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Dekan FMIPA Unesa

Prof. Dr. Madlazim, M.Si.
NIP 196511051991031012

Ketua Pelaksana,

Dr. Asnawi, M.Si.
NIP 196612011998021001

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PicsAR: A Physics Visualisation to Enhance Students' Thinking Skills in Abstract Concepts

N Suprapto* **and W Nandyansah**

Physics Education Programme, Universitas Negeri Surabaya, Surabaya, Indonesia

*Email: nadisuprapto@unesa.ac.id

Abstract. The aim of the research was to visualise abstract physics concepts through a PicsAR (Physics Augmented Reality) application to enhance students' thinking skills in abstract concepts. Previously, the researchers developed the PicsAR by utilising Research and Development (R & D) design with an ADDIE model (Analysis, Design, Develop, Implementation, and Evaluation) and reported through previous publication. It has claimed that the PicsAR has fulfilled the criteria of valid, practice, and effective. The atomic model was exemplified as an abstract concept in physics as an outcome of visualisation. Totally, 33 high school students with their teacher in Surabaya Indonesia contributed to this study. To explore students' thinking skills in abstract concepts, the descriptive statistics were used in guiding the data analysis. The visualisation of research trends in physics augmented reality was performed by VOSviewer software. Empirically, the finding of the research described the feature of PicsAR and the performance of the augmented reality of atomic models. Additionally, students' abstract thinking skills of atomic models were also discussed, including four types of reasoning: proportional, probabilistic, combinatorial, and correlational reasoning. Overall, the students achieved excellent of all proportional reasoning indicators, two-thirds of probabilistic and correlational reasoning indicators, and seventy-five percent of combinatorial reasoning indicators.

1. Introduction

In the era of disruption of technology, the use of media in physics learning is hugely needed. Smartphones that keep us connected to the outside world are important instruments in the industrial revolution 4.0. One of the many kinds of technologies adopted in learning is Augmented Reality, supporting smartphones [1-4]. Therefore, this research utilises the smartphone's contribution to the "PicsAR" (physics augmented reality).

Currently, a new technology emerges in the form of Augmented Reality (often abbreviated as AR). Based on the previous researchers, such as [1-5], AR is "a technology that combines 2-D and or 3-D virtual objects into a real 3-D environment and then projects these virtual objects in real-time" [5]. Meanwhile, AR is an effort to combine the virtual and real-world created through a mainframe so that the gap between the two becomes much closed [6]. According to these descriptions, a simple AR is an effort to combine 3D animated objects into the real world in real-time.

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The steps in making Augmented Reality are as follows:

1. The initial step is to create the object that will be exhibited first. Generally, the objects formed are photos, videos, 3D objects, or animations made with object design software such as Google Sketchup, 3DMax, or with Blender.
2. After the object is finished, the object will be saved into the library. Then after that what needs to be made is a marker. A marker is a marker that has a special pattern. This marker is what will be detected by the webcam to display the object. After that the marker pattern created must be saved into the library as well so that later the application made can distinguish it from other markers. Usually this marker storage requires the help of other applications such as vuforia.
3. After the two main components, the marker and the object are ready. The next step is to create an application that can generate objects from markers created with the help of a builder, for this thesis is to unity.

The central research questions (RQs) of this research are twofold: (1) to what extent do the features performed at PicsAR of atomic models? And (2) to what extent do the students' thinking skills in the abstract concepts?

2. Method

After developing the PicsAR through Research and Development (R & D) design with an ADDIE model (Analysis, Design, Develop, Implementation, and Evaluation) as seen from the previous publications [7-9], the researchers' analysis of the features of the PicsAR and explore the students thinking skills as the shape of implementation of the product. It has claimed that the PicsAR has fulfilled the criteria of valid, practice, and effective [7-8,10]. The research trial design used was a one-shot case study [7-9]. The atomic model was exemplified as an abstract concept in physics as an outcome of PicsAR. Totally, 33 high school students with their teacher in Surabaya Indonesia contributed to this study [7]. The research was conducted in the Spring semester of 2019. Thus, this article focuses on the features of PicsAR and explores the students' thinking skills in abstract concepts.

Figure 1. The trend of research on augmented reality in physics based on Scopus database (2011-2020).

3. Result and Discussion

In the context of the emerging technology of learning, AR could be used to visualise objects temporally and spatially [2,11]. Making objects that are far or very small within reach visible can be done by increasing the microscopic scale, decreasing the macroscopic scale, or making the interior exterior of everything made invisible to be visible. The trend of research on augmented reality in physics-based on the Scopus database is depicted in Figure 1. There are four significant clusters and one little cluster regarding physics augmented reality in the world. The first cluster (red colour) emerges in emerging technologies in learning, while the second cluster (blue) represents the mechanism and structure of augmented reality. Additionally, the yellow one focused on the display of the AR and the green one indicates the procedure and the accuracy of the image in the physics augmented reality. The last minor cluster raises the sensitivity of the application.

