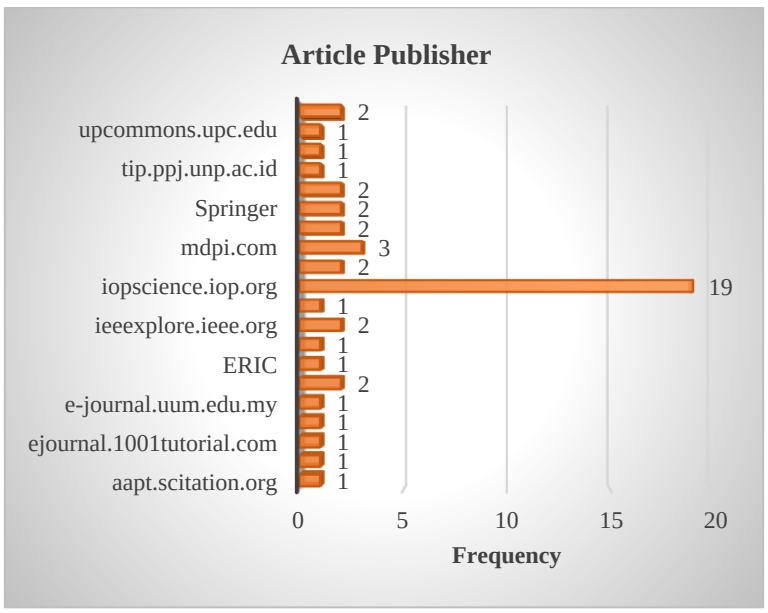

Figure 6. Distribution of Article Publications Obtained

Based on Figure 6, the most widely obtained distribution of article publications was from iopscience.iop.org as many as 19 articles. The screened articles came from 20 reputable article publishers.. Thus it can be concluded that the characteristics of the articles obtained in the screening, mostly carried the keywords student, augmented reality, study and medium with the year distribution of the articles being mostly in 2021. The highest number of citations was 259 citations. From the acquisition of these articles, most of the journal sources came from the Journal of Physics: Conference Series with the most publications namely iopscience.iop.org.

The Trend of Using Augmented Reality in Learning Physics

The use of augmented reality in the field of education is an innovative learning media that can make it easy for students to explain an abstract concept such as a physics subject. Physics learning is not far from abstract concepts for students because it relates to scientific natural phenomena. Based on the articles that have been obtained, the use of augmented reality is often applied to explain the physics topics shown in Figure 7

