25 (2), 2024, 582-600

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

How is Augmented Reality Developed in Physics Education? A Review with NVivo from 2019-2024

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Abstract: This review aims to identify developments in Augmented Reality (AR) in physics education from 2019-2024 through NVivo analysis. A total of 19 articles from the Scopus database (SJR 2023: 2 (Q1), 6 (Q2), 4 (Q3), and 7 (Not Applicable)) were used in this review and filtered through the prism guide. The focus of this review includes: 1) The Aim; 2) Methods; 3) Participants; 4) Instruments; 5) Analysis; 6) Concept, and; 7) Software or Device. The results of this review explain that: 1) Based on the objective, the application used is AR (89%); 2) The method used is the development method (47%); 3) Most participants are high school students (42%); 4) The instruments used were questionnaires (37%); 5) N-gain analysis is the most widely used analysis (11%); 6) The physics concept used is electricity (16%), and; 7) The software or device used is 3D Blender (16%) and Unity (16%). Thus, we concluded that the development of AR for physics concepts has become interesting research over the last 5 years (2019-2024). The recommendation from this review is that when developing AR in physics learning, especially abstract ones, you can conduct research using development methods and 3D Blender and Unity software.

Keywords: augmented reality, physics education, NVivo analisis.

▪ INTRODUCTION

Current technological developments mean that all fields must adapt to these developments. Especially after the Covid-19 pandemic, all fields in Indonesia have adapted very quickly to this day. Various fields are adapting to technological developments after the Covid-19 pandemic, one of which is in the education sector (Marini & Milawati, 2020; Rulandari, 2020; Samsudin et al., 2023). In the education sector, online learning became popular during the pandemic in Indonesia (Dewi et al., 2023; Salsabila et al., 2020). Various digital and streaming-based learning media are starting to be used. Several platforms such as Zoom, Google Classroom, and Microsoft Teams are used as virtual classes that allow interaction between users (Azlan et al., 2020; Shurygin et al., 2022; Wea & Dua Kuki, 2021). This digital-based learning transition is also ongoing today in Indonesia. These changes are also accompanied by the development of learning media that supports digitalization or is streaming-based. Thus, many providers of online learning-based course learning services are offered and are an alternative because they make it easier for users and have affordable costs. Likewise, developments in teaching media such as during practicums, demonstrations, or even worksheets (for all school/campus subjects), are slowly starting to have alternatives provided online (Eambaipreuk & Unyapoti, 2023; Kidd & Murray, 2020; Sari et al., 2022). Various research during the pandemic and even afterward has developed various digital-based learning media. One of the most widely developed is Augmented Reality (AR). Based on

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DOI: http://dx.doi.org/10.23960/jpmipa/v25i2.pp582-600
Received: 20 August 2024
Accepted: 08 September 2024
Published: 17 September 2024

research (Samsudin et al., 2023), the learning media that are most widely developed are virtual reality, simulation, and AR.

Augmented Reality (AR) is a technology used to project an object using a device (such as a smartphone, tablet, or special headset) that originally 2-dimensional (2D) into a 3-dimensional (3D) form in real-time (Ariano et al., 2023; Kanangkaew et al., 2023; Sudirman et al., 2024). In addition, some developers can create interactions between users and objects in AR. Research related to AR is also starting to become a research topic as a learning medium for several researchers. The use of AR has been aimed at achieving various aspects of education, such as increasing motivation (Anuar et al., 2021), STEM learning (Amin et al., 2021), critical thinking (Faridi et al., 2021), and improving students' conceptions (Cai et al., 2021). Apart from that, the development of AR in the field of physics can be carried out for learning needs such as demonstrations, practicums, or visualization of abstract objects.

Many concepts in physics are abstract, for example, the concepts of momentum, electricity, magnetism, force, and waves, and almost all concepts if studied at a micro level require visualization to make them easier to understand (Aminudin et al., 2019; Gunawan et al., 2021; Samsudin et al., 2024). Apart from that, sometimes physics is often considered difficult due to various factors, such as having mathematical calculations, being abstract, lots of practice questions, and explanations that are sometimes difficult to understand (Batlolona et al., 2024; Maknun, 2020; Pullicino & Bonello, 2020). Thus, the development of media in physics such as AR can be an alternative to learning media. Especially now that information can be accessed anytime, anywhere, and by anyone, the development of learning media must be able to adapt to these conditions.

Digital-based learning media is one of the media that can adapt to current conditions which is flexible and mobile. Several factors influencing the need for digital-based media in physics education include the difficulty of creating ideal conditions (such as during demonstrations/practicums) (Hidayati et al., 2023), limited funds in purchasing equipment (Mohzana et al., 2023), and collectiveness in learning or practicum (every student can use their learning media). These factors make the development of digital-based media a research focus that is currently becoming popular (Samsudin et al., 2023). However, how to develop AR and the details of its development in physics education are interesting things to explore. Because some people only focus on the product, without looking at the purpose, how AR is made, and for whom AR was developed, are some interesting questions to review. Thus, this article aims to review and identify developments in Augmented Reality (AR) in physics education from 2019-2024 through NVivo analysis. We limit this review to narrow the scope of AR development before the Covid-19 pandemic and after until now. Meanwhile, NVivo analysis is used to assist in mapping the review results to make it easier to read the results obtained.

NVivo analysis is often used in a lot of research related to text to map the findings (Eliya et al., 2024; Samsudin et al., 2023; Syaodih et al., 2021). Manual coding based on the findings obtained makes this analysis usable as in this review. The code can be created based on the findings during the review. Then, pulling a series of codes based on the criteria created makes NVivo analysis easier to understand the results of the review. To map the results of the review in this article, we first focus on the objectives that have been set into several research questions. Meanwhile, the focus of this review is presented in the following research questions:

1. The Aim : What are the goals of research to develop AR in physics education?
2. Methods : What methods are used in research on the development of AR physics education?
3. Participants : Who are the participants usually used in research on the development of AR in physics education?
4. Instruments : What types of instruments are often used in physics education AR development research?
5. Analysis : How is the data analysis carried out in research on the development of AR physics education?
6. Concept : What physics concepts are often used in research into the development of AR physics education?
7. Software or Device: What software or devices can be used in AR research and development in physics education?

