PERJ
Physics Education Research Journal
ISSN 2685 - 6190 (p)
ISSN 2714 - 7746 (e)
Department of Physics Education
Faculty of Science and Technology
UIN Walisongo Semarang-Indonesia

Developing Physics Learning Media Based on Augmented Reality to Improve Students' Critical Thinking Skills

Hannatun Nusroh[1], Muhammad Ardhi Khalif [2], and Affa Ardhi Saputri[1*]

[1]Physics Education Department, Universitas Islam Negeri Walisongo Semarang, Indonesia
[2]Physics Department, Universitas Islam Negeri Walisongo Semarang, Indonesia

ARTICLE INFO

Article history:
Submitted : November 11th, 2021
Revised : January 28th, 2022
Accepted : February 19th, 2022

Keywords:
Augmented reality; critical thinking; learning media; optical devices.

ABSTRACT

Media has a significant role in achieving learning objectives, including critical thinking skills. This study develops Augmented Reality-based physics learning media to improve students' critical thinking skills in XI class of senior high schools on optical instruments. This is Research and Development (R&D) through the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The study was conducted with a small-scale trial of 30 students of XI class MIPA 1 MAN Demak. The instruments used were expert validation sheets, teacher and student response sheets, and pre-test and post-test questions for students' critical thinking skills. The product feasibility test is carried out based on the validation results of media and material experts. N-gain test is used to determine the improvement of students' critical thinking skills. The feasibility test results show that Augmented Reality-based learning media on optical instruments is feasible, with a feasibility score percentage of 78.79% (valid) based on media experts and 90% (very valid) based on material experts. The learning media received an excellent response from the physics teacher with an average score of 4.27 (very good) and 4.28 (very good) from the students. The use of physics learning media has increased students' critical thinking skills, based on the N-gain test results of 0.415 with moderate improvement criteria. Augmented Reality-based learning media can be applied to improve students' critical thinking skills.

Introduction

Schools are educational institutions that function to prepare the nation's next generation. The results of the current educational process contribute to the main actors in Indonesia's golden generation in 2045. It is crucial to prepare for education from now. One of the efforts to prepare for Indonesia's golden age is to improve the quality of education (Darman, 2017).

The quality of education can be improved by implementing various strategies. Strategies to improve the quality of education include making learning innovations and promoting literacy skills (Retnaningsih, 2019). Learning innovations can be carried out in various aspects. They are the methods used, materials/media/learning resources, and the assessment and evaluation process.

Learning media plays a vital role in the success of the learning process. The primary function of learning media is a tool in the teaching and learning process. The use of media can stimulate the activation and improvement of both aspects of students' attitudes, knowledge, and skills to achieve learning objectives. Innovation in learning media makes its role broader and more meaningful. One of them, teaching media, is developed to improve higher-order thinking skills (Yusuf & Widyaningsih, 2019).

Higher-order thinking skills are complex learning skills that involve problem-solving and critical thinking

*Correspondence email: affaardhi@walisongo.ac.id
doi: 10.21580/perj.2022.4.1.10912

skills. High critical thinking skills make a person acquire intellectual resources such as background knowledge, operational knowledge of appropriate standards, key concepts, practical heuristic thinking, and good thinking habits (Bailin et al., 1999). Critical thinking skills are not a new concept. Critical thinking skills are currently being highlighted because they are considered essential skills, especially as a provision in facing global challenges. A model of critical thinking skills is designed to improve students' thinking skills and meet international competition and complex social conditions (ŽivkoviĿ, 2016).

Training students' critical thinking skills in education is one of the efforts to prepare Indonesia's golden generation in 2045 (Darman, 2017). The student's critical thinking skills profile in Indonesia is still below. This is evidenced by Indonesia's achievement in the PISA (Program for International Student Assessment) assessment. Critical thinking skills are one aspect of the evaluation in the program. Indonesia is in the bottom 10 of the 79 countries participating in the PISA assessment (Kemendikbud, 2019). This is reinforced by several studies on students' low critical thinking skills in Indonesia in physics subjects (Nurazizah et al., 2017).

Critical thinking skills of students are essential to be trained and developed. Teachers as educators are expected to be able to facilitate the development of students' critical thinking skills. Innovation and development of learning media can facilitate training and development of students' critical thinking skills.

The characteristics and types of learning media are very diverse. Various research on learning media has been carried out to improve students' critical thinking skills. Today's learning media innovation involves information and communication technology. Media with the technology has succeeded in enhancing students' critical thinking skills, including the use of tracker applications (Wati et al., 2020); application of virtual laboratory media PhET simulation (Putranta & Kuswanto, 2018); as well as the application and development of media with Augmented Reality technology.

