OmniaScience

Journal of Technology and Science Education
JOTSE, 2023 – 13(1): 53-64 – Online ISSN: 2013-6374 – Print ISSN: 2014-5349
https://doi.org/10.3926/jotse.1714

THE EFFECTIVENESS OF THE USE OF AUGMENTED REALITY-ASSISTED PHYSICS E-MODULE BASED ON PEDICAB TO IMPROVE MATHEMATICAL COMMUNICATION AND CRITICAL THINKING ABILITIES

Poppy Sari Dewi, Heru Kuswanto

Universitas Negeri Yogyakarta (Indonesia)

poppydewi02@gmail.com, herukus61@uny.ac.id

Received May 2022
Accepted July 2022

Abstract

This study aims to reveal the effectiveness of the use of an augmented reality-assisted physics e-module based on the local wisdom of the pedicab in improving mathematical communication and critical thinking abilities. The study used the 4D model. Empirical trials were conducted involving 255 grade XII students. The effectiveness test was conducted in class X with 36 students as the experimental class and 36 students as the control class at SMA Negeri 1 Depok, Sleman. The data analysis used the QUEST to see the validity and reliability of the items, and the MANOVA test was carried out to see the effectiveness of the media. The results showed that the augmented reality-assisted physics e-module based on the local wisdom of pedicab was effective in improving mathematical communication with a score of 0.40 (large) and critical thinking abilities with a score 0.11 (medium).

Keywords – Augmented reality, Mathematical communication, Critical thinking, E-module, Pedicab.

To cite this article:

Dewi, P.S., & Kuswanto, H. (2023). The effectiveness of the use of augmented reality-assisted physics e-module based on pedicab to improve mathematical communication and critical thinking abilities. *Journal of Technology and Science Education,* 13(1), 53-64. https://doi.org/10.3926/jotse.1714

---

1. Introduction

Students still find it difficult to understand physics concepts because they consider physics as a subject to memorize formulas. Physical events can actually be described visually, but there needs to be a special method that is expected to be able to explain these events so that they can be understood (Ajlouni & Jaradat, 2021; Rahmawati, Rustaman, Hamidah & Rusdiana, 2018). Students are required to read physics books without being equipped with supporting multimedia (Manurung & Panggabean, 2020; Sadaghiani, 2014). Media in the learning process equipped with multimedia can improve students' understanding of physics material (Kurniawan, Darmaji, Astalini, Kurniawan, Hidayat, Kurniawan et al., 2019; Suprapto, Ibisono & Mubarok, 2021). E-modules as alternative media are able to help students to learn more freely because they are not limited to time and place in the learning process, and therefore multimedia-based e-modules are usually better than print media modules as learning resources (Sadaghiani, 2014). This

development demands learning innovations, both media and learning resources in order to train the ability and independence of students, so that learning is more effective and dynamic.

The use of technology in learning has been widely applied so that smartphones are now a learning companion for students. The use of augmented reality technology can develop and contribute to higher order thinking skills. Augmented reality makes objects look real and allows students to interact with digital information using cell phones (Grinshkun, Perevozchikova, Razova & Khlobystova, 2021; Mailizar & Johar, 2021; Wahyu, Suastra, Sadia & Sunarni, 2020). Augmented reality makes a positive contribution by attracting the attention and interest of students in learning because it creates a unique and realistic learning experience so that it can increase student activity and achievement. (Sirakaya & Cakmak, 2018; Wahyu et al., 2020).

In physics teaching and learning, there are many abilities that students need in order to solve physics problems, such as mathematical communication abilities. Mathematical communication can translate physics concepts into mathematical formulas to solve a problem. Mathematical representation skills also include the ability to interpret mathematical symbols and equations into physical meaning. It is used to observe predictions and assumptions of a problem by using reasoning skills so that students can understand, make, and evaluate mathematical and systematic assumptions and arguments (Doran, 2017; Tajudin & Chinnappan, 2016; Purwadi, Sudiarta & Suparta, 2019). This ability can help students analyze a problem and help them solve it.

Expressing opinions in solving various problems systematically can improve student's critical thinking skills. Critical thinking skills include the high-level thinking skills that students must possess in solving a problem (Abdurrahman, Halim & Sharifah, 2021; Suhirman, Prayogi & Asy'ari, 2021). Critical thinking enables a person to be able to distinguish opinions and facts and prove the truth. They still find it difficult to understand the concepts of certain materials in each physics teaching topic (Habibi, Mundilarto, Jumadi, Gummah, Ahzan & Prasetya, 2020; Rahayu & Kuswanto, 2020; Sagala et al., 2019) and they often use mathematical communication abilities in learning and life (Docktor & Mestre, 2014).