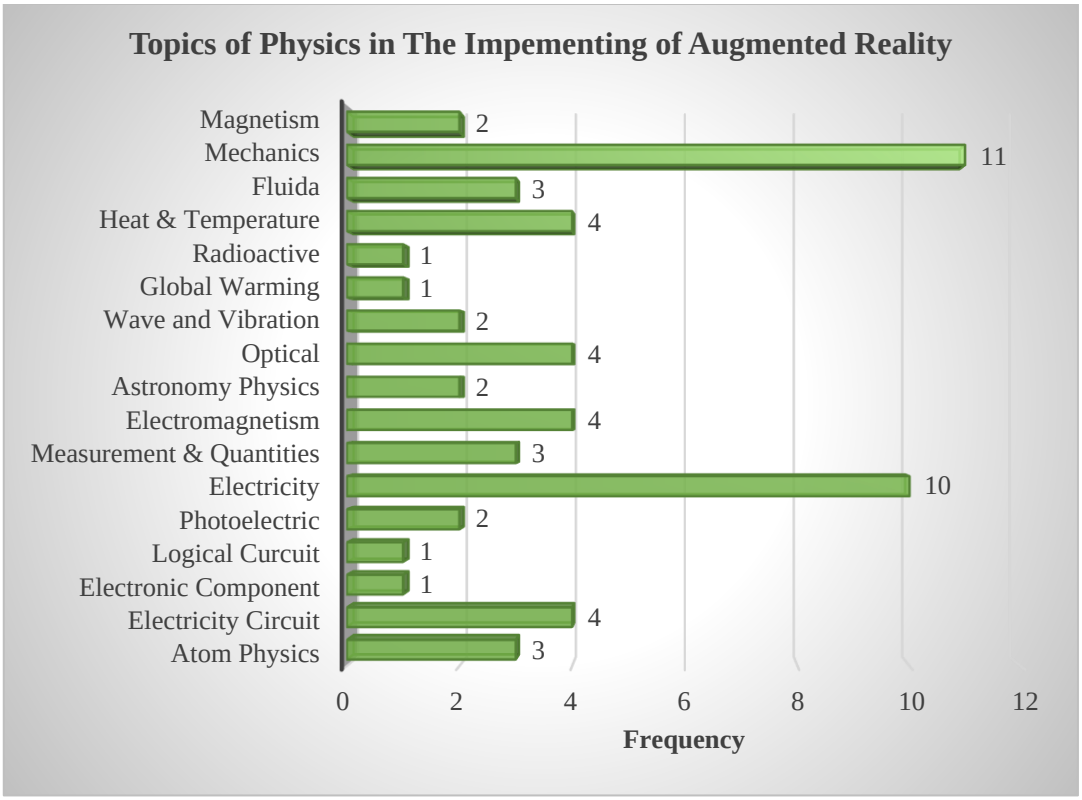

Figure 7. Physics Topics Implemented in Augmented Reality

Based on Figure 7 it can be shown that the physics topics that are most often implemented in augmented reality technology are the topics of Mechanics and Electricity. This is because the mechanics material requires 3-dimensional visualization because there are several directions of forces and vectors that need to be understood conceptually. Meanwhile, electricity is a material that is quite abstract because electricity cannot be seen by the eye directly, therefore media such as AR is needed to clarify the visualization. Overall, there are 17 physics topics covered in the physics learning research using AR. Based on the articles that have been obtained, the form of presentation of augmented reality in physics learning can be shown through the diagram in Figure 8.

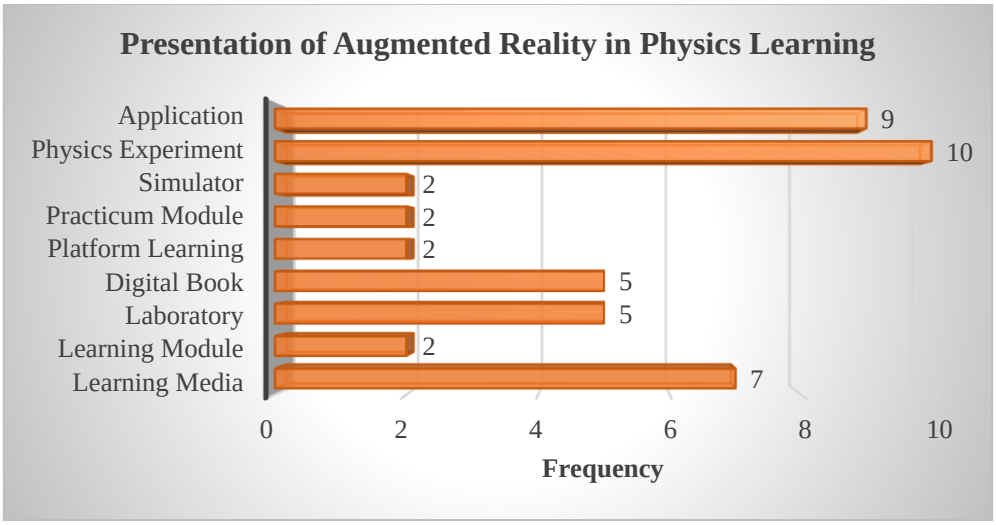

Figure 8. Presentation of Augmented Reality in Physics Learning

Based on Figure 8, the presentation of augmented reality in physics learning based on the screened articles consists of 8 forms of presentation. The form of presentation of augmented reality that is often used in physics learning is in the form of physics experiments and applications. Physics experiments using AR are commonly used by students as a visualization medium in observing physics concepts in virtual and 3-dimensional form so that the material is presented contextually. While the presentation of AR applications is usually integrated by hardware such as smartphones to operate it. The form of presentation of augmented reality is adjusted based on the needs and objectives of learning physics to develop students' abilities. The abilities of students that need to be developed in learning include cognitive, affective and psychomotor abilities. The use of augmented Reality can provide an increase or impact on the cognitive students. Based on the articles that have been obtained cognitive abilities that can have a positive impact on the use of augmented reality can be shown through the diagram in Figure 9.