▪ METHOD

Research Design

This research uses the Systematic Literature Review (SLR) method to review, identify, analyze, and evaluate publications from relevant sources to answer the research questions created (Mangiri & Prabawanto, 2024; van Dinter et al., 2021). Several studies use the SLR method as a reference material in identifying existing problems, to obtain recommendations regarding follow-up actions that can be taken (Putri et al., 2022; Samsudin et al., 2023; Winarno et al., 2020). Thus, this research, we use the SLR method because it is considered to be able to answer and provide recommendations for the problems that have been submitted.

Search Strategy

This review uses a prism guide in filtering the samples to be used. Some researchers use a prism guide to carry out a Systematic Literature Review (SLR) on their documents (Glor, 2021; Mangiri & Prabawanto, 2024; Samsudin et al., 2023). In this review, document filtering can be seen in Figure 1.

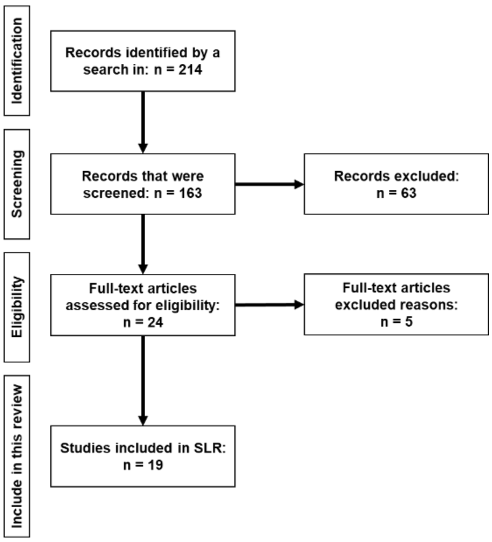

Figure 1. The prism guides

In Figure 1, stage 1 (Identification) is carried out by searching for articles in the Scopus database, with a search regarding, "(TITLE-ABS-KEY (development) AND TITLE-ABS-KEY (augmented AND reality) AND TITLE-ABS-KEY (physics))". Then in stage 2 (Screening), we screen for focus on the criteria, "(PUBYEAR > 2019 AND PUBYEAR < 2024 (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT -TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) AND (LIMIT-TO (LANGUAGE, "english")) AND (LIMIT -TO (SUBJAREA, "soci"))". In stage 3 (Eligibility), we selected based on the availability of documents that could be analyzed. Thus, in stage 5 (Included in this review) we used the article as material in this review.

Inclusion and Exclusion

Based on the discussion in Figure 1, the inclusion and exclusion criteria used in this research can be identified. However, the criteria used refer to the filters available in the Scopus database. The results can be seen in Table 1.

Table 1. Description of inclusion and exclusion

Criterion	Inclusion	Exclusion
Year	2019 - 2024	< 2019
Document type	Article and Conference paper	Conference review, Review, Book chapter, and Book
Publication stage	Final	-
Source type	Journal and Conference proceeding	Book series and Book
Language	English	Chinese, Korean, and Spanish

Table 1 explains that some criteria are used and others are not. These criteria refer to the display shown by the Scopus database. For example, for "Publication stage", in the Scopus database only the "Final" criterion is available, so in the Exclusion section there are no other options and are filled with a minus symbol (blank). Meanwhile, for other criteria there are other options that are not used in this research.

Document

Based on the Prisma guide, a total of 19 articles from the Scopus were used in this review. Then we created a categorization based on SJR 2023 data, publication year from 2019-2024, country, and journal name. Thus, the 19 articles used were included in the criteria that had been created, and the results were mapped in a hierarchy (SJR 2023, year of publication, country, and journal name) which can be seen in Figure 2.

Based on Figure 2, we selected articles based on a prism guide. However, there are 5 proceeding articles (purple), and the rest are journal articles (green). Then the red arrow shows the existence of the same journal for different years. A total of 19 articles from the Scopus database (SJR 2023: 2 (Q1), 6 (Q2), 4 (Q3), and 7 (Not Applicable)) were used in this review. Of the articles used, dominance belongs to SJR 2023: Not Applicable with 7 articles. The Not Applicable code is the SJR value in 2023 which no longer appears. Many factors can cause this to happen, but we still included the article for review because the article title had already appeared in the Scopus database. Then, the green suitcase symbol is the symbol for journal articles, and the pink symbol is the symbol for proceeding articles. Meanwhile, a description for each article can be seen in Table 2.