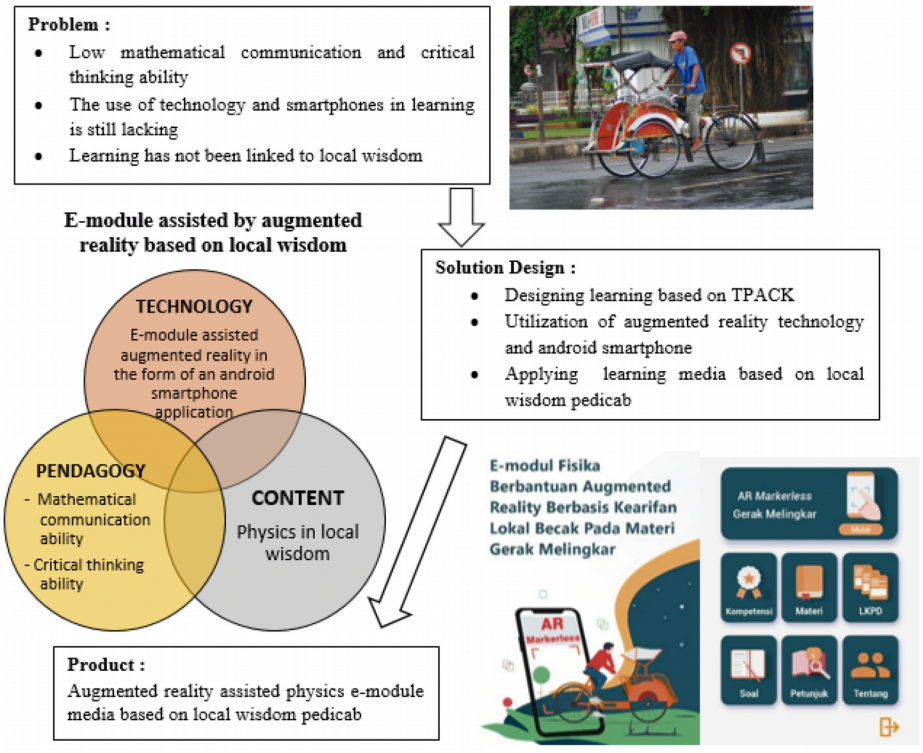

Figure 1. Problem solving framework

In this study, the concepts of physics are explained in one of the local wisdoms of Indonesia. Learning activities that are associated with local wisdom can motivate students and support learning (Liliarti & Kuswanto, 2018; Wati, Hartini, Hikmah & Mahtari, 2018). Introducing local wisdom to students through local transportation in education is one of the efforts to preserve local transportation, one of which is the pedicab. This three-wheeled vehicle has a lot to do with physics teaching material, namely the concept of circular motion such as linear velocity, angular velocity, and angular acceleration.

This study applies an augmented reality-assisted e-module based on the local wisdom of pedicab, which is effective in improving mathematical communication and critical thinking abilities. If the media has an appeal and makes students want to try it, then the media developed is expected to improve mathematical communication and critical thinking abilities in learning physics. The problem-solving framework can be seen in Figure 1.

2. Research Method

2.1. Method

This study used a quasi-experimental research design with the different treatments of two classes. The experimental class use of augmented reality-assisted e-module based on a pedicab, while the control class using manual book that are often used by physics teachers at SHS 1 Depok, Sleman. The research design as shown in Table 1.

Group	Pretest	Treatment	Posttest
Experimental Class	P_1	T_1	P_2
Control Class	P_1	T_2	P_2

Table 1. Research design

P_1: Test before being given treatment

P_2: Test after being given treatment

T_1: Physics teaching using AR e-module

T_2: Physics teaching not using AR e-module

2.2. Research Sample

Empirical tests were conducted to determine the validity and reliability of the test instrument on circular motion material. The empirical test was administered to grade XI Science students of Senior High School 6 Yogyakarta and Senior High School 9 Yogyakarta involving a total of 255 students. The selection was made in class XI Science because they had studied circular motion material. The effectiveness test was administered to grade X Science at Senior High School 1 Depok, Sleman.

2.3. Research Instrument

The research instruments used are lesson plans, augmented reality-assisted e-modules, power points, and a test. The test items in the circular motion chapter can be seen in Table 2.