Augmented Reality (AR) is a technology used to image objects in the natural environment in a two-dimensional form and project them in a three-dimensional structure (Affandi et al., 2014). This media has been applied to various fields ranging from medicine, games, and image processing. However, this media is rarely used in education (Mustaqim, 2016).

Augmented Reality Media has been applied to various models and learning materials. Augmented Reality supports the learning process, improves student learning outcomes, and makes physics concepts more real (Wulandari et al., 2021). Augmented Reality also enhances students' critical thinking skills in physics learning (Herliandry et al., 2021).

Optical tools are one of the physics materials rich in concepts and visualized in videos or animations. Optical instruments contain images often encountered in everyday life to be interesting for students in the investigation process (Azizah et al., 2019). The utilization of augmented reality media can assist in visualizing the concept of optical devices in three-dimensional form. This study aims to develop Augmented Reality-based learning media on optical instruments to improve students' critical thinking skills.

Methods

This research is a research and development through the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The data collection instruments used are 1) product validation sheets, 2) teacher response questionnaires, 3) student response questionnaires, and 4) questions of pretest and post-test of critical thinking skills.

The product feasibility test involves one material expert and one media expert. Table 1 is an expert validation criterion with a Likert scale of 1-4.

Table 1
Media Validity Assessment Criteria (Akbar, 2013)

Average Score	Criteria
85,01%-100%	very valid, it can be used without revision
70,01%-85%	valid, it can be used but needs minor revision
50,01%-70%	less valid, it is recommended not to use it because it needs a major revision
1%-50%	invalid or cannot be used

Product readability test in the learning process through responses from one teacher as an education practitioner and 15 students. Table 2 is the product readability criteria.

The trial was to determine the improvement of critical thinking skills involving 30 students. Analysis of students' critical thinking skills improvement using N-gain. Table 3 shows the criteria for improving students' critical thinking skills.

$$g = \frac{\%S_{post} - \%S_{pre}}{100 - \%S_{pre}} \quad (1)$$

Information:
S_{pre} = average score pretest
S_{post} = average score posttest

Table 2
Criteria for Assessment of Teacher and Student Responses (Sugiyono, 2009)

Average Score ($\bar{x}$)	Criteria
$4{,}20 < \bar{x} \leq 5{,}00$	Very good
$3{,}40 < \bar{x} \leq 4{,}20$	Good
$2{,}60 < \bar{x} \leq 3{,}40$	Good enough
$1{,}80 < \bar{x} \leq 2{,}60$	Less
$1{,}00 < \bar{x} \leq 1{,}80$	Very less

Table 3
Criteria for improving critical thinking skills (Lestari & Yudhanegara, 2015)

N-gain Score	Criteria
$(g) < 0{,}3$	Low
$0{,}3 \leq (g) < 0{,}7$	Medium
$(g) \geq 0{,}7$	High

Result and Discussions

Augmented Reality-based learning media is developed in seven components. The components of learning media consist of 1) cover; 2) instructions for using media; 3) learning objectives; 4) AR scans; 5) Material; 6) sample questions; and 7) discussion of questions. Table 4 shows the design of the Augmented Reality learning media base.

Figure 1
Cover Learning Media Based on Augmented Reality

The application's cover contains the logo of UIN Walisongo Semarang, the title of the material studied, and the author's name. Instructions for using the media have guidelines for learning media that are made simple so that students easily understand them. Learning objectives describe the students' competencies. AR scan contains space for scanning objects with optical instruments to produce 3D images. The material comprises an explanation of material about optical devices. Sample questions have questions that serve as a stimulus for students' critical thinking on the material being studied. The answer key contains an answer key that discusses the questions from the sample questions so that students can learn them.

Table 4
Augmented Reality-Based Learning Media Design on Optical Instruments Materials to Provide Improvements to Students' Critical Thinking Skills

Design	Information
Product Specification	The application size is 231 MB; it consists of 6 menus, namely instructions, learning objectives, AR scan, materials, practice questions, and discussion of questions. There are following and back navigation icons and menus on each slide. The use of applications can be done offline without requiring the internet to connect to a smartphone.
Topics	Optical Instruments
Language	Indonesia
Content	There is a cover at the beginning of the media and six menus in the learning media, namely instructions for use, learning objectives, AR scans, learning materials, practice questions, and discussion of questions.

Table 5
Media Expert Rating

Aspects of assessment	Total score	Eligibility Percentage (%)
Software engineering	38	76%
Instructional design	31	77,5%
Visual communication	29	82,8%
Total Skor	98	
Average	3,92	78,79%
Criteria	Valid	

The product validation results are listed in Table 5 based on media experts and Table 6 based on material experts. Product validation from the media expert's point of view covers aspects of software engineering, instructional design, and visual communication.

