Development of Augmented Reality-Based High School Physics Learning Media on Static Electricity Material

Khairunnisa Hayatul Fadhilah*, Zeni Haryanto, & Laili Komariyah
Physics Education Study Program, University of Mulawarman, Indonesia
*Corresponding Author: 26khairunnisahf@gmail.com

Received: 24th August 2024; **Accepted**: 14th September 2024; **Published**: 20th September 2024
DOI: https://dx.doi.org/10.29303/jpft.v10i2.7553

Abstract - *Physics is a branch of science that discusses natural phenomena. Physics learning process is expected to facilitate students to observe the phenomenon directly, but not all phenomena can be observed directly. One of them is static electricity subject material. So, learning media is needed that can channel information to students. Teachers can create various learning media with dynamic representations such as Augmented Reality. This study aims to determine the feasibility of Augmented Reality based learning media on static electricity material developed. This research is a type of R & D (Research and Development) research with the 4D model (Define, Design, Development, and Disseminate). The media feasibility test was determined through validation by four validators. These included two media experts and two material experts. The results of the feasibility test in terms of media with indicators of graphics and language got a percentage of 81% with very feasible criteria and in terms of material with content, presentation, and contextual indicators of 83% with very feasible criteria. Thus, the development of Augmented Reality-based learning media on static electricity material is very feasible to use in supporting physics learning.*

Keywords*: Learning Media; Augmented Reality; 4D; Feasibility Test.*

INTRODUCTION

The process of physics subjects at school only tends to discuss the theory of the textbook material that has been provided, then given formulas and examples of problems. Therefore, students can only imagine physics without seeing the events directly, because physics has been reduced to reading. (Nandyansah et al., 2019).

If students can see the events in the form, they may have a better understanding of the material in physics. One of the most visible problems in education that plagues students today is the lack of motivation towards educational activities. Moreover, there are many learners who have problems in imagining and understanding the subject matter at school. (O'Shea, 2011).

The branch of science that discusses natural phenomena that occur around us is the subject of physics. Every physics learning process is expected to facilitate students to directly observe these phenomena, but not all phenomena can be observed directly. Static electricity is one of the physics materials that has many phenomena but cannot be observed directly by students.

So far, the phenomenon in static electricity material that students can observe is very limited. Therefore, teachers or educators are required to be creative and can facilitate learning related to these physics phenomena so that the learning material can be delivered and easily understood by students. (Mukti et al., 2020).

Augmented Reality is a concept that combines two-dimensional or three-dimensional virtual objects into a three-dimensional real scope and then processes these virtual objects in real time. Augmented Reality has the advantage of being interactive because it uses markers to display certain three-dimensional objects that are pointed at the camera. In addition, the application of the concepts used can increase

the reasoning power and imagination of students (Pradana, 2020).

The development of the first Augmented Reality application designed specifically for use in educational environments the technology has also contributed greatly to education. It is about twenty-five years since the development of the first Augmented Reality application designed specifically for use in educational environments. Since then, Augmented Reality applications have been successfully applied at various levels of education. Different fields of education, and different educational environments provide many benefits to learners. (Garzón, 2021).

Augmented Reality uses a camera to recognize marker images continuously, process and then generate virtual interactions that appear in the real world to see the screen display and Head Mounted Display (HMD). (Purnomo et al., 2018).

Teachers or educators must be able to make the most of existing technologies to improve the quality of the teaching and learning process in each educational unit. A good way to build technology-based learning media for teachers or educators is to utilize Augmented Reality learning media. (Mukti et al., 2020).

In research conducted by Sannikov and cited by Nandyansyah & friends with the title "Interactive Educational Content Based on Augmented Reality and 3D Visualization" concluded that Augmented Reality has a great influence to be able to foster student interest in explaining abstract physics material topics. (Nandyansah et al., 2019).

Selection of materials on static electricity: 1) electric charge; 2) positive and negative current electric fields; 3) positive and positive current electric fields; 4) negative and negative current electric fields; 5) positive current electric fields; 6) negative current electric fields; and 7) capacitors are considered important because this is not only learning how to calculate but also the direction of each electric charge and electric field current that cannot be seen by the naked eye. In addition, the selection of capacitors to be developed in the form of 3D Augmented Reality is due to the lack of schools, especially the SMA / MA Equivalent level, to be able to facilitate props in the form of capacitor types in the physics laboratory.