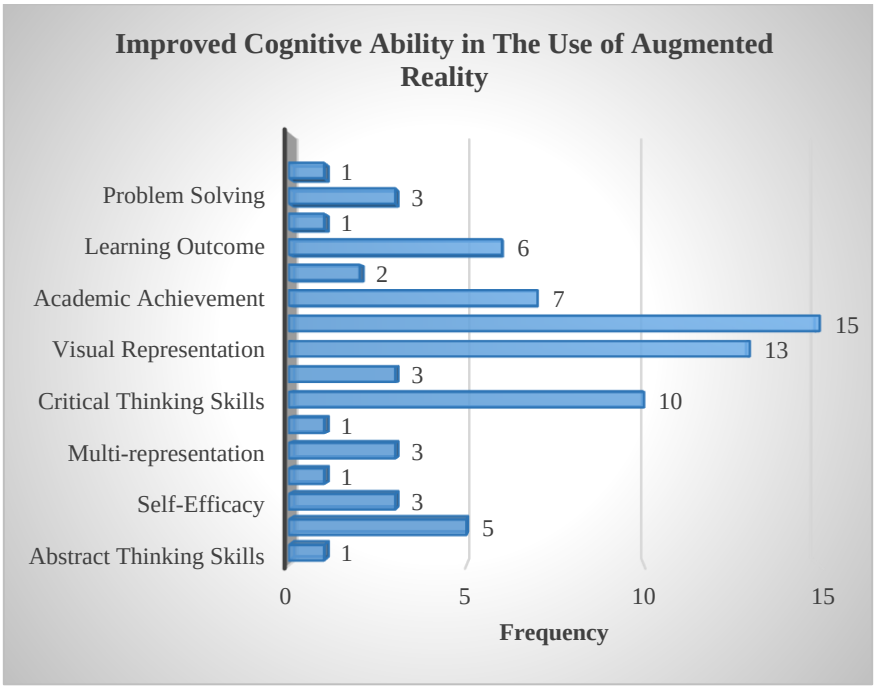

Figure 9. Increasing the Cognitive Ability of Physics Learning in the Use of AR

Based on Figure 9, there are 16 cognitive abilities that have a positive impact on the use of AR in physics learning. The cognitive abilities of physics learning in the use of AR are most often found to experience an increase, namely conceptual understanding and visual representation. Conceptual understanding ability can be easily developed when using the right learning media such as AR technology. Students' visual representation skills when using AR technology will be very impactful because AR can explain material in a real and three-dimensional way through a virtual visualization. Therefore, it can be concluded that the effectiveness of using AR in learning physics shows the material that is often implemented in AR, namely Mechanics and Electricity with the form of presentation which is mostly done in the form of physics experiments and applications. The use of AR in physics learning provides effectiveness to improve cognitive and affective abilities with the cognitive abilities that are often found in the articles obtained, namely conceptual understanding and visual representation.