As part of the first cluster, this study emphasises AR was developed by using several applications, namely “vuforia which is useful for creating markers to be used, 3D blender which is suitable for making 3-D animation, and unity which is useful for uniting 3-D animation with markers that have been made” [6-8,12]. This form of AR output itself is an (apk.) format that can be integrated with a cell phone or Android smartphone.

The operating process of AR media is not difficult, "when opening the application directly fixed to the smartphone camera, markers available on the handout will be spotted by the camera so that it will bring up an animated 3-D object on the Android screen" [8].

3.1 The features of PicsAR of atomic models

The following are the performance of the augmented reality of atomic models that has been detected from the camera. Figure 2 to Figure 5 illustrates the AR performance of Dalton's atomic models to Bohr [3].

Figure 2. AR performance of Dalton atomic model.

Figure 3. AR performance of Thomson atomic model.

Figure 4. AR performance of Rutherford atomic model.

Figure 5. AR performance of Bohr atomic model.

Figure 6. A 3-dimensional animation that explains that atoms are the smallest particles that cannot be divided again.

Figure 7. A 3-dimensional animation of examples of Carbon and Oxygen atoms according to the Dalton atomic model.

Figure 8. A 3-dimensional animation of examples of Carbon and Oxygen atoms according to the Thomson atomic model.

Figure 9. A 3-dimensional animation of examples of Carbon and Oxygen atoms according to the Rutherford atomic model.

Figure 10. A 3-dimensional animation of examples of Carbon and Oxygen atoms according to the Bohr atomic model.

3.2 Students' abstract thinking skills of atomic models

The existence of AR as a learning media was aimed at increasing the understanding of the students' abstract thinking skills. The criteria guided this research are "if the percentage of abstract thinking skills reaches a percentage of ≥ 61 %, then the media can be said to be effective for use" [8,10]. The abstract thinking skills are obtained from abstract thinking skills tests, which are seen from the students' worksheet. Subsequently, the indicators assessed on abstract thinking skills are "controlling

variables, proportional reasoning, probabilistic reasoning, combinatorial reasoning, and correlational reasoning" [13-15].

The research resulted in 100 % of students got very good and good categories on the variable controlling indicator, 100 % of students gained same categories on proportional reasoning indicators, 66.67 % of students reached similar categories on probabilistic reasoning indicators, 75.76 % of students got identical categories on combinatorial reasoning indicators, and 66.67 % of students got equal categories on correlational reasoning indicators. Thus, one of the requirements for augmented reality media to be said to be effective can be fulfilled. On the variable controlling indicators, students who gained very good and good categories were 100 %. As many as 15.15 % got an excellent category, while 85.85 % got a good category. This information showed students able to control and set variables. The summary of the students' abstract thinking skills can be seen in Figure 11.

In proportional reasoning indicators, students who got very good and good categories were 100 %. As many as 33.33 % reached an outstanding category, while 66.67 % gained a good category. This situation indicated that students could transfer reasoning from 2D to 3D or vice versa. The probabilistic reasoning indicator has a reasonably low percentage but remains in the good category equal to 66.67 %. Totally, 18.18 % of students got fewer categories, and 15.15 % got a good category. This situation can be explained because of students have difficulty understanding the alpha particle scattering video. The video displayed cannot be accelerated or repeated in individual sections to hear an explanation. Even if we repeat it, we have to start over again so that it will waste time. Researchers still have not developed so that the video produced there are forward buttons or back buttons.

Figure 11. The results of students' abstract thinking skills.

In the combinatorial reasoning indicators of students who acquired good and very good categories with a percentage of 75.76 %, this indicator achieved a good category overall. But as much as 24.24 % of students earned enough scores. This situation was due to 3-dimensional animation explaining the classical physics theory on the atomic model. Students have difficulty explaining the classical physics theory on the atomic model.

Students have also got a relatively low score of 66.67 % for the good and very good categories in the correlational reasoning indicator. It was about 33.33 % of students got enough categories. Students

can only explain the skin of a Bohr atom, but it cannot explain the skin of an atom of quantum mechanics. This condition was consistent with the validation score on the material aspect. The 3-dimensional animation in quantum mechanics' atomic model is less appropriate if it is made more real in 3 dimensions. Based on the previous researchers [5, 6], with the mastery of knowledge about physical objects by individuals, it is possible to achieve the physics concept's learning outcome. With the objects that can be observed directly, it will help students practice abstract thinking skills. This factor causes scores on indicators of probabilistic reasoning, combinatorial reasoning, and students' correlational reasoning to have low scores.

Regarding abstract thinking skills, the effectiveness of augmented reality media is also viewed in terms of the percentage of students' responses in conducting the learning process using augmented reality. Students' responses showed a perfect category with a percentage of 95.75 % in the material aspect, an outstanding category with a percentage of 90.15 % in the language aspect, an excellent category with a percentage of 92.12 % in the media aspect, and a very good category with a percentage of 92.42 % in aspects of learning. Overall, students' