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Validation of Physics Augmented Reality-Based Learning Media on the Critical Thinking Skills and Visual Representation of Students in High School

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Abstract

This study aims to analyze: the feasibility of augmented reality (AR)-based learning media to improve students' critical thinking skills and visual representation. This research is an ADDIE (Analysis, Design, Developed, Implementation and Evaluation) development research. The Analysis stage consists of concept analysis, student analysis, and specification of learning objectives (2) Design, related to designing initial products from learning media, critical thinking test instruments and visual representation (3) Developed stage related to the stage of content feasibility testing as well as revision of critical results and suggestions from validators and field trials (4) Implement, which is the stage of implementing products with non-equivalent pretest postes control group design quasi experiment method (5) Evaluate, the evaluation process starts from the analysis stage to the implementation stage. The subjects in this study were 102 students of SMA N 8 Ternate city as a field trial. The products developed include learning media, feasibility assessment sheets, student response questionnaires and test instruments. The instrument developed was a question instrument in the form of 10 questions describing critical thinking skills and visual representation. The data analysis techniques carried out are descriptive and inferential analysis. The analysis also uses the ideal standard deviation (SBi) to assess the feasibility of learning media, and a questionnaire on the practicality of students. While the analysis using V Aiken is to assess the results of the analysis of critical thinking test instruments and visual representation. The result of this study is that augmented reality (AR)-based learning media on Newton's law material is suitable for use to improve critical thinking skills and visual representation

Keywords: *Learning Media; Augmented Reality (AR); Newton's Law; Critical Thinking; Visual Representation*

Introduction

21st century learning is currently evolving and it is important to do. In this learning, one of the abilities developed for students is the 7C skills (Critical Thinking, Collaboration, Communication, Creativity, Citizenship, Character, Curiosity) Nuraini et al. (2024). What educators need to prepare in developing these abilities are lesson plans, media development, and assessment instruments (Rudisnto, 2022). Therefore, in achieving this, it can be done through a learning and then assisted by learning media.

The development of science and technology in the 21st century is going very rapidly. The 21st century, which is marked by the industrial revolution 4.0, demands the improvement of the quality of human resources through educational pathways ranging from primary, secondary to tertiary education as the key to being able to keep up with the development of the Industrial Revolution 4.0. Saputri et al., (2022) The era of the industrial revolution 4.0 which emphasizes the digital economy, artificial intelligence, big data and robotics, requires the world of education to think creatively, think critically, master technology and digital literacy skills. 21st Century Learning in Indonesia is realized through the 2013 curriculum (Putro et al., 2019) and the independent curriculum. Learning in the classroom is expected to be able to train 21st century skills. Among the 21st century skills are critical thinking, problem solving, decision-making, Communication, Collaboration (teamwork), Information Literacy, Communication and Technology (Fatmawati, 2019). In this 21st century, a teacher in carrying out the teaching and learning process is expected to be able to innovate learning, have teaching skills that are able to balance with current conditions, be able to design learning that is interesting, fun and meaningful and others (Inayati, 2022). The concept of teaching and the perspective on education changed as a result of the shift in education that occurred in the modern era.

Learning in the 21st century does not only depend on knowledge, but focuses on skills and understanding of concepts. However, in reality, critical thinking skills and visual representation are still in the low category. Sudibyo (2022) stated that students lack confidence, fear of being wrong, find it difficult to string together words, consider the material too difficult and lazy. In addition, Critical thinking does have a variety of benefits, but if not used wisely, it can lead to some drawbacks. People who analyze too much often have difficulty making decisions, which can lead to anxiety and stress (Nugraha Ady et al., 2024). This causes many students to experience weaknesses in critical thinking. The development of critical thinking skills requires representation as a visualization of the results of thought. The importance of visual representation skills in an effort to develop thinking skills is very necessary for students. The weak visual representation ability in students is due to the difficulty of describing abstract concepts, can be misinterpreted, relies on technology, lacks mathematical detail, and can make students focus more on images than concepts (Hasanah & Gunawan, 2025). Syahrial et al. (2022) weaknesses in visual representation, such as unclear images, static media, and lack of support for mathematical understanding. In addition, the lack of real-life examples makes the concept feel less relevant, and the technology used is still traditional.