Variable	Indicators	Treatment
Mathematical communication	Creating an equation from another given representation	Formulating mathematical equations from verbal representations
	Solving physics problems using mathematical equations	Solving physics problems using mathematical equations
	Examining the problem based on mathematical data in the given figure, table, diagram, graph, or equation	Presented with a picture of the relationship between several wheels, and then analyzing the ratio of the angular velocity and linear velocity between the wheels

Variable	Indicators	Treatment
Critical Thinking	Analyzing facts	• Analyzing facts presented in tables and/or important information in questions • Presented with an image of the front wheel of a pedicab, analyzing the magnitudes of circular motion and analyzing the event by observing the axis of the wheel
	Formulating problems	• Analyzing the event of the difference in the diameter of a pedicab wheel to speed to formulate the main problem in accordance with the concept of circular motion • Analyzing a pedicab incident on a sharp bend to formulate the main problem according to the concept of circular motion
	Defending, selecting, classifying, and evaluating logical arguments	Presented with several arguments, then analyzing and choosing the arguments that are considered appropriate according to the concept of circular motion and centripetal acceleration
	Drawing conclusions	• Explanation of the frequency and period relationship based on the concepts presented • Explanation of linear velocity conclusions based on the concept of circular motion on several wheels presented

Table 2. Matrix of variable and treatment

2.4. Data Analysis

The test items for mathematical communication and critical thinking abilities were analyzed for their validity and reliability by using the QUEST application. The validity of the items was seen from the infit mean square (MNSQ) value with a limit of 0.77 - 1.33 and if the OUTFIT t value was < 2 then the item was valid (Bond & Fox, 2007).

Mathematical communication and critical thinking abilities can be analyzed for improvement in the pretest and posttest data and then it was analyzed by using normalized gain (<*g*>) which could be calculated using equation (1) (Meltzer, 2002).

$$< g >= \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}} \quad (1)$$

The result of the normalized gain calculation was included in the criteria as shown in Table 3.

Gain Score	Interpretation
$-1.00 \leq g < 0.00$	Decrease
$g = 0.00$	No Increase
$g < 0.30$	Low
$0.30 \leq g \leq 0.70$	Medium
$g > 0.70$	High

Table 3. Interpretation of Normalized Gain

Statistically, the increase differences between mathematical communication and critical thinking abilities was calculated by using the MANOVA test on the SPSS application by first doing normality test (Shapiro Wilk-Kolmogorov Smirnov), homogeneity test (box's M), correlation test. The effectiveness test was carried out by means of effect size analysis and can be seen using the partial eta squared results in the Tests of Between Subjects Effects table on the MANOVA test (Cohen, 1988). Interpretation of partial eta squared as shown in Table 4.

Partial eta squares	Interpretation of Effect Size
0.00 – 0.10	Small
0.11 – 0.25	Medium
0.26 – 0.40	Large
> 0.40	Very Large

Table 4. Interpretation of partial eta squared

3. Results and Discussion

3.1. Result

3.1.1. Validity and Reliability of Mathematical Communication and Critical Thinking Ability Items Test

Validity and reliability are determined through empirical tests by testing the questions that have been made involving grade XI Science students. The empirical test analysis was carried out using the QUEST application. There are 14 questions consisting of six mathematical communication questions and eight critical thinking questions and that are in a fit state with PCM or suitable for use (valid). The infit mean square value is in the range of 0.77 to 1.33 as shown in Figures 2 and 3.

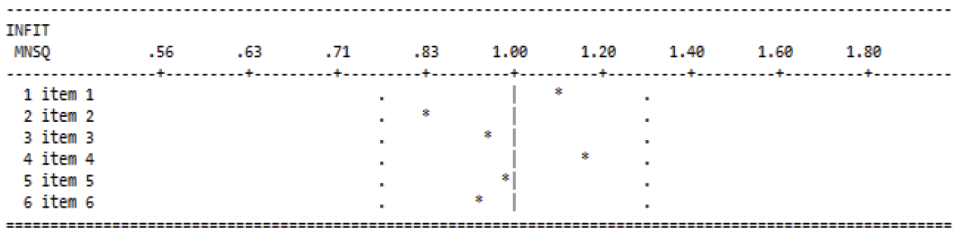

Figure 2. Results of the analysis of mathematical communication from infit mean square