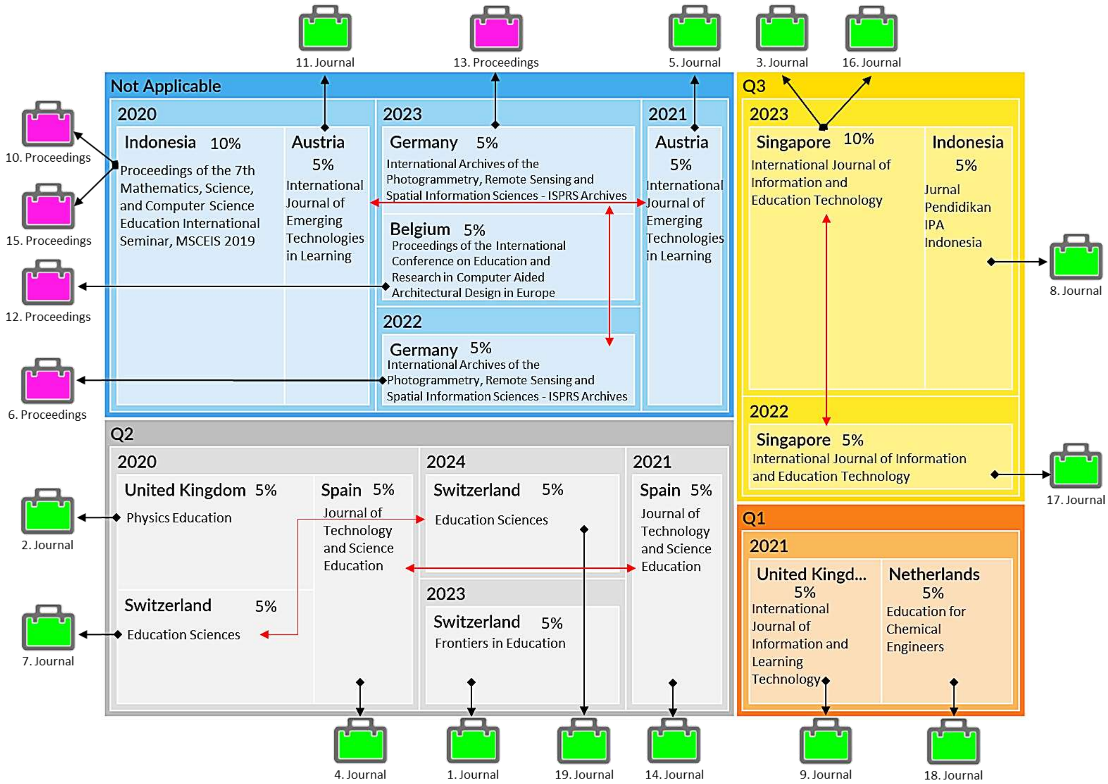

Figure 2. Hierarchical map of the reviewed articles

Table 2. Description of each article

No Article	Authors	Title
1.	Freese M.; Teichrew A.; Winkelmann J.; Erb R.; Ullrich M.; Tremmel M.	Measuring Teachers' Competencies for A Purposeful Use of **Augmented Reality** Experiments in Physics Lessons
2.	Aoki Y.; Ujihara S.; Saito T.; Yuminaka Y.	Development of **Augmented Reality** Systems Displaying Three-Dimensional Dynamic Motion in Real Time
3.	Alfianti A.; Kuswanto H.; Rahmat A.D.; Nurdiyanto R.	Development of **DICTY-AR** Integrated Local Wisdom to Improve Multiple Representation and Problem-Solving Skills
4.	Bakri F.; Permana H.; Wulandari S.; Muliyati D.	Student Worksheet with **AR** Videos: Physics Learning Media in Laboratory for Senior High School Students
5.	Troyanskaya M.; Tyurina Y.; Morgunova N.; Nemtyreva L.; Choriyev R.	**Mobile Learning Programs** for Spatial Decision Making
6.	Arymbekov B.S.; Turekhanova K.M.;	Development of **Augmented Reality** Application for Physics and Geophysics Laboratory

	Alipbayev D.D.; Tursanova Y.R.	
7.	Jesionkowska J.; Wild F.; Deval Y.	Active Learning **Augmented Reality** for STEAM Education-A Case Study
8.	Ropawandi D.; Husnin H.; Halim L.	Comparison of Student Achievement in Electricity Using **Augmented Reality** between Offline and Online Classes
9.	Onime C.; Uhomoibhi J.; Wang H.; Santachiara M.	A Reclassification of Markers for Mixed **Reality Environments**
10.	Bakri F.; Permana A.H.; Chaeranti S.N.; Muliyati D.	Module Equipped with **Augmented Reality** Technology: An Easy Way to Understand Concepts and Phenomena of Quantum
11.	Suprapto N.; Nandyansah W.; Mubarok H.	An Evaluation of the "**PicsAR**" Research Project: An Augmented Reality in Physics Learning
12.	Kyaw A.H.; Otto J.M.; Lok L.	Active Bending in **Physics-Based Mixed Reality** the design and fabrication of a reconfigurable modular bamboo system
13.	Janovský M.	New Technologies and Their Interconnection an The Creation and Processing of **3dmodels and Scenes**
14.	Suprapto N.; Ibisono H.S.; Mubarok H.	The Use of Physics Pocketbook Based on **Augmented Reality** on Planetary Motion to Improve Students' Learning Achievement
15.	Muliyati D.; Baiti D.H.; Bakri F.; Permana H.	Physics Textbook Enriched **Augmented Reality**: Easy Way to Understand the Physical Concept
16.	Nasir M.; Fakhruddin Z.	Design and Analysis of Multimedia Mobile Learning Based on **Augmented Reality** to Improve Achievement in Physics Learning
17.	Ropawandi D.; Halim L.; Husnin H.	**Augmented Reality** (AR) Technology-Based Learning: The Effect on Physics Learning during the COVID-19 Pandemic
18.	Solmaz S.; Dominguez Alfaro J.L.; Santos P.; Van Puyvelde P.; Van Gerven T.	A Practical Development of Engineering Simulation-Assisted Educational **AR** Environments
19.	Henne A.; Syskowski S.; Krug M.; Möhrke P.; Thoms L.-J.; Huwer J.	How to Evaluate **Augmented Reality** Embedded in Lesson Planning in Teacher Education

Data Analysis

Data analysis in this review is focused on 7 research questions that have been created previously. For the mapping, we used NVivo assistance which was assisted by percentage calculations for ease in reading the results (Samsudin et al., 2023). NVivo Analysis has a map creation feature that makes it easier to review review results and several researchers have done this. Technically, we created a code, in which there were sub-codes according to the findings in this review, which can be seen in full in Figure 3.

In NVivo analysis, we first coded according to the research questions in this research. Then, we created sub codes based on the findings obtained during the identification of all documents. After that, we created a classification for all documents analyzed, with the classification as in Figure 2. After all documents were analyzed based

Figure 3. Analysis stages

on the codes created, we started to create a map for further interpretation according to the research questions that had been created previously.

- **RESULT AND DISSCUSSION**

This section will explain the results of the review based on the 7 research questions that have been created. Meanwhile, a detailed presentation based on NVivo analysis mapping will be presented for each research question. We present this review for convenience in concluding. Overall, the results for the 7 research questions that have been created are presented hierarchically from the NVivo analysis seen in Figure 4. Based on Figure 4, the results section will present each result complete with the findings made in code form. Several sub-codes were created based on the findings obtained. The codes or subcodes that are created are not set before the review is carried out. However, both were made based on the findings when the review was conducted. Thus, we don't set the number of codes or sub-codes, but we only add them based on our findings during the review.

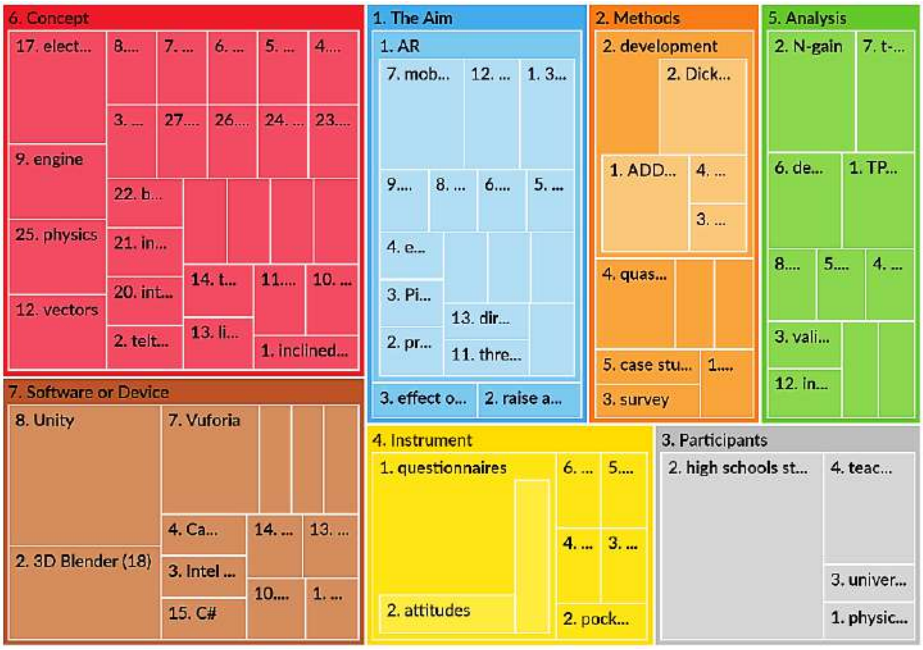

Figure 4. Hierarchical map of the codes for each research question

Figure 4 explains in general the hierarchy of the number of codes created based on the 7 research questions. The hierarchical results in Figure 4 show that the most codes are found in research question number 6 (Concept) which has 27 codes (red). Meanwhile, the code with the lowest number is in research question number 1 (The aim) with a total of 3 codes. However, of the 3 codes, code 1 related to AR has an additional 16 sub-codes. The details of each code and sub-code in Figure 4 will be explained based on the discussion for each research question.

The Aim

In the aim section, we review the entire article regarding the objectives to be achieved in the research. For this reason, we present each finding obtained in the form of codes and sub-codes based on our review. In full, each finding obtained is mapped as shown in Figure 5.

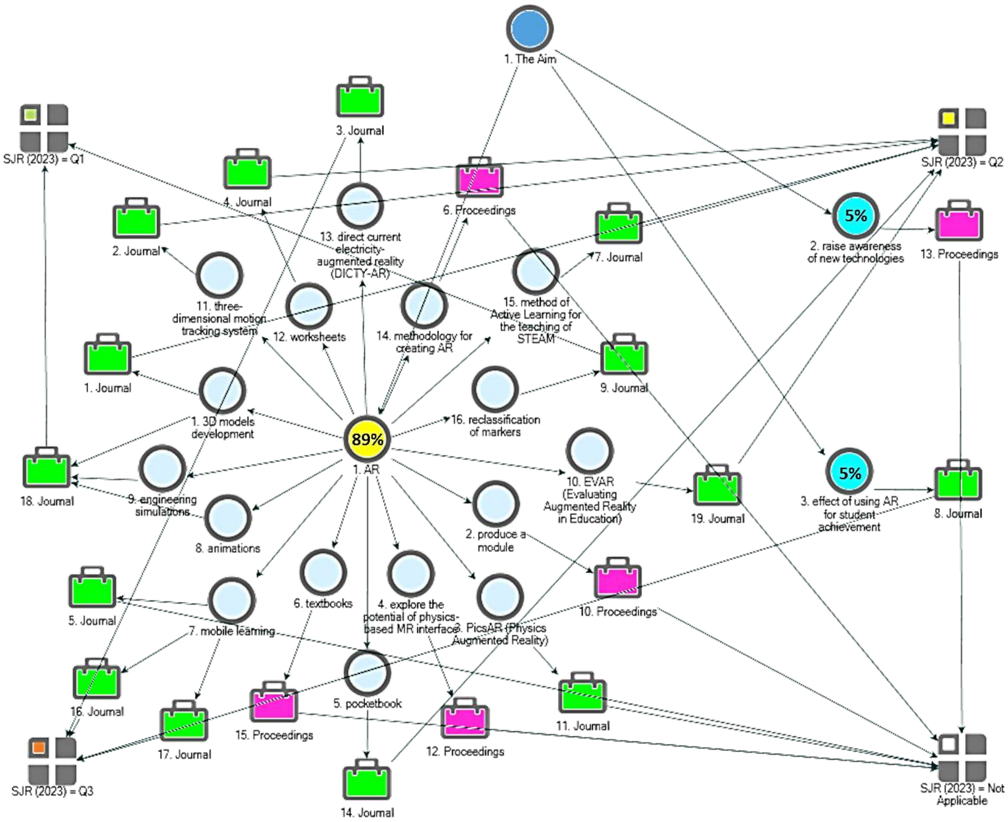

Figure 5. Map of analysis results from the aim section

In Figure 5, there are several symbols that in the next picture have the same meaning. For example, the circle with the color corresponding to Figure 4 shows the symbol for the research question being reviewed. Then the circle in turquoise blue (which is equipped with a percentage) is the code obtained based on the review. The other circle (without percentage) is a sub-code that comes from the code that has been created. The box symbols are green (for SJR 2023: Q1 articles), yellow (for SJR 2023: Q2 articles), orange (for SJR 2023: Q3 articles), and white (for SJR 2023 articles: which are not listed on SJR 2023).