Physics learning requires a good understanding of concepts, but there are several cases in learning in school the physics material taught makes students not understand the material because of conventional teaching methods or using lecture methods. Physics also discusses the concepts and laws of physics as a product and conducts observations, experiments, and investigations as a learning process (Kd Aristawati et al., 2018). Some abstract and complex concepts such as mechanics, optics, and thermodynamics are difficult to understand only with conventional learning that is limited to textbooks and two-dimensional presentations. Learning physics is not just a collection of formulas and concepts that must be remembered. Some concepts can be presented in a variety of ways, known as multirepresentation. Representation itself means something that represents, depicts, or symbolizes an object and/or process. While multirepresentation means rerepresenting the same concept in a different format, for example into the form of verbal, visual, and/or mathematical representations (Marzuqah et al., 2019). Visual representation is one of the most effective ways in teaching and improving students' understanding, as it has the ability to display information through various types of media, including images, animations, videos, infographics, and others.

The development of technology and information, learning media plays an important role in helping in the teaching and learning process, so that an educator can take advantage of learning media that is starting to develop to be used as a tool in conveying material so that the teaching and learning process is easier to do (Sapriyah, 2019). The development of technology is characterized by the existence of several applications that can be used as teaching media to help in the learning process. Learning media is

an important element in the learning process. Media as one of the components in the learning system, has a function as a means of non-verbal communication. As one of the components of the system, it means that the media must absolutely exist or must be used in every learning (Magdalena Nona et al., 2023). Learning media is used as a learning resource that can help teachers in enriching students' insights, with various types of learning media by teachers, it can be material in providing knowledge to students. The use of learning media can foster students' interest in learning new things in the learning material delivered by the teacher so that it is easy to understand. Learning media that is interesting to students can be a stimulus for students in the learning process.

The development of learning media is a means to visualize the learning process that is often used in physics teaching. Physics is a subject that requires an understanding of concepts that are hierarchically related to each other, many people consider that this Physics lesson is very saturated so that it seems that this Physics makes students passive in the learning process, so this greatly affects the results of the learning obtained, learning Physics means trying to get to know real life processes, Therefore, the teaching needs to be delivered with the right media so that the learning goals can be achieved. There are 2 types of learning media development, namely: (a) 2-dimensional learning media, which is a medium that only has a length and width size that is on one flat plane. For example, books, worksheets, powerpoints, flipbooks, etc.; (b) 3-dimensional learning media is a medium that allows the virtualization of learning objects into computers. 3D virtualization technology has been widely developed to simulate various needs, be it in the field of architecture, system design, and so on (Ashari, 2023). This technology allows the representation of objects to be displayed virtually to students, one of which is *augmented reality* and virtual reality.

Augmented Reality (AR) is the latest technology that can be a solution for educators to present learning that is innovative, informative, interesting, and can present virtual objects in virtual 3D in real form and presented in real time (real time) (Aripin & Suryaningsih, 2019). Mustaqim et al., n.d. (2017) Augmented Reality is an application that combines the real world with the virtual world in the form of two-dimensional or three-dimensional that is projected in a real environment at the same time. So it can be concluded that Augmented Reality (AR) is a technology that combines the real world with virtual elements added in real-time. This technology can provide a more realistic and interactive visual representation, so that students can better understand physics concepts. The use of AR in physics learning can help students visualize the motion of objects, understand the relationships between variables, and develop critical thinking skills in analyzing physical phenomena. However, Indonesian learning currently does not apply the use of AR.

The lack of real implementation that *Augmented Reality* (AR) has not been implemented as a mandatory medium in educational institutions, but it does not provide concrete case studies or empirical data demonstrating its effectiveness and the lack of perspectives from students and teachers in this study makes it difficult to assess how AR is actually accepted and utilized in learning Nistrina (2021). Sari et al. (2024) Teachers need to understand how to integrate technologies such as AR into learning in order to encourage students to think critically.