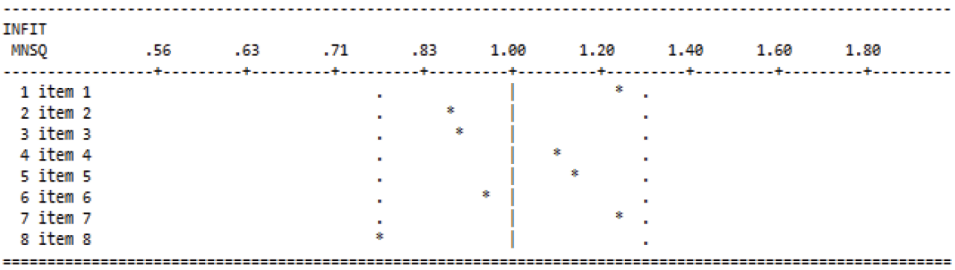

Figure 3. Results of the analysis of critical thinking from infit mean square

Mathematical communication and critical thinking abilities are categorized as reliable and can be seen by reading the summary of item estimates and summary of case estimates shown in Table 5.

Indicators	Summary of item estimates	Interpretation	Summary of case estimates	Interpretation
Mathematical Communication	0.61	Reliable	0.70	Reliable
Critical Thinking	0.63	Reliable	0.81	Very Reliable

Table 5. Results of the analysis of the reliability

The test instrument to measure mathematical communication and critical thinking abilities consisted of seven questions with all indicators represented in an essay form and they were declared valid and reliable so that they could be used.

3.1.2. Improvement in Mathematical Communication and Critical Thinking Ability

Mathematical communication and critical thinking abilities were measured by using essay tests on pretest and posttest. The experimental class was taught by using the augmented reality-assisted e-module based on local wisdom pedicab and the control class was taught by using the conventional teaching method. Each of the classes consisted of 36 students. The Normalized Gain (N-Gain) analysis was conducted to determine the improvement in mathematical communication and critical thinking abilities of both classes. The results of the N-Gain analysis can be seen in Table 6.

Increase in N-Gain between the experimental and control classes if the graph can be seen in Figure 4.

The statistical test analysis used IBM SPSS Statistics 21 software. Before conducting analysis using multivariate test (MANOVA) to determine the effect of augmented reality-assisted physics e-module based on local wisdom pedicab on mathematical communication and critical thinking abilities, there are several analytical requirements that must be met. First, the normality test was analyzed by looking at the Shapiro-Wilk column in the mathematical communication and critical thinking group the obtained a Sig value > 0.05 proving that the data were normally distributed. This can be seen in Table 7.

Indicators	Class	Average		Average N-Gain	Category
		Pretest	Posttest		
Mathematical Communication	Experimental	29.4	81.3	0.74	High
	Control	21.5	71.5	0.64	Medium
Critical Thinking	Experimental	30.6	84.5	0.78	High
	Control	31.3	70.3	0.56	Medium

Table 6. Results of the analysis of N-Gain

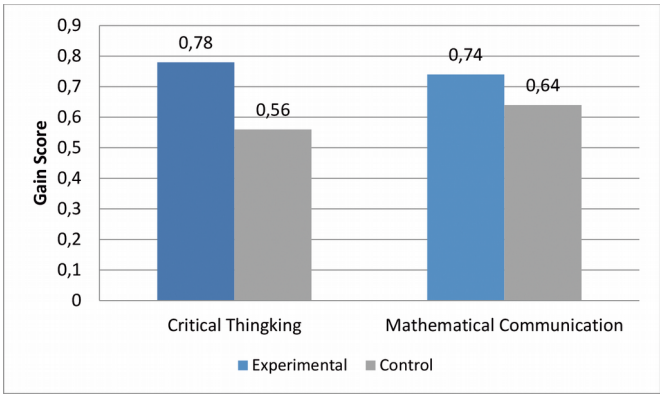

Figure 4. N-Gain Differences between Experimental and Control Classes

Variable	Class	Shapiro-Wilk		
		Statistic	df	Sig.
Mathematical Communication	Pre_ Experimental	0.943	36	0.062
	Post_ Experimental	0.942	36	0.059
	Pre_Control	0.941	36	0.055
	Post_Control	0.954	36	0.141
Critical Thinking	Pre_ Experimental	0.956	36	0.165
	Post_ Experimental	0.941	36	0.056
	Pre_Control	0.948	36	0.091
	Post_Control	0.949	36	0.094

Table 7. Result of normality test

The results of the homogeneity test analysis can be seen in the Box's M section. In the homogeneity test, only posttest data were analyzed and the results were to help analyze the distribution of a homogeneous population if the sig value was > 0.05. Based on the result of the analysis, obtained was the value of sig. 0.357 > 0.05, which means that the data are homogeneous, as shown in Figure 5.