Meanwhile, the results of the review in Figure 5 show that from the objective aspect, there were 3 codes found, namely those related to AR (89%), raising awareness of new technologies (5%), and the effect of using AR for student achievement (5%). However, in the AR section, there are 16 sub-codes (1. 3D models development; 2. Produce a module; 3. PicsAR (Physics Augmented Reality); 4. Explore the potential of physics-based MR interface; 5. Pocketbook; 6. Textbooks; 7. Mobile learning; 8. Animations; 13. EVAR (Evaluating Augmented Reality in Education); AR); 14. Methodology for creating AR; 15. Method of Active Learning for the teaching of STEAM, and; 16. reclassification of markers) with the most subcodes in number 7 (mobile learning (19%)) which comes from articles 5, 16, and 17. This explains that the purpose of the articles analyzed show the development of AR related to mobile learning. Meanwhile, the other sub-codes only come from one article (6%), except for sub-code number 1 (3D models development (13%)) which comes from articles 1 and 18. The results of this review are in line with the research Samsudin et al. (2023) which shows that AR research is the third most popular research after Virtual Reality (VR) and simulation. Avila-Garzon et al. (2021) also mentioned that augmented reality (AR) research in the field of education seems to be getting the right time and is developing actively throughout the world. If you look at the 16 sub-codes obtained in AR, most sub-codes are related to mobile learning. This is not surprising because currently, all human activities are within the grasp of smartphones (Ferrari et al., 2021). Thus, AR development from the reviews carried out is mostly carried out on smartphones.

Methods

In method analysis, we analyze based on the findings obtained. Several codes were created, but after review, there was a sub-code for one of the codes. The results obtained are based on method analysis, the results can be seen in Figure 6.

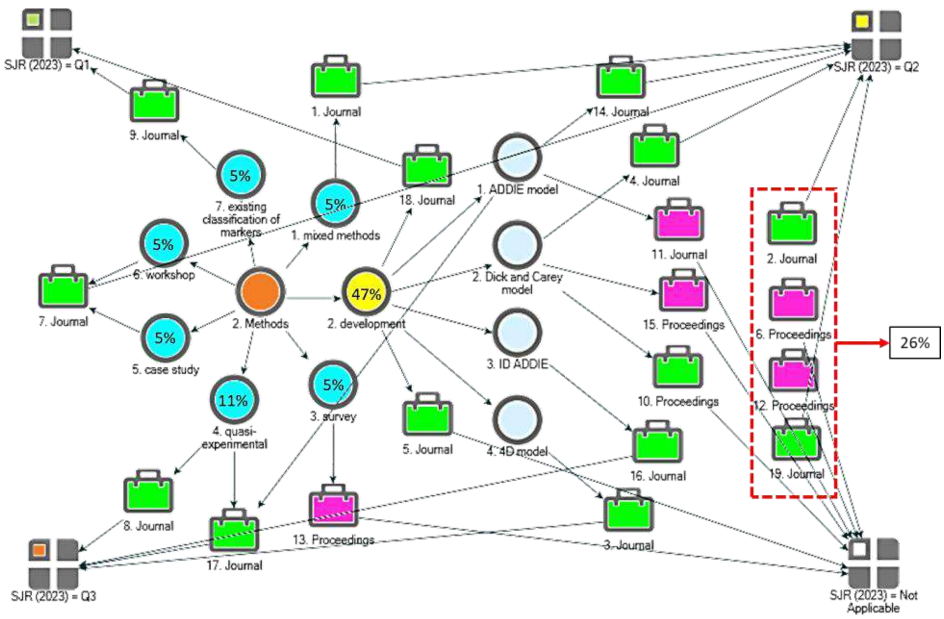

Figure 6. Map of analysis results from the methods section

Figure 6 shows the method analysis with results for method 2 (Development) with the highest percentage of 47%, and the others with an average of 5% (survey, case study, workshop, and existing classification of markers). Meanwhile, quasi-experimental methods (11%) and No Coding (26%). This No Coding code is the result of a review that is not visible in the article regarding the method used and comes from the article from SJR: 2023 in Q2 and NO SJR. Thus, we don't include it in the code that has been created. The most common method (Development) has 4 sub-codes (1. ADDIE model; 2. Dick and Carey model; 3. ADDIE ID, and; 4. 4D model). Of each sub-code, sub-codes 1 and 2 have a percentage of 75%. This shows that the ADDIE model and Dick and Carey model designs are designs that are widely used in development research.

ADDIE design was created to meet design needs in complex educational development, especially learning approaches, online learning environments, and multimedia development (Branch, 2009). There is also a lot of development research with ADDIE designs such as research Fratiwi et al. (2020) with the title “Developing MeMoRI on Newton's Laws: For Identifying Students' Mental Models”, research Mufida et al. (2022) with the title “Developing MOFI on Transverse Wave to Explore Students’ Misconceptions Today: Utilizing Rasch Model Analysis”, and research Baifeto et al. (2022) with the title “Developing PHYCOM (Physics Comics) on Newton’s Law Material for 10th Grade High School Students”. Although the ADDIE model can also be used in learning, its use can also be used in development research, as in the example described. It's not just about AR development, but other developments but the realm is still in education.

Participants

Participant analysis was carried out to review the targets most widely used in implementing AR development results. These results serve to provide an overview of how AR is applied according to its development. The mapping results from NVivo analysis for reviewing participant aspects can be seen in Figure 7.