Augmented reality has the effect of developing facial expressions, attention, stimulating thinking, and increasing understanding of information for students or students in the presentation of physics material. (Pochtoviuk et al., 2020). However, the literature has also emphasized that the use of Augmented Reality does not guarantee academic success, but provides students with alternative ways of learning by providing learning media facilities.

Students who take part in learning using Augmented Reality media enjoy the learning process and engage in the learning process by thinking critically, which supports the idea that Augmented Realityassisted environments can really make learning an alternative way. (Abdusselam & Karal, 2020). Some of the goals that Augmented Reality can achieve when applied in the learning process are: The technology can a) illustrate spatial and temporal concepts, b) emphasize contextual relationships between real and virtual objects, c) provide intuitive interactions, d) visualize and interact in 3D, and e) facilitate collaborative learning. (Thees et al., 2020).

From the results of Hafi & Supardiyono's research, which used a questionnaire to test students, showed data results of 78.2% of students still had difficulty understanding Physics material. Students still think that physics learning

seems difficult and boring because it is only based on monotonous textbooks and questions containing formulas. From the study, it was found that 100% of physics lessons in schools used monotonous learning media and sourced from only one textbook. (Hafi & Supardiyono, 2018).

Augmented Reality can display objects that are very small or far in range to be visible that are integrated in learning. Developing Augmented Reality uses several applications, namely 3D Blender which functions to create 3-dimensional animations, vuforia which functions to create markers that will be used, and Unity which is useful for uniting 3-dimensional animations with markers that have been created. (Krüger et al., 2019).

This research uses 3D Unity to create a three-dimensional model of the scene and to detect and track the totem function of the Vuforia engine. It can set animations and play videos. Vuforia AR Software Development (Vuforia AR SDK) is designed by Qualcomm for mobile device AR applications. The interaction between virtual buttons and virtual reality can also be created as virtual buttons (Liu et al., 2018).

Based on the description above, the researchers want to develop a learning media that is Augmented Reality which will be used steps in this research is a method of research and development or Research and Development (R & D). This product development model or procedure refers to the 4D development model of research methods used by Thiagarajan. The stages that will be carried out are: 1) Define, in the form of needs analysis; 2) Design, in the form of design, data collection, and making teaching material designs and making electronic teaching materials; 3) Develop, in the form of validation, and revision; and 4) Disseminate, in the form of dissemination to physics teachers.

RESEARCH METHODS

In this research, the method used is the Development Model This development model is Research and Development (R&D). This research used a development model based on the 4D model, which consisted of four stages. The four stages are defining, designing, developing, and disseminating.

The data collection techniques in this study are observation, interviews and questionnaires. And the data analysis technique used is the instrument of data results using the Percentage formula.

$$P = \frac{\sum \text{JV}}{\sum \text{STV}} \times 100\%$$

Description:
P = Percentage
$\sum$JV = Total number of respondents' answers
$\sum$STV = Maximum score of the respondent

Results Analysis is used as a determinant of the feasibility of Augmented Reality-based learning media that has been developed.

Table 1. Categories of Questionnaire Assessment Results

Scor Percentage (%)	Interpretation
$0 \leq P < 25$	Very Less
$25 \leq P < 50$	Less
$50 \leq P < 75$	Worth
$75 \leq P < 100$	Very Feasible

The development will be terminated if it has reached the minimum standard percentage of $50\% \leq P < 75\%$ or Feasible.

RESULTS AND DISCUSSION

The feasibility test was carried out by giving questionnaire products to 4 validators consisting of 2 media expert lecturers and 2 material expert lecturers. The material expert validation test serves to determine the feasibility of the learning media developed from the aspects of media design, software, and media benefits. Meanwhile, the material expert validation test serves to determine the feasibility of the material in a learning

media. This questionnaire consists of 5 aspects, namely graphics, language, content, presentation, and contextual. The following is the percentage of feasibility test results by validators can be seen in Table 2.