The relationship between the dependent variable of mathematical communication and critical thinking abilities can be seen by doing a correlation testing by using SPSS. The testing result of the correlation between the dependent variables obtained the value of sig. (2-tailed) < 0.05, which means that the dependent variable is the ability to think critically and mathematical communication is linear or directly proportional between the control and experimental classes. The result of the correlation analysis can be seen in Figure 6.

The multivariate test (MANOVA) was carried out because there was a correlation between the dependent variables of mathematical communication and critical thinking ability and it was carried out after several prerequisite testing, namely normality, homogeneity, and correlation testing. The data analysis was carried out in the final test (posttest) to determine the effect of the augmented reality-assisted physics e-module based on the pedicab. The result of the analysis carried out by the Hotteling's Trace section is shown in Table 8.

The effectiveness of the developed augmented reality-assisted physics e-module based on pedicab in physics learning is seen based on the results of field testing using the calculation of effect size and the percentage of N-Gain. The result of the effect size as shown in Table 9.

Box's Test of Equality of Covariance Matrices[a]

Box's M	3,340
F	1,079
df1	3
df2	882000,000
Sig.	,357

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.
a. Design: Intercept + Name

Figure 5. Result of homogeneity test

Correlations

		Critical Thingking	Mathematical Communication
Critical Thingking	Pearson Correlation	1	,341**
	Sig. (2-tailed)		,003
	N	72	72
Mathematical Communication	Pearson Correlation	,341**	1
	Sig. (2-tailed)	,003	
	N	72	72

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 6. Result of correlation test

Effect	Value	Sig.
Hotelling's Trace	0.737	0.000

Table 8. Result of Manova test

Variable	Eta Square	Interpretation
Mathematical communication	0.11	Medium
Critical thinking	0.38	Large

Table 9. Result of analysis of effect size

3.1.3. Product of Augmented Reality Assisted Physics E-Module Based on Pedicab

The Augmented reality-assisted physics e-module based on the pedicab can be used on android smartphones. The e-module is designed to be simple and convenient to use when studying independently as shown in Figure 7. The explanation of the material is made easier by the augmented reality pedicab that can be adjusted as shown in Figure 8.

Figure 7. Cover and Menu of E-module

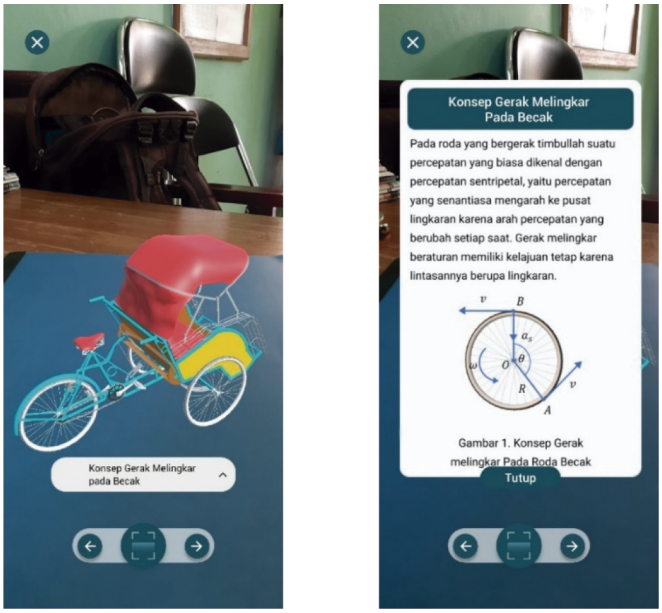

Figure 8. Augmented reality-assisted physics e-module based on pedicab

3.2. Discussion

This research produced a product in the form of an augmented reality-assisted e-module based on local wisdom pedicab and a question instrument to test the effectiveness of the product on mathematical communication and critical thinking abilities. Increased mathematical communication and critical thinking abilities can be obtained by giving test questions to students. First, the test questions are tested for validity and reliability using the QUEST application. The results of the analysis of mathematical communication and critical thinking are in the range of 0.77 to 1.33 so that they are declared valid and reliable.

Based on the analysis, it was found that there was an increase in mathematical communication and critical thinking abilities in the experimental and control classes. A significant improvement was found in the experimental class, which was taught by using the augmented reality-assisted physics e-module based on the pedicab. The teaching in the control class was focused on delivering learning materials, without connecting physics phenomena and concepts with everyday life. Of course, this is different from using learning media in the experimental class that connected physics content with local wisdom and technological assistance.