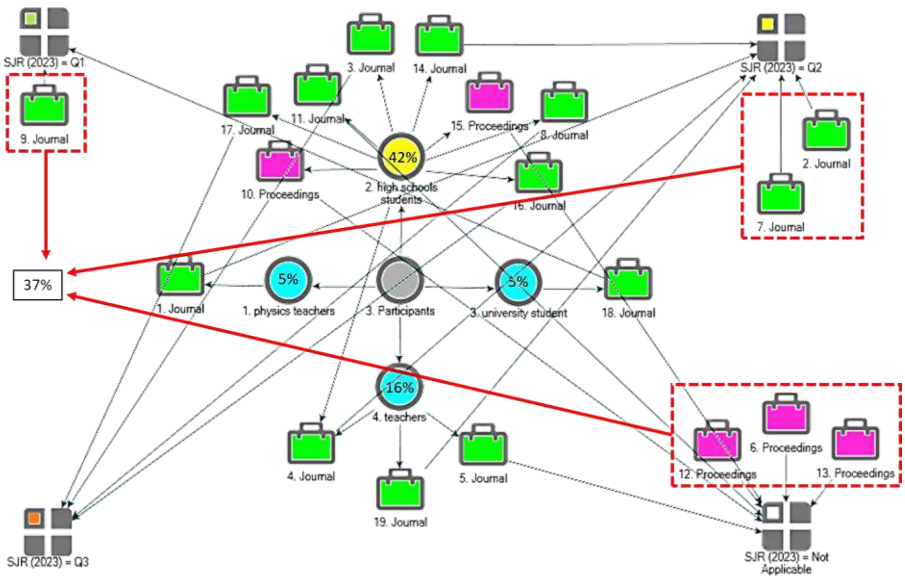

Figure 7. Map of analysis results from the participant’s section

Figure 7 shows the distribution of participants used, dominated by code number 2 (high schools students) at 42%. Other results include: 1) Physics teachers (5%); 3) University students (5%), and; 4) Teachers (16%). However, in the results of this review, there is also a No Coding category of 37%. The articles included in No Coding come from articles from SJR: 2023 in Q1, Q2, and NO SJR. This category emerged because we did not find the participants used. There are no additional sub-codes in the participant review because we consider that the code created already describes the information we want to obtain. These results explain that most research related to the development of AR in physics education is focused on high school students.

What is seen in Figure 7 makes sense because high school-age students have sufficient ability to learn abstract concepts (Demetriou et al., 2020). Unlike elementary or middle school students, they still need to learn through real objects. Even though high school students should use real objects, in some conditions, they can be invited to think abstractly. However, several studies have also developed AR at the elementary or middle school level, although it is not as complex as at the high school level and beyond (Hidayat et al., 2021; Rahmat et al., 2023; Sahin & Yilmaz, 2020). This result may be because this search focused on physics which is usually studied starting from the high school level. Meanwhile, at the elementary or middle school level in Indonesia, they still study science. Thus, it is not surprising that participants related to the development of AR physics are dominated by high school students. There are also participants in Figure 7 such as university students and teachers, but the results are not as big as high school students.

Instruments

The review results for instrument analysis show how the AR development process was carried out. These results provide insight into AR development, whether in testing or otherwise. The map of NVivo analysis results for instrument aspects can be in Figure 8.

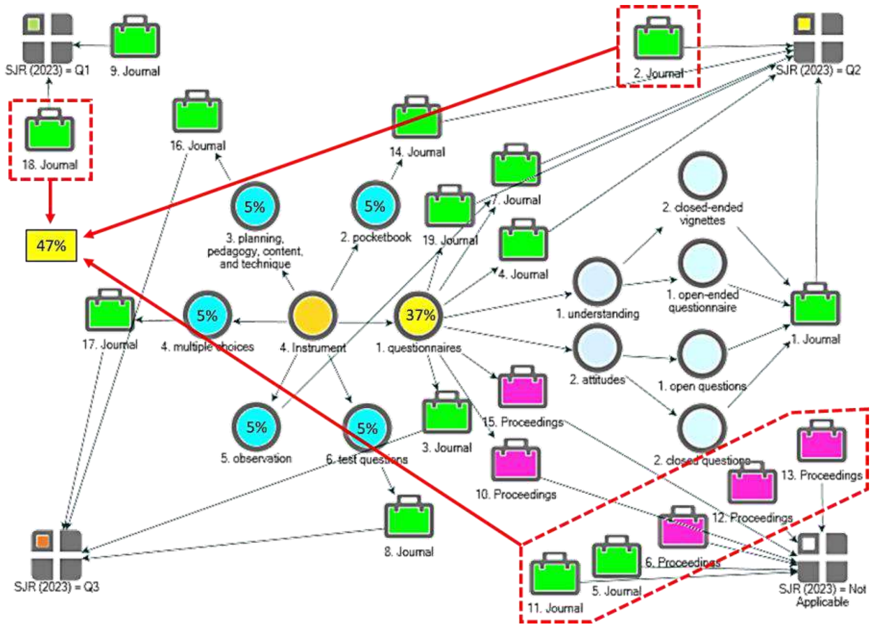

Figure 8. Map of analysis results from the instruments section

Figure 8 shows that in the development of AR, several instruments can be used with the most widely used being the instrument in code number 1 (Questionnaires) at 37%. For other codes (number: 2) Pocketbook; 3) Planning, pedagogy, content, and technique; 4) Multiple choices; 5) Observation, and; 6) Test questions) have a percentage of 5%. In this analysis, the real dominance found was in the No Coding category (47%). The articles included in No Coding come from articles from SJR: 2023 in Q1, Q2, and NO SJR. This is because articles that fall into this category were not identified based on our review regarding the instruments they used. This questionnaire instrument has 2 sub-codes (Understanding and Attitudes). Each of these sub-codes has 2 other sub-codes (Understanding (open-ended questionnaire and closed-ended vignettes) and Attitudes (open questionnaire and closed questionnaire). Based on these results, the instruments most widely used when developing AR are instruments in the form of questionnaires.