Table 2. Results of the Feasibility Test of the Validators

Validator	Position	Percentage	Criteria
Media Expert 1	Lecturer in Physics Education, Mulawarman University	77%	Very Feasible
Media Expert 2	Lecturer in Physics Education, Mulawarman University	90%	Very Feasible
Material Expert 1	Lecturer in Physics Education, Mulawarman University	81%	Very Feasible
Material Expert 2	Lecturer in Physics Education, Mulawarman University	87%	Very Feasible
Average		84%	Very Feasible

Then the results of the feasibility test percentage for each aspect can be seen in Figure 1.

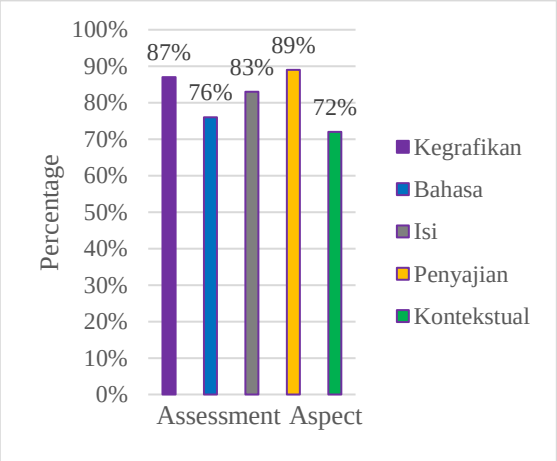

Figure 1. Percentage of Feasibility Test for All Aspects

Define

The defining stage is the initial stage in the process of developing Augmented Reality learning media. At this stage, material analysis, user analysis, and specification analysis are carried out. These three stages are analyzing the need to study materials that include static electricity material, analyzing user response needs, and analyzing the specifications of the learning media to be developed. (Widiyasari et al., 2020).

In the first stage is material analysis, the material analyzed is static electricity material. The selection of static electricity material is because the topic needs extra effort to understand and integrate abstract or invisible knowledge from real life that is difficult to find (Liu et al., 2018). So that at this stage an analysis of static electricity material is carried out in accordance with the demands given by (Kemendikbudristek BSKAP, 2022).

The selection of material on electric charge, positive and negative current electric fields, positive and positive current electric fields, negative and negative current electric fields, positive current electric fields, and negative current electric fields, and capacitors is considered important because this is not only learning how to calculate but also the direction of each electric charge and electric field currents that cannot be seen by the naked eye. In addition, the selection of capacitors to be developed in the form of 3D Augmented Reality is due to the lack of schools, especially the SMA / MA Equivalent level, to be able to facilitate props in the form of capacitor types in the physics laboratory.

The curriculum used adapts to the use of the curriculum at the school where it is used. conducting research. At this stage, a literacy study is carried out with references to determine material topics that are in

accordance with the learning materials contained in the 2013 Curriculum and Merdeka Curriculum.

Literature studies are also carried out to analyze the concept and sequence of material to adjust to the cognitive development of students, and literature studies are carried out to find examples of static electricity material in the real world. In the second stage, namely user analysis, at this stage user interviews (teachers) and observation of the research site were carried out. The interview results show that the school still lacks the tools that need to be used to understand the concept of static electricity, and there is no other alternative used to understand the concept of static electricity material. The teacher also said that what is needed is a more complex experimental tool than just a ruler and rubbed paper.

From the results of observations, the learning system, and the use of media, the majority still apply conventional learning. (Ningrum et al., 2021). After conducting material analysis and user analysis, the next stage is the third stage which is the specification analysis stage. Unity 3D is an engine for creating 2D and 3D applications, while Vuforia is Augmented Reality support software on the Unity 3D Android program, and Blender is a 3D software for animation, simulation, modeling, rigging, and rendering. (Hartono, 2022).

If Unity is used in the unification of applications, then in the development of Augmented Reality applications, Vuforia SDK is also needed for the process of tracking markers or target images made into Augmented Reality books. The selection of Blender as software in making 3D objects because Blender is a familiar application, open source, easy to use, and also free. (Cahyono et al., 2018).

In the Blender application, it does not make it difficult for researchers to create 3D objects. On the other hand, the results of the specification analysis found that the hardware or laptop used uses the Windows 11 operating system, 8 GB RAM, AND Ryzen 6800H 64-bit screen, and supports DX12. In addition to laptops, mobile hardware or cellphones have minimum specifications of Android 5.1 "Lolipop" OS, 1 GB RAM, and 2 MP Camera. This states that the minimum specifications from the analysis of software and hardware specifications used have met the minimum requirements in terms of specifications. This serves to be able to develop Augmented Reality-based learning media with minimal constraints.