The MANOVA test was conducted to determine the effect of augmented reality-assisted physics e-modules based on local wisdom pedicab on mathematical communication and critical thinking abilities, there are several analytical requirements that must be met such as normality test, homogeneity test and correlation test. The results of the analysis show that the value of sig. 0.00 < 0.05 as in Table 8,The results of the analysis show the value of sig. 0.00 < 0.05, which means that there is a difference between the dependent variable and the independent variable. This analysis is the answer to the hypothesis that has been prepared previously with the result of H_O being rejected and *Ha* accepted so that there are differences in student's mathematical communication and critical thinking abilities after they were taught by using the augmented reality-assisted physics e-module based on pedicab.

The result of the effect size analysis on mathematical communication is 0.11 with a medium effect size interpretation and critical thinking is 0.40 with the interpretation of large effect size interpretation. Tables 6 and 9 show the developed e-module has an effect on student's abilities. So, e-module is effective to improve mathematical communication and critical thinking abilities.

Table 6 corresponds to previous studies (Astalini, Darmaji, Kurniawan, Anwar & Kurniawan, 2019; Handayani, Yuberti, Saregar & Wildaniati, 2021; Misbah, Sasmita, Dinata, Deta & Muhammad, 2021) and e-modules and augmented reality (Daineko, Tsoy, Seitnur & Ipalakova, 2022; Gopalan, Bakar & Zulkifli, 2020) the developed e-module is the development of innovative learning media by utilizing technology. Students think that the developed augmented reality can help them understand the material more easily and can improve their critical thinking abilities (Syawaludin, Gunarhadi & Rintayati, 2019).

Other findings state that physics learning media by utilizing the Androids based on local wisdom can stimulate the ability to represent critical thinking knowledge (Damayanti & Kuswanto, 2021) and student's mathematical representation knowledge (Rahayu & Kuswanto, 2021). Table 9 shows Android mobile learning development is considered effective (Dolzhich, Dmitrichenkova & Ibrahim, 2021) and can improve the skills of students (Sari, Supahar & Ralmugiz, 2018). Local wisdom is widely developed in teaching and learning and has a positive effect on the improvement of the student's character (Hartini, Firdausi, Misbah & Sulaeman, 2018; Suastra, Jatmiko, Ristiati & Yasmini, 2017; Wati et al., 2018), especially the local wisdom of the pedicab, as shown in the research by Kurniawan & Kuswanto (2021). The pedicab can be shown in this course and teaching has the aim of preserving culture and students can analyze the relationship between physics concepts and cultural phenomena in their environment.

The augmented reality-assisted e-module based on the pedicab allows students to learn individually, anytime, anywhere and material adapted to everyday phenomena. The design of e-modules and augmented reality based on local wisdom of pedicab can be seen in Figures 7 and 8.

4. Conclusion

Augmented reality-assisted e-module media based on local wisdom of the pedicab for learning circular motion material can improve mathematical communication and critical thinking abilities based on N-Gain scores, and the use of e-modules on learning achievement is effective in increasing mathematical communication abilities of 0.11 (medium effect size) and on critical thinking by 0.40 (large effect size).

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

Abdurrahman, M.S., Halim, A.A., & Sharifah, O. (2021). Improving polytechnic students' high-order-thinking-skills through inquiry-based learning in mathematics classroom. *International Journal of Evaluation and Research in Education*, 10(3), 976-983. https://doi.org/10.11591/IJERE.V10I3.21771

Ajlouni, A.O., & Jaradat, S. (2021). The Effect of Integrating an Educational Robot with Hypermedia on Students' Acquisition of Scientific Concepts: The Case of Fifth-Grade Students. *International Journal of Interactive Mobile Technologies*, 15(11), 113-132. https://doi.org/10.3991/ijim.v15i11.18537

Astalini, Darmaji, Kurniawan, W., Anwar, K., & Kurniawan, D.A. (2019). Effectiveness of using e-module and e-assessment. *International Journal of Interactive Mobile Technologies*, 13(9), 21-39. https://doi.org/10.3991/ijim.v13i09.11016

Bond, T.G., & Fox, C.M. (2007). *Applying the Rasch Model: Fundamental Measurement in the Human Sciences* (2nd ed.). Lawrence Erlbaum Associates Publishers.

Cohen, J. (1988). *Statistical Power Analysis for Behavioral Science*.