Meanwhile, from the point of view of a material expert, it includes elements of the feasibility of the content and the presentation.

Table 6
Material Expert Assessment

Aspects of assessment	Total score	Eligibility Percentage (%)
Content	14	93,33%
presentation	13	86,67%
Total	27	
Average	4,5	90%
Criteria	Very Valid	

The product readability test in learning was carried out through the responses of one physics teacher and 15 students. Based on the results of the readability test, it was obtained that the Augmented Reality learning media was responded to very well by teachers and students. Table 7 shows the results of user responses (teachers and students) to the readability of the product.

Table 7
Student Response Assessment

No.	Respondent	Total	Average
1	Teacher	1	4,27
2	Student	15	4,28
Criteria		Very good	

The implementation of AR media to improve students' critical thinking skills was tested with the N-gain test. Calculation of N-gain on students' critical thinking skills obtained results of 0.415 in the medium category. The pretest and posttest results of students' critical thinking skills can be seen in Table 8.

Table 8
The average results of the pretest and posttest scores of students' critical thinking skills.

No.	Information	Average Score	N-gain
1.	Pretest	66,67	0.415
2.	Posttest	80,5	

Improving the quality of education begins with innovating in various aspects. One of them is the innovation of learning media or learning resources used. Appropriate learning resources can attract students' attention and arouse students' interest in learning in the learning process (Handayani & Rahayu, 2020). AR learning media is designed with an attractive appearance and is easy to use. Students welcome the existence of Augmented Reality-based learning media as a learning application in an independent learning process. Students are more interested in the learning process assisted by flexible learning applications or mobile learning than conventional ones. This is also reinforced by the NCTM (National Council Of Teachers of Mathematics) statement that using technology in authentic learning is essential because it affects the material being taught and increases the quality of education (NCTM, 2000). AR learning media is designed with an attractive appearance and is easy to use. Students welcome the existence of Augmented Reality-based learning media as a learning application in an independent learning process. Students are more interested in the learning process assisted by flexible learning applications or mobile learning than conventional ones. This is also reinforced by the NCTM (National Council of Teachers of Mathematics) statement that using technology in authentic learning is essential because it affects the material being taught and increases the quality of education.

Mobile learning is an innovation in education to improve a superior society in the digital era (Surahman, 2019). Students must be literate in information technology, especially mobile learning. Mastery of technology aims to enable students to adapt to various developments in science and technology. The student's readiness for technological developments impacts broader thinking and views. AR learning media creates mobile learning technology and functions as a bridge between education, society, and technological developments.

Learning through mobile learning technology has been identified as one of the strategies that can improve students' higher-order thinking skills (Hwang et al., 2014). AR learning media supports improving students' higher-order thinking skills, starting from the operating process and how the media works to the content contained in the learning media.

AR learning media can improve higher-order thinking skills, one of which is critical thinking skills. Learning media provides an attractive display of objects provides training materials to hone students' critical thinking skills. Through augmented reality learning media, students can access information and carry out learning independently because of the nature of mobile learning that is not limited by space and time. Mobile technology (mobile learning) can improve critical thinking skills because students can develop their understanding and solve problems without the presence of a teacher (Ismail et al., 2016). Besides being flexible (it can be accessed anytime), AR learning media can be accessed offline. Augmented Reality learning media is a breakthrough in creating a smarts society and improving students' critical thinking skills.

Conclusions

Augmented Reality learning media has been successfully developed on optical materials. The feasibility test results show that Augmented Reality-based physics learning media is feasible to use as a learning media, with a feasibility score percentage of 78.79% (valid) based on media experts and 90% (very valid) based on material experts. The media readability test in the learning process by users got an excellent response based on the physics teacher with an average score of 4.27 and 4.28 based on students. Learning media increased students' critical thinking skills based on the N-gain test results of 0.415 with moderate improvement criteria. This AR learning media can be developed again for other materials as a breakthrough in creating an intelligent society and improving students' critical thinking skills.

References

Affandi, H., Suwarna, I. P., & Hertanti, E. (2014). Pengaruh Media Pembelajaran Berbasis Augmented Reality terhadap Hasil Belajar Siswa Kelas X pada Konsep Dinamika Partikel. *Tarbiya*, *1*(1), 1–43.

Akbar, S. (2013). *Instrumen Perangkat Pembelajaran*. Pemaja Rosdakarya.