Design

In the product design stage is divided into 2 parts, namely the design of Augmented Reality applications and Augmented Reality books. In the design of Augmented Reality applications consists of 3 stages, these stages are storyboard, flowchart, and flow-work. The design of the three stages is an interface design stage that becomes an activity diagram.

Activity diagrams are a way to explain the interaction between users of a system and the system used and tell the process of how a system is used. (Suryanto et al., 2018). This activity diagram consists of users, applications and databases by Vuforia SDK.

The design of the activity diagram is done to provide a more real realization for the process of developing Augmented Reality-based learning media applications. This explains the tracking process for 3D object output, namely: 1)The camera image performs image processing to find information from an image or target image; 2) Image transfer from the database assisted by Vuforia SDK as a service in the tracking

process that detects the presence of markers (target images); 3) Vuforia is connected to the Augmented Reality application on Android through Unity 3D. When the application is started and the camera is directed to focus on the target image, the Augmented Reality is displayed, so this development is continued with the design of the target image in the form of 2D images and given information on the understanding of the material, formulas, and others that will become Augmented Reality books, this is expressed by several researchers that image-based Augmented Reality is considered more convenient than other types of markers (Yulianti et al., 2023).

The Augmented Reality book consists of 38 pages of preface, instructions for use, table of contents, list of tables and list of images, learning flow, learning outcomes and objectives, sample questions, and glossary. Then in the material section there are 7 materials that have access to be the target image. The size of the book to be developed is B5 according to ISO standards of 17,6 cm × 25 cm.

Development

At this stage, researchers developed 3D objects, made applications in Unity 3D, and feasibility testing by validators. Beginning with the step of creating 3D objects with Blender software, object creation follows the reference of the 7 materials that have been compiled during the literature study. Furthermore, after all objects have been developed in the Blender application, they are exported in the form of FBX files. The FBX file form provides several advantages in the development of Augmented Reality-based learning media that can embed textures (object colors) that have been developed, FBX file format also supports exporting 3D objects in the form of animation and supports the unification of objects in the target image in Unity 3D.

In the next stage, the unification stage of all components, components in terms of application interface design design and Augmented Reality books (target images). Before importing all components into Unity, Unity must first be linked to the Vuforia SDK which requires an Augmented Reality camera and a target image that has a role in displaying objects on it. Next, import 7 materials that will be used as Augmented Reality markers.

Figure 2. Results of Unifying All Components in Unity3D

Imported results on the Vuforia SDK website with 4 or 5 stars are markers that have good quality in terms of color and complexity which is almost the same as the QR Code. The 7 materials that have been used as markers pass to be able to provide tracking or response in bringing up 3D objects in capturing images from cameras with a quick and easy process. Then the 7 imported material markers have become a database on the Vuforia website, and can be downloaded to download the database. Next, researchers get the app license key code into the camera that is integrated with the Vuforia SDK in Unity 3D. After that, the unification stage of each of the 7 3D objects is adjusted to the 7 material markers in Unity 3D. Then, entering the Augmented Reality interface design (application) for the main menu page, about, instructions for use, AR camera, and developer information is linked to the use of

coding with the C# or C-sharp programming language. The overall unification result can be seen in Figure 2.

After everything is successfully put together, naming and giving a logo to the Augmented Reality application developed under the name Electrostatic with a logo. The form of the application that has been developed through Unity 3D is in the form of .apk. The next stage, after the product has been successfully developed and in accordance with the feasibility material, a feasibility test is carried out that measures the validity of a product. The feasibility test stage is carried out before conducting a user response test by providing validation instruments to experts. In this stage, the feasibility test is carried out by 4 expert validators who are experienced in their respective fields. The four validators are lecturers from the physics education study program at Mulawarman University, the reason for choosing these validators is because they are experts in assessing research instruments.