Discussion

The Use of AR in Physics Topics

In the world of education, the implementation of augmented reality provides a technology-based learning orientation. Augmented reality can support students in doing abstractions in three dimensions, so that they look real through electronic devices such as smartphones, laptops and tablets. augmented reality is a technology to combine the real and virtual worlds to visualize 3-dimensional objects through scanning markers or 2-dimensional images in real time and environments (Aggarwal & Singhal, 2019; Baker et al., 2020; Chen, 2019). Visualization in augmented reality can make it easy for students to explain a concept as in physics material. Physics learning is often encountered with concepts that are abstract and difficult to understand. Therefore augmented reality technology can be a media solution for students' physics learning. Based on the articles obtained, the use of AR media in physics learning brings up various physics topics, including Magnetism(Abdusselam & Karal, 2020; Yu, Liu, Ma, Le, & Ba, 2022), Mechanics (Aoki, Ujihara, Saito, & Yuminaka, 2020; Oktaviyani Rosniadi Pratama, Connie, & Risdianto, 2021; Vidak, Movre Šapić, & Mešić, 2021), Fluida (Permana et al., 2021; Sanderasagran, Aziz, & Idris, 2020), Heat & Temperature (Suryadi, Rahayu, Amalia, Hamdani, & Nuraeni, 2019; Thees et al., 2020), Radioactive (Schiano Lo Moriello et al., 2022), Global Warming(Kholiq, 2020), Wave & Vibration (Aji, Setyowati, Jumina, & Hudha, 2021; Cai, Liu, Wang, Liu, & Liang, 2021; Muliyati, Bakri, & Ambarwulan, 2019), Optical (Astra & Saputra, 2018; Kencana, Iswanto, & Wibowo, 2021; Muliyati et al., 2019), Astronomy Physics(Nasir, Fakhruddin, & Prastowo, 2019; Suprapto, Ibisono, & Mubarok, 2021), Electromagnetism (Faridi, Tuli, Mantri, Singh, & Gargrish, 2021), Measurement & Quantities (Arifin, Haryanti, Trinova, Halim, & Cakranegara, 2021), Electricity (Ismail, Gumilar, Amalia, Bhakti, & Nugraha, 2019; Ropawandi, Halim, & Husnin, 2022), Photoelectric(Riyanda et al., 2021), Logical Circuit (Arıkan & Özgür, 2020), Electric Component(Villanueva et al., 2021), Electricity Circuit (Stolzenberger, Frank, & Trefzger, 2022), dan Atom Physics (Nandyansah, Suprapto, & Mubarok, 2020). From these physics materials, the material that is mostly used in research using augmented reality is Mechanics and Electricity material. This is due to the material on Mechanics and often creates misconceptions, especially on the material on Mechanics Dynamic Rotation and Equilibrium of rigid bodies in visualizing moments of force and inertia. This is in line with Oktavia and Admoko's research which states that there are misconceptions in the dynamics of rotation with the lowest misconception of 19.84% on the concept of moment of force and the highest of 46.31% on the concept of kinetic energy in rotational motion

objects (Oktavia & Admoko, 2019) . Whereas in electricity material it is still abstract and difficult to see directly with the senses of the eye, so it is difficult for students to understand. This is supported by the statement that physics material is abstract, such as electricity material, which is difficult to visualize, causing difficulties for students (Ismail et al., 2019; Ivanjek et al., 2021).

AR Presentation in Physics Learning

In physics learning, the presentation of augmented reality has been adjusted to the needs and learning objectives to be achieved. Based on final result screened article, the form of presentation of augmented reality in physics learning includes application (Fidan & Tuncel, 2019; Vidak et al., 2021; Volioti et al., 2022), physics experiment (Aji et al., 2021; Schiano Lo Moriello et al., 2022; Stolzenberger et al., 2022), simulator (Riyanda et al., 2021; Sung, Ma, Choi, & Hong, 2019), practicum module (F. Bakri, Kusuma, & Permana, 2021; Firmansyah, Suhandi, Setiawan, & Permanasari, 2020), platform learning (Daineko, Tsoy, Seitnur, & Ipalakova, 2022; Volioti et al., 2022), digital book (Astra & Saputra, 2018; Fauzi Bakri, Oktaviani Marsal, & Muliyati, 2019; Kholiq, 2020; Wibowo, Nasbey, Sanjaya, Darman, & Ahmad, 2021), laboratory (Abdusselam & Karal, 2020; Fawzi, 2018; Schiano Lo Moriello et al., 2022; Yu et al., 2022), learning module (O R Pratama, Connie, & Risdianto, 2022; Oktaviyani Rosniadi Pratama et al., 2021), dan learning media (Nandyansah et al., 2020; Permana et al., 2021; Sanderasagran et al., 2020). From the several forms of presentation of augmented reality that are most often carried out in research, namely in the form of Physics Experiment presentations. Physics Experiment is an activity in physics learning where students are required to experience firsthand to prove physics concepts, so that it is more effective in providing students with understanding. Field experiments using AR applications in education have shown that the educational process is enhanced by increasing student fun, interest and engagement (Streitz & Markopoulos, 2017)