Azizah, L. M., Poernomo, J. B., & Faqih, M. I. (2019). Pengembangan Modul Pembelajaran Fisika Kekas XI MA/SMA Berbasis Guided Inquiry pada Materi Alat-Alat Optik. *Physics Education Research Journal*, *1*(1), 11. https://doi.org/10.21580/perj.2019.1.1.4006

Bailin, S., Case, R., Coombs, J. R., & Daniels, L. B. (1999). Conceptualizing critical thinking. *Journal of Curriculum Studies*, *31*(3), 285–302. https://doi.org/10.1080/002202799183133

Darman, R. A. (2017). Mempersiapkan Generasi Emas Indonesia Tahun 2045 Melalui Pendidikan Berkualitas. *Edik Informatika*, *3*(2), 73–87. https://doi.org/10.22202/ei.2017.v3i2.1320

Handayani, D., & Rahayu, D. (2020). Pengembangan Media Pembelajaran Interaktif Berbasis Android Menggunakan Ispring dan APK Builder. *Jurnal Matematika Dan Pendidikan Matematika*, *5*(1), 12–25.

Herliandry, L. D., Kuswanto, H., & Hidayatulloh, W. (2021). Improve Critical Thinking Ability Through Augmented Reality Assisted Worksheets. *Proceedings of the 6th International Seminar on Science Education (ISSE 2020)*, *541*(Isse 2020), 470–475. https://doi.org/10.2991/assehr.k.210326.067

Hwang, G. J., Shi, Y. R., & Chu, H. C. (2014). A Concept Map Approach to Developing Collaborative Mindtools for Context-Aware Ubiquitous Learning. *British Journal of Educational Technology*, 778–789.

Ismail, N. S., Harun, J., Md Salleh, S., & Megat Zakaria, M. A. Z. (2016). Supporting Students Critical Thinking With a Mobile Learning Environment: a Meta-Analysis. *INTED Proceedings*, 3746–3755.

Kemendikbud, B. (2019). Pendidikan di Indonesia belajar dari hasil PISA 2018. *Pusat Penilaian Pendidikan Balitbang Kemendikbud*, *021*, 1–206. http://repositori.kemdikbud.go.id/id/eprint/16742

Lestari, E. ., & Yudhanegara, R. . (2015). *Penelitian Pendidikan Matematika*. PT Refika Aditama.

Mustaqim, I. (2016). Pemanfaatan Augmented Realityy Sebagai Media Pembelajaran. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *13*(2), 174–183.

NCTM. (2000). *Principles and Standards for School Mathematics*. The National Council of Teachers of Mathematics, Inc.

Nurazizah, S., Sinaga, P., & Jauhari, A. (2017). Profil Kemampuan Kognitif dan Keterampilan Berpikir Kritis Siswa SMA pada Materi Usaha dan Energi. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *3*(2), 197–202. https://doi.org/10.21009/1.03211

Putranta, H., & Kuswanto, H. (2018). Improving Students ' Critical Thinking Ability Using Problem Based Learning (PBL) Learning Model Based on PhET Simulation. *SAR Journal*, *1*(3), 77–87. https://doi.org/10.18421/SAR13-02

Retnaningsih, D. (2019). Tantangan dan Strategi Guru di Era Revolusi Industri 4.0 dalam Meningkatkan Kualitas Pendidikan. *Prosiding Seminar Nasional: Kebijakan Dan Pengembangan Pendidikan Di Era Revolusi Industri 4.0.*, *September*, 23–30.

Sugiyono. (2009). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Alfabeta.

Surahman, E. (2019). Integrated Mobile Learning System (Imoles) Sebagai Upaya Mewujudkan Masyarakat Pebelajar Unggul Era Digital. *JINOTEP (Jurnal Inovasi Dan Teknologi Pembelajaran) Kajian Dan Riset Dalam Teknologi*

Pembelajaran, *5*(2), 50–56. https://doi.org/10.17977/um031v5i22019p050

Wati, S., Halim, A., & Mustafa. (2020). The impact of the media tracker on student critical thinking skills. *Journal of Physics: Conference Series*, *1460*(1). https://doi.org/10.1088/1742-6596/1460/1/012139

Wulandari, S., Wibowo, F. C., & Astra, I. M. (2021). A review of research on the use of augmented reality in physics learning. *Journal of Physics: Conference Series*, *2019*(1). https://doi.org/10.1088/1742-6596/2019/1/012058

Yusuf, I., & Widyaningsih, S. W. (2019). HOTS profile of physical education students in STEM-based classes using PhET media. *Journal of Physics: Conference Series*, *1157*(3). https://doi.org/10.1088/1742-6596/1157/3/032021

ŽivkoviĿ, S. (2016). A Model of Critical Thinking as an Important Attribute for Success in the 21st Century. *Procedia - Social and Behavioral Sciences*, *232*(April), 102–108. https://doi.org/10.1016/j.sbspro.2016.10.034