As a result of observations and interviews with teachers at SMAN 8 in Ternate city, the author still found that teachers still use conventional learning media (PPT, Whiteboard, etc.) in learning physics. This is supported by research from (Andriani & Ramadani, 2022) Many of the students do not pay attention to the explanation of teachers who are still teaching using conventional methods and whiteboard assistance without using innovative learning media which causes learning to be monotonous. The learning media used today is less interactive and less able to attract students' interest in physics. This results in students having difficulty understanding physical concepts and being less able to develop their critical thinking skills.

Method

The instrument feasibility validation sheet utilizes 4 interval scales of V Aiken validation data analysis. The power process is carried out in steps

a. Compiling a table of the results of the validation from the expert
b. Measuring the validity coefficient of the content using V Aiken (Aiken Lewis R, 1985)

$$V = \frac{\Sigma s}{[n\,(c-1)]}$$

V = Content validity coefficient
s= The sum of s of n rater s – l_0
r = Score given by validators
l_0 = The lowest validity assessment score (in this case =1)
c = The highest validity assessment score (in this case =4)
n = Number of validators

The aiken V index for each item is converted into qualitative data with a range of 1 to 0. The results of the validation analysis are compared with the *right-Tail Probabilities* (P) *for selected Value of Validity Coefficient* (V) table that for a scale of 4 with 7 validators, the instrument is said to be valid if the coefficient = 0.86 (Aiken, 1985)

Table 1. Eligibility assessment category criteria

Formula	Category
$X \geq X_i + 1{,}8SB_i$	Excellent
$X_i + 0{,}6SB_i < \times \leq X_i + 1{,}8SB_i$	Good
$X_i - 0{,}6SB_i < \times \leq X_i + 0{,}6SB_i$	Enough
$X_i - 1{,}8SB_i < \times \leq X_i - 0{,}6SB_i$	Less
$\times \leq X_i - 1{,}8SB_i$	Very Less

Keterangan

X= Average score ($\frac{Xi}{n}$) With X_i is the total score from *i* Wed *n* and *n* is the number of validators

X_i = rerata ideal $\frac{1}{2}$ (Maximum score + minimum score idel)

SB_i = Ideal Deviation $\frac{1}{6}$ (Idela Maximum Score – Ideal Minimum Score)

Minimum score of idel = number of criteria items x lowest score

Results and Discussion

Feasibility of Measurement Instruments

Products rated by experts using a qualification measuring instrument. The measurement instrument must be validated first before being given to experts. The measurement instruments in question are test instruments for critical thinking and visual representation, and questionnaire instruments

for students' practicality. The instrument was validated by two experts, namely physics lecturers and 5 practitioners, namely physics teachers. The results of the validation of the measurement instrument are as follows:

Results of the Feasibility Study of Critical Thinking Ability Test and Visual Representation

The critical thinking ability test instrument is in the form of 7 *essay questions*, while the critical thinking ability test instrument is in the form of 3 *essay questions*. The feasibility assessment is seen from the material, construction, and language aspects. The validation results are calculated using *the V Aiken equation.* The validation results are shown in table 2.

Table 2. Results of the Feasibility Test of Critical Thinking Ability and Visual Representation

No	Aspects	Grain	Value	Category
1	Material	Question Items according to the question indicator	0.86	Valid
2		Question items are suitable for measuring critical thinking skills and visual representation	0.76	Valid
3		The material in the questions is in accordance with the Learning Objectives (TP)	0.86	Valid
4	Construction	The statement of the question item is clearly formulated	0.81	Valid
5		Question items do not depend on the previous question	0.81	Valid
6		Logical and rational answers	0.76	Valid
7		There are scoring guidelines	0.81	Valid
8		There are instructions for working on the questions	0.76	Valid
9		Clearly presented images	0.86	Valid
10	Language	Questions about using language according to the General Guidelines for Indonesian Spelling (PUEBI)	0.86	Valid
11		Using commonly used terms	0.76	Valid
12		Communicative in formulating statement sentences.	0.76	Valid
13		Do not use multi-interpreted sentences	0.81	Valid
Average amount			0.81	Valid

Based on the critical value of V Aiken in the table, for the number of validators of 7 people, the minimum value of V Aiken for an item is said to be valid is 0.76. The results of the analysis of V Aiken's calculations show that all critical thinking ability questions meet the criteria of V Aiken's critical value of

0.81 so that all test questions on critical thinking ability and visual representation are declared valid and can be used.