The Positive Impact of Using AR on Cognitive Abilities

Cognitive ability in learning is an ability that students need to develop the potential that exists in students. Cognitive abilities are related to intellectuals such as thinking, remembering, understanding and analyzing a case. Intelligence or cognitive ability can be defined as a very general mental ability which, among other things, involves the ability to reason, plan, solve problems, think abstractly, understand complex ideas, learn quickly and learn from experience. (Gottfredson, 1997). Cognitive presence as the ability of students to build and confirm meaning through reflection and continuous discourse in critical discussions or investigations (Garrison, Anderson, & Archer, 2001).

Cognitive abilities can also emerge when given a learning experience such as the use of augmented reality learning media. The use of augmented reality based on the articles that have been obtained has a positive impact on the cognitive abilities of students which include scientific literacy skills (Kholiq, 2020), problem solving (Sanderasagran et al., 2020), computational thinking skill (Volioti et al., 2022), creative thinking skills (Oktaviyani Rosniadi Pratama et al., 2021) , conceptual understanding (Cheng & Tsai, 2013; Lauer et al., 2020; Ropawandi et al., 2022; Sánchez & Ramírez Diaz, 2022), academic achievement (Abdusselam & Karal, 2020;

Hsiao & Rashvand, 2011), learning outcome (Astra & Saputra, 2018; Sriadhi, Hamid, Sitompul, & Restu, 2022; Villanueva et al., 2021), visual representation (Cheng & Tsai, 2013; Liono et al., 2021; Sanderasagran et al., 2020; Vidak et al., 2021), high order thinking skill (F. Bakri et al., 2021; Putri, Soleh, Saregar, Anugrah, & Susilowati, 2021), critical thinking skills (Ismail et al., 2019; Sriadhi et al., 2022; Villanueva et al., 2021), reasoning ability (O R Pratama et al., 2022; Putri et al., 2021; Sriadhi et al., 2022), multi-representation (Fauzi Bakri et al., 2019), communication(Cai et al., 2021; O R Pratama et al., 2022), self-efficacy (Cai et al., 2021; Nasir et al., 2019), cognitive load (Lauer et al., 2020; Thees et al., 2020), the abstract thinking skills (Nandyansah et al., 2020). From some of these cognitive abilities, the positive impact of using AR is often found, namely conceptual understanding, visual representation and critical thinking skills. This is also in line with the opinion that augmented reality (AR) can be collaborated with smartphones to become an effective, efficient and useful learning medium in the learning environment so that it can increase digital era literacy, creative thinking, conceptual understanding, critical thinking, communication, collaboration, ability problem solving and visual representation (Papanastasiou, Drigas, Skianis, Lytras, & Papanastasiou, 2019).

Conclusion

Based on the results and discussion of this study, it can be concluded that the trend of AR research in physics learning has always increased every year from 2017-2022 and in 2021 the use of AR in physics learning is most popular. Research on the use of AR in physics learning raises 17 physics topics, but the physics topics that are often raised in AR research are mechanics and electricity. This is because both materials are difficult material but can be overcome through three-dimensional visualization through augmented reality technology. There are 8 forms of AR presentation in physics learning including application, physics experiment, simulator, practicum module, learning platform, digital book, laboratory and learning module. However, in the trend of AR research, physics learning is often presented in the form of physics experiments and applications. The use of AR in physics learning has a positive impact on students' cognitive abilities. There are 16 cognitive abilities of students that have an impact when using AR in physics learning, but the cognitive abilities that most often appear in research are conceptual understanding and visual representation.

Recommendations

In this study, it is hoped that future research can discuss more deeply regarding the positive impact of affective abilities on the use of AR in physics learning. This is to provide insight and support this research which focuses on the cognitive abilities of students in physics learning using AR, so that teachers can have resources to design AR media for physics learning.

Acknowledgements

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