A questionnaire is a research instrument for collecting relevant data regarding the topic being researched (Taherdoost, 2022). This questionnaire instrument is widely used by various studies in various fields. Fairclough & Thelwall (2022) explained that the use of questionnaires between 1996 and 2019 increased threefold, and its dominance was in 27 Scopus fields. However, these results only present the results of the review found, the quality and use of which must be considered again according to the requirements of the provisions for making a correct questionnaire. Efforts to maximize the questionnaire are based on the research objectives and in deciding the hypothesis or research question, as well as what must be obtained in answering the research question or hypothesis.

Analysis

A review of the research question aspect of analytics was conducted to provide an overview of what analyses are typically used in AR development. These results can be a reference when developing AR in general or in physics education. A map of NVivo analysis results related to analysis aspects can be seen in Figure 9.

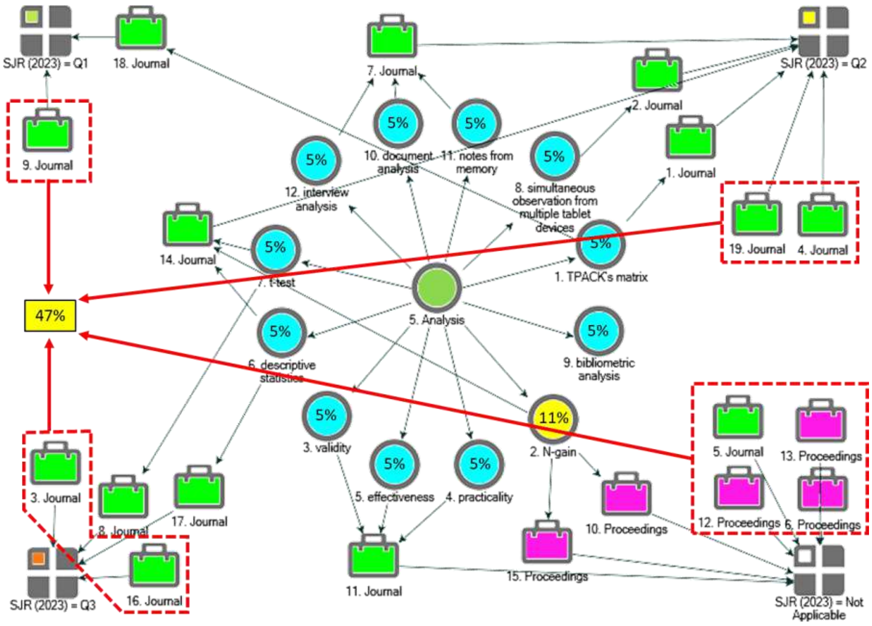

Figure 9. Map of analysis results from the analysis section

Figure 9 shows that the most code in the analysis aspect is code number 2 (N-gain) at 11%. Meanwhile, for other codes (number: 1) TPACK's matrix; 3) Validity; 4) Practicality; 5) Effectiveness; 6) Descriptive statistics; 7) T-test; 8) Simultaneous observation from multiple tablet devices; 9) Bibliometric analysis; 10) Document analysis; 11) Notes from memory, and; 12) Interview analysis) all have a percentage of 5%. However, based on the results of the review carried out, there were 47% of articles that fell into the No Coding category and came from SJR articles: 2023 Q1, Q2, Q3, and NO SJR. These results indicate that the article was not identified using the kind of analysis used in the research. Meanwhile, this aspect does not have additional sub-codes because we consider that the information provided has answered the research questions that have been asked. A review of the analysis aspect also illustrates that N-gain analysis is the most widely used in the development of AR in physics education.

The use of N-gain in research is very widely used. Gain normalization is a comparison between actual gain and maximum gain. Usually, the most widely used n-gain is the formulation by Hake (1998). Gain normalization provides an overview of the size of learning improvements or more objective and fair evaluation results of the various treatments provided. Identifying students' prior knowledge, the gain normalization helps researchers understand the effectiveness of the treatment used. So it is not surprising that the results of this review are also dominated by N-gain analysis because, in the education sector, there is a lot of identification of the success of a treatment.

Concept

An analysis of questions about concepts in AR development is presented in this section. We created a map based on the findings obtained. The mapping results from NVivo analysis for questions about concepts can be seen in Figure 10.