Results of the Feasibility Study of Students' Practicality Questionnaire

Feasibility assessment is seen from the Appearance, Presentation of the material, media operation and media benefits. The feasibility study was carried out by 35 students and the test was limited. The results of the feasibility study of the practical questionnaire items for students are listed in table 3.

Table 3. Eligibility Test Recapitulation

No	Aspects	Total Average Score	Category
1	Display	16,382	Excellent
2	Presentation of Materials	9,918	Excellent
3	Media Operation	7,596	Excellent
4	Media Benefits	9,507	Excellent

The results of the calculation using SBi show that the value of all questions on the practical questionnaire of the peseeta didik is very good. This shows that all students' practical questionnaire questions are valid and can be used.

Results of Learning Media Eligibility Study

The feasibility assessment of learning media is seen from the material aspect and the media aspect. The assessment of the material aspects is divided into 3 assessment components, namely the content of Learning, Material and Language. The media aspect is seen from 4 components of presentation, namely Visual Display, Design, Implementation and Engineering of Software. The material that is included in this learning media is Legal material. The feasibility study of learning media was carried out by 2 lecturers who are experts in the material and 5 practitioners. The data on the feasibility assessment of *learning media was* analyzed using the SBI average equation (ideal standard deviation) to determine the eligibility criteria for learning media. The scores of the study results are listed in tables 4 and 5.

Table 4. Results of Learning Media Feasibility Analyst from Material Experts

Aspects	Value	Category
Learning	5.564	Highly Worth It
Material	13.953	Highly Worth It
Purpose	6.456	Highly Worth It
Average	8.658	Highly Worth It

Table 5. Results of Feasibility Analysis of Learning Media by Media Members

Aspects	Value	Category
Visual Display	11.014	Highly Worth It
Design	6.685	Highly Worth It
Execution	4.495	Highly Worth It
Software Engineering	2.580	Highly Worth It
Average	6.194	Highly Worth It

Based on tables 4 and 5 in the results of the feasibility assessment of learning media, seen from the material aspect, obtained a score of 8,658 with very feasible criteria, while the media aspect of 6,194 criteria is feasible so that the learning media is based *on augmented reality* (AR). The calculation of the feasibility assessment of learning media from the material and media aspects using SBi is more complete attached in the appendix.

Limited Trial Results

The limited trial aims to see the readability of learning media before it is implemented in learning. Through a limited trial, it is known that the students' response to *augmented reality* (AR)-based learning media is known. The limited trial was carried out in class XI D at SMAN 8 Ternate City with 35 students. The data is based on the results of the student response questionnaire. The limited trial was only carried out in one class because the class was made quite representative of the students' abilities based on physics learning outcome data. The results of the readability of augmented reality *(AR)*-based learning media can be seen in table 6.

Table 6. Results of Students' Responses to Augmented Reality *(AR)*-Based Learning Media in Limited Trial Classes

Aspects	Category	Kategori
Display	14,043	Highly Worth It
Presentation of Materials	9,745	Highly Worth It
Media Operation	7,405	Highly Worth It
Media Benefits	9,590	Highly Worth It
Average	10,195	Highly Worth It

The data above shows that all aspects of obtaining a very feasible category based on the ideal standard deviation criterion of 10.19. Some of the obstacles encountered in the use of this learning media are the problem of the availability of data packages and the smooth internet network. The solutions carried out are using school wifi, using cellular network backups from different providers and collaboration between friends in a group during the learning process.

Conclusion

Augmented reality (AR)-*based learning media* is suitable for use in learning physics of Newton's law materials to improve critical thinking skills and visual representation based on the assessment of material experts of 0.80 and media experts of an average of 0.83 are classified as very feasible, and the assessment of students of 10.195 is considered feasible.

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