The validators are two material experts and two media experts. The material expert validation test serves to determine the feasibility of the learning media developed from the aspects of media design, software, and media benefits. The material expert validation test serves to determine the feasibility of the material in a learning media developed from the aspects of content, presentation and context. The feasibility test was carried out to revise the development results until it reached the feasibility test results without revision. the overall results of each validator in assessing both from the material aspect and from the media aspect. The highest percentage was given by media expert validator 2 which was 90% and the lowest percentage was 77% by media validator 1. Furthermore, it was found that an average of 81% for media aspects with very feasible criteria and an average of 83% for material aspects with very feasible criteria. So overall Augmented Reality-based learning media has a percentage of 82% with very feasible criteria. Then, the percentage of each aspect is kegrafikan, language, content, presentation, and contextual. The highest percentage is obtained in the presentation aspect and the lowest percentage is obtained in the contextual aspect.

After the feasibility test was carried out by expert validators, then the user (educator) response test was carried out by one physics teacher of SMA Negeri 1 Muara Badak and one physics teacher of SMA Negeri 2 Muara Badak. The interview results show that the school still lacks the tools that need to be used to understand the concept of static electricity, and there is no other alternative used to understand the concept of static electricity material. Teachers also said that what is needed is a more complex experimental tool than just a ruler and rubbed paper.

In terms of media use, it has been pointed out that the availability of media tools needs to be increased and improved. On the other hand, experiments are only done occasionally when the materials are available. The expectations of teachers or educators in this study become a reference to realize in the development of Augmented Reality-based learning media. This has the potential to provide solutions in accordance with the ability of Augmented Reality to visualize a phenomenon or object in the real world environment.

The highest percentage in terms of media is obtained from the aspect of graphics with a percentage of 100% while in terms of the highest material obtained in the aspect of presentation with a percentage of 96%, namely between concepts proven by descriptions or examples presented in the

Augmented Reality book, systematic consistency in presenting material, the sequence of concepts from concrete to abstract, there is a preface, glossary, and bibliography relevant to the material, as well as the integrity of meaning in paragraphs in the Augmented Reality book.

In addition, it is obtained in terms of material has the lowest percentage on the indicator of the suitability of the material with KI and KD with a percentage of 81%. Furthermore, it was found that the average of 99% for media aspects with very good criteria and an average of 91% for material aspects with very good criteria. So overall from the response test of Augmented Reality-based learning media educators have a percentage of 95% with very good criteria.

CONCLUSION

The feasibility of Augmented Reality-based learning media on static electricity material developed shows that the feasibility test in terms of media with indicators of graphics and language gets a percentage of 81% with very feasible criteria and feasibility test in terms of material with content, presentation, and contextual indicators of 83% with very feasible criteria. Then the overall average percentage of 82% which means that the Augmented Reality-based learning media developed is in very feasible criteria. The response of the user/teacher assessment of static electricity Augmented Reality learning media seen from the learning design aspect, the media display aspect, the software aspect, the material aspect, and the benefit aspect, which states "Very Feasible" as a learning medium.

To improve the quality of this research, the authors provide the following suggestions: 1) Electrostatic book development can be done with other subject matter; 2) For future researchers, it is better to develop learning media that can be used not only Android users but also IOS users; 3) For future researchers, adding features to Augmented Reality applications such as the addition of sound effects, 3D object control (zoom in, zoom out, turn right, and turn left).

REFERENCES

Abdusselam, M. S., & Karal, H. (2020). The effect of using augmented reality and sensing technology to teach magnetism in high school physics. *Technology, Pedagogy and Education*, *29*(4), 407–424. https://doi.org/10.1080/1475939X.2020.1766550

Cahyono, B., Firdaus, M. B., Budiman, E., & Wati, M. (2018). Augmented Reality Applied to Geometry Education. *Proceedings - 2nd East Indonesia Conference on Computer and Information Technology: Internet of Things for Industry, EIConCIT 2018*, *November*, 299–303. https://doi.org/10.1109/EIConCIT.2018.8878553

Garzón, J. (2021). An overview of twenty-five years of augmented reality in education. *Multimodal Technologies and Interaction*, *5*(7). https://doi.org/10.3390/mti5070037

Hafi, N. N., & Supardiyono. (2018). Pengembangan buku saku fisika dengan teknologi *augmented reality* berbasis android pada materi pemanasan global. *Inovasi Pendidikan Fisika*, *07*(02), 306–310.

Hartono, T. P. (2022). Perancangan Augmented Reality Menggunakan Unity Dan Blender Dengan Metode Multimedia Development Life Cycle. *Universitas Palangkaraya*, *December*.