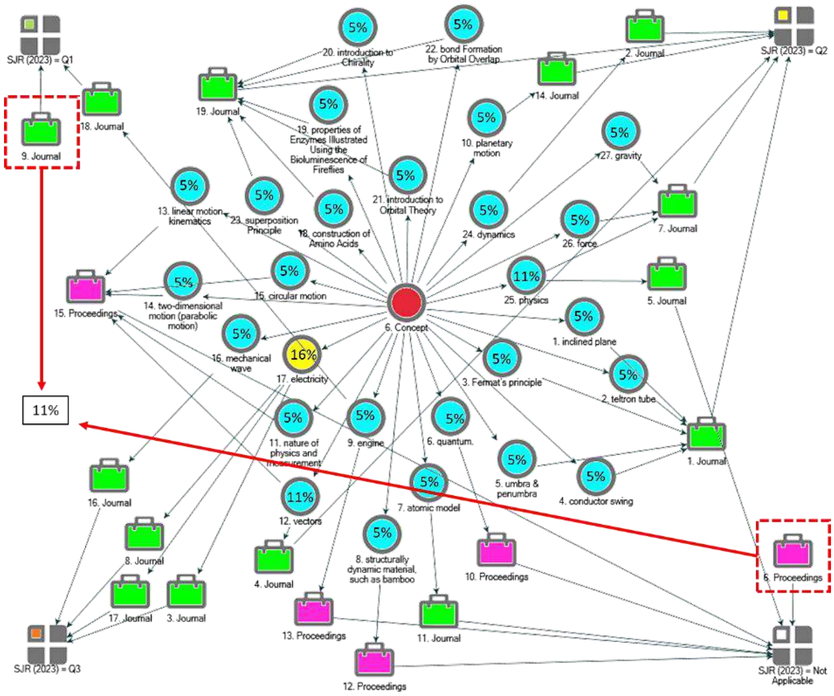

Figure 10. Map of analysis results from the concept section

Based on Figure 10, we see that the physics concept most often used in AR development is found in code number 17 (Electricity) as much as (16%). Meanwhile, for other codes, there are 27 codes (such as: 1) Inclined plane; 2) Teltron tube; 3) Fermat's principle; 4) Conductor swing; 5) Umbra & penumbra; 6) Quantum; 7) Atomic model; 8) Structurally dynamic materials, such as bamboo; 9) Engine; 10) Planetary motion; 11) Nature of physics and measurement; 12) Vectors; 13) Linear motion kinematics; 14) Two-dimensional motion (parabolic motion); 15) Circular motion; 16) Mechanical waves; 18) Construction of Amino Acids; 19) Properties of Enzymes Illustrated Using the Bioluminescence of Fireflies; 20) Introduction to Chirality; 21) Introduction to Orbital Theory; 22) Bond Formation by Orbital Overlap; 23) Superposition Principle; 24) Dynamics; 25) Physics; 26) Force, and; 27) Gravity) has a percentage of 5%, except for codes number 12 and 25 which is 11%. However, of the articles reviewed, there were also 11% of articles that were included in the No Coding category, meaning they were not included in any code. The articles included in No Coding come from articles from SJR: 2023 in Q1 and NO SJR. These results illustrate that the physics concept that is often used in AR development is the electricity concept.

The concept of electricity is indeed the concept that is most researched in research (Samsudin et al., 2023). However, other concepts in physics are widely researched, although the quantities are not as large as electricity. This is an opportunity for other research that some concepts may not have been included in the code resulting from this review. Almost all concepts in physics, if looked at more deeply, will require the help of media that can visualize them. It can be seen in Figure 10 that the total codes for this concept are 27 codes from the 19 articles reviewed. And this is also good news for other developments that will develop AR for other physics concepts.

Software or Device

Analysis of this aspect is one of the illustrations in this AR development research. The results of a review of the use of software or devices in AR development can be a reference that can be used. The map of this review can be seen in Figure 11.

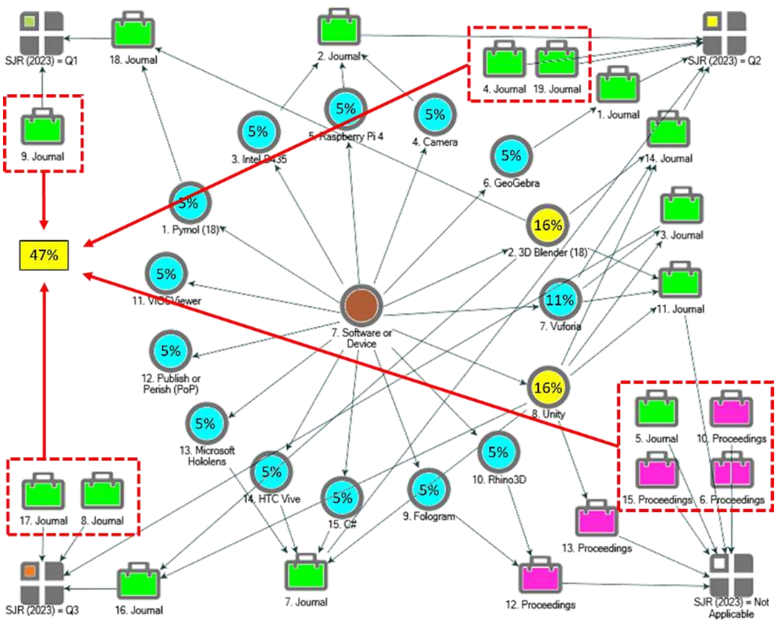

Figure 11. Map of analysis results from the software or device section

Figure 11 shows that there are 15 codes obtained based on the review made. The code with the highest percentage is code number 2 (3D Blender (18)) and number 8 (Unity) at 16%. For other codes (such as: 1) Pymol (18); 3) Intel D435; 4) Camera; 5. Raspberry Pi 4; 6) GeoGebra; 7) Vuforia; 9) Phologram; 10) Rhino3D; 11) VIOSViewer; 12) Publish or Perish (PoP); 13) Microsoft Hololens; 14) HTC Vive, and; 15. C#) has a percentage of 5%. Articles that do not explain the software or device used are included in No Coding with a percentage of 47%. The articles included in No Coding come from the SJR: 2023 articles in Q1, Q2, Q3, and NO SJR. These results illustrate that in AR development, the software or devices that can be used are 3D Blender and Unity.

This section is an important part because it provides information related to software that is usually used in developing AR. Usually, 3D Blender is used to create 3D objects and animations before they are created in AR simulations (Priyoatmoko & Arifah, 2020). Meanwhile, Unity is used to create AR based on the results from 3D Blender (Kassim & Bakar, 2021). Thus, 3D Blender and Unity have a very important role in AR development.

▪ CONCLUSION

The conclusions that can be drawn from this review based on the results obtained include:1) Based on the objective, the application used is AR (89%); 2) The method used is the development method (47%); 3) Most participants are high school students (42%); 4) The instruments used were questionnaires (37%); 5) N-gain analysis is the most widely used analysis (11%); 6) The physics concept used is electricity (16%), and; 7) The software or device used is 3D Blender (16%) and Unity (16%). Thus, we concluded that the development of AR for physics concepts has become interesting research over the last 5 years (2019-2024). The recommendation from this review is that when developing AR in physics learning, especially abstract ones, you can conduct research using development methods and 3D Blender and Unity software.

▪ ACKNOWLEDGMENTS

Thank you to the Directorate General of Higher Education, Research and Technology, Ministry of Education, Culture, Research and Technology for funding this research.

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