Daineko, Y.A., Tsoy, D.D., Seitnur, A.M., & Ipalakova, M.T. (2022). Development of a Mobile e-Learning Platform on Physics Using Augmented Reality Technology. *International Journal of Interactive Mobile Technologies*, 16(5), 4-18. https://doi.org/10.3991/ijim.v16i05.26961

Damayanti, A.E., & Kuswanto, H. (2021). The effect of the use of indigenous knowledge-based Physics comics of Android-based marbles games on verbal representation and critical thinking abilities in Physics teaching. *Journal of Technology and Science Education.*, 11(2), 581-593. https://doi.org/10.3926/jotse.1142

Docktor, J.L., & Mestre, J.P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics - Physics Education Research*, 10(2), 020119. https://doi.org/10.1103/PhysRevSTPER.10.020119

Dolzhich, E., Dmitrichenkova, S., & Ibrahim, M.K. (2021). Using M-Learning Technology in Teaching Foreign Languages: A Panacea during COVID-19 Pandemic Era. *International Journal of Interactive Mobile Technologies*, 15(15), 20-34. https://doi.org/10.3991/ijim.v15i15.22895

Doran, Y.J. (2017). The role of mathematics in physics: Building knowledge and describing the empirical world. *Onomazein*, 35, 209-226. https://doi.org/10.7764/onomazein.sfl.08

Gopalan, V., Bakar, J.A.A., & Zulkifli, A.N. (2020). Development of the MARPEX App Embedding the Mobile Augmented Reality Factors for Learning Motivation in Science Experiments. *International Journal of Interactive Mobile Technologies*, 14(17), 155-166. https://doi.org/10.3991/ijim.v14i17.16641

Grinshkun, A.V., Perevozchikova, M.S., Razova, E.V., & Khlobystova, I.Y. (2021). Using Methods and Means of the Augmented Reality Technology when Training Future Teachers of the Digital School. *European Journal of Contemporary Education*, 10(2), 358-374. https://doi.org/10.13187/ejced.2021.2.358

Habibi, Mundilarto, Jumadi, J., Gummah, S., Ahzan, S., & Prasetya, D.S.B. (2020). Project brief effects on creative thinking skills among low-ability pre-service physics teachers. *International Journal of Evaluation and Research in Education*, 9(2), 415-420. https://doi.org/10.11591/ijere.v9i2.20531

Handayani, E.S., Yuberti, Saregar, A., & Wildaniati, Y. (2021). Development of STEM-integrated physics e-module to train critical thinking skills: The perspective of preservice teachers. *IOP Conference Series: Earth and Environmental Science*, 1796(1). https://doi.org/10.1088/1742-6596/1796/1/012100

Hartini, S., Firdausi, S., Misbah, & Sulaeman, N.F. (2018). The development of physics teaching materials based on local wisdom to train Saraba Kawa characters. *Jurnal Pendidikan IPA Indonesia*, 7(2), 130-137. https://doi.org/10.15294/jpii.v7i2.14249

Kurniawan, H.D., & Kuswanto, H. (2021). Improving Students' Mathematical Representation and Critical Thinking Abilities Using the CAKA Media Based on Local Wisdom. *International Journal of Interactive Mobile Technologies*, 15(2), 72-87. https://doi.org/10.3991/ijim.v15i02.11355

Kurniawan, W., Darmaji, D., Astalini, A., Kurniawan, D.A., Hidayat, M., Kurniawan, N. et al. (2019). Multimedia physics practicum reflective material based on problem solving for science process skills. *International Journal of Evaluation and Research in Education*, 8(4), 590-595. https://doi.org/10.11591/ijere.v8i4.20258

Liliarti, N., & Kuswanto, H. (2018). Improving the Competence of Diagrammatic and Argumentative Representation in Physics through Android-based Mobile Learning Application. *International Journal of Instruction*, 11(3), 106-122. https://doi.org/10.12973/iji.2018.1138a

Mailizar, & Johar, R. (2021). Examining students' intention to use augmented reality in a project-based geometry learning environment. *International Journal of Instruction*, 14(2), 773-790. https://doi.org/10.29333/iji.2021.14243a

Manurung, S.R., & Panggabean, D.D. (2020). Improving students' thinking ability in physics using interactive multimedia based problem solving. *Cakrawala Pendidikan*, 39(2), 460-470. https://doi.org/10.21831/cp.v39i2.28205

Meltzer, D.E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American Journal of Physics*, 70(12), 1259-1268. https://doi.org/10.1119/1.1514215

Misbah, M., Sasmita, F.D., Dinata, P.A.C., Deta, U.A., & Muhammad, N. (2021). The validity of introduction to nuclear physics e-module as a teaching material during covid-19 pandemic. *IOP Conference Series: Earth and Environmental Science*, 1796(1). https://doi.org/10.1088/1742-6596/1796/1/012070

Purwadi, I.M.A., Sudiarta, I.G.P., & Suparta, I.N. (2019). The effect of concrete-pictorial-abstract strategy toward students' mathematical conceptual understanding and mathematical representation on fractions. *International Journal of Instruction*, 12(1), 1113-1126. https://doi.org/10.29333/iji.2019.12171a

Rahayu, M.S.I., & Kuswanto, H. (2020). Development of android-based comics integrated with scientific approach in physics learning. *Journal of Physics: Conference Series*, 1440(1). https://doi.org/10.1088/1742-6596/1440/1/012040

Rahayu, M.S.I., & Kuswanto, H. (2021). The effectiveness of the use of the android-based carom games comic integrated to discovery learning in improving critical thinking and mathematical representation abilities. *Journal of Technology and Science Education*, 11(2), 270-283. https://doi.org/10.3926/JOTSE.1151

Rahmawati, Rustaman, N.Y., Hamidah, I., & Rusdiana, D. (2018). The development and validation of conceptual knowledge test to evaluate conceptual knowledge of physics prospective teachers on electricity and magnetism topic. *Jurnal Pendidikan IPA Indonesia*, 7(4), 483-490. https://doi.org/10.15294/jpii.v7i4.13490

Sadaghiani, H.R. (2014). Using multimedia learning modules in a hybrid-online course in electricity and magnetism. *Physical Review Special Topics - Physics Education Research*, 7(1), 1-7. https://doi.org/10.1103/PhysRevSTPER.7.010102

Sagala, R., Umam, R., Thahir, A., Saregar, A., & Wardani, I. (2019). The effectiveness of stem-based on gender differences: The impact of physics concept understanding. *European Journal of Educational Research*, 8(3), 753-761. https://doi.org/10.12973/eu-jer.8.3.753

Sari, D.K., Supahar, & Ralmugiz, U. (2018). The influence of android-based isomorphic physics (Forfis) application on analogical transfer and self-diagnosis skill of students at SMA Negeri 3 Kupang. *Jurnal Pendidikan IPA Indonesia*, 7(2), 154-161. https://doi.org/10.15294/jpii.v7i2.14268

Sirakaya, M., & Cakmak, E.K. (2018). The effect of augmented reality use on achievement, misconception and course engagement. *Contemporary Educational Technology*, 9(3), 297-314. https://doi.org/10.30935/cet.444119

Suastra, I.W., Jatmiko, B., Ristiati, N.P., & Yasmini, L.P.B. (2017). Developing characters based on local wisdom of bali in teaching physics in senior high school. *Jurnal Pendidikan IPA Indonesia*, 6(2), 306-312. https://doi.org/10.15294/jpii.v6i2.10681

Suhirman, S., Prayogi, S., & Asy'ari, M. (2021). Problem-Based Learning with Character-Emphasis and Naturalist Intelligence: Examining Students Critical Thinking and Curiosity. *International Journal of Instruction*, 14(2), 217-232. https://doi.org/10.29333/iji.2021.14213a

Suprapto, N., Ibisono, H.S., & Mubarok, H. (2021). the Use of Physics Pocketbook Based on Augmented Reality on Planetary Motion To Improve Students' Learning Achievement. *Journal of Technology and Science Education*, 11(2), 526-540. https://doi.org/10.3926/jotse.1167

Syawaludin, A., Gunarhadi, & Rintayati, P. (2019). Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning. *International Journal of Instruction*, 12(4), 331-344. https://doi.org/10.29333/iji.2019.12421a

Tajudin, N.M., & Chinnappan, M. (2016). The link between higher order thinking skills, representation and concepts in enhancing TIMSS tasks. *International Journal of Instruction*, 9(2), 199-214. https://doi.org/10.12973/iji.2016.9214a

Wahyu, Y., Suastra, I.W., Sadia, I.W., & Suarni, N.K. (2020). The effectiveness of mobile augmented reality assisted STEM-based learning on scientific literacy and students' achievement. *International Journal of Instruction*, 13(3), 343-356. https://doi.org/10.29333/iji.2020.13324a

Wati, M., Hartini, S., Hikmah, N., & Mahtari, S. (2018). Developing physics learning media using 3D cartoon. *Journal of Physics: Conference Series*, 997, 012044. https://doi.org/10.1088/1742-6596/997/1/012044

Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2023 (www.jotse.org)