Kemendikbudristek BSKAP. (2022). Salinan Keputusan Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan, Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi

Nomor 008/H/KR/2022 Tentang Capaian Pembelajaran Pada Pendidikan Anak Usia Dini Jenjang Pendidikan Dasar dan Jenjang Pendid. In *Kemendikbudristek* (Issue 021).

Krüger, J. M., Buchholz, A., & Bodemer, D. (2019). Augmented reality in education: Three unique characteristics from a user's perspective. *ICCE 2019 - 27th International Conference on Computers in Education, Proceedings*, *1*, 412–422.

Liu, X., Sohn, Y.-H., & Park, D.-W. (2018). Application development with vuforia and Unity 3D. *International Journal of Applied Engineering Research*, *13*(21), 43. https://www.ripublication.com/ijaer18/ijaerv13n21_33.pdf

Mukti, W. M., N, Y. B. P., & Anggraeni, Z. D. (2020). Media Pembelajaran Fisika Berbasis Web Menggunakan Google Sites pada Materi Listrik Statis. *Webinar Pendidikan Fisika 2020*, *5*(1), 51–59. https://sites.google.com/view/fisikakuyess.

Nandyansah, W., Suprapto, N., & Surabaya, U. N. (2019). Pengembangan Media Pembelajaran Berbasis Augmented Reality Untuk Melatihkan Keterampilan Berpikir Abstrak Pada Materi Model Atom. *IPF: Inovasi Pendidikan FIsika*, *8*(2), 756–760.

Ningrum, V. F., Sumarni, W., & Cahyono, E. (2021). Development of Augmented Reality-Based Learning Media on Concept of Hydrocarbon to Improve Multi-representation Ability. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 256–265. https://doi.org/10.29303/jppipa.v7ispecialissue.1038

O'Shea, P. M. (2011). Augmented Reality in Education. *International Journal of Gaming and Computer-Mediated Simulations*, *3*(1), 91–93. https://doi.org/10.4018/jgcms.201101 0108

Pochtoviuk, S. I., Vakaliuk, T. A., & Pikilnyak, A. V. (2020). Possibilities of application of augmented reality in different branches of education. *CEUR Workshop Proceedings*, *2547*, 92–106. https://doi.org/10.31812/educdim.v54i2.3867

Pradana, R. W. (2020). Penggunaan Augmented Reality Pada Sekolah. Jurnal Teknologi Pendidikan, 5(1), 97–115.Purnomo, F. A., Santosa, P. I., Hartanto, R., Pratisto, E. H., & Purbayu, A. (2018). Implementation of Augmented Reality Technology in Sangiran Museum with Vuforia. IOP Conference Series: Materials Science and Engineering, 333(1). https://doi.org/10.1088/1757-899X/333/1/012103

Purnomo, F. A., Santosa, P. I., Hartanto, R., Pratisto, E. H., & Purbayu, A. (2018). Implementation of Augmented Reality Technology in Sangiran Museum with Vuforia. *IOP Conference Series: Materials Science and Engineering*, *333*(1). https://doi.org/10.1088/1757-899X/333/1/012103

Suryanto, A., Kusumawati, D. A., & Sanhoury, I. M. H. (2018). Development of Augmented Reality Technology Based Learning Media of Lathe Machines. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *24*(1), 32–38. https://doi.org/10.21831/jptk.v24i1.18245

Thees, M., Kapp, S., Strzys, M. P., Beil, F., Lukowicz, P., & Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior*, *108*, 106316. https://doi.org/10.1016/j.chb.2020.106316

Yulianti, E., Mustikasari, V. R., Muhlisin, N., Farahwahidah, N., Rahman, A., &

Phang, F. A. (2023). *An augmented reality-based science book for junior high school students: Case study on environmental pollution and global warming topics An Augmented Reality-Based Science Book for Junior High School Students : Case Study on Environmental Pollution and G. 060010(January).*

Widiyasari, R., Astriyani, A., & Irawan, K. V. (2020). Pengembangan Perangkat Pembelajaran Matematika Dengan Bantuan Media Evaluasi Thatquiz. *FIBONACCI: Jurnal Pendidikan Matematika Dan Matematika*, *6*(2), 131. https://doi.org/10.24853/fbc.6.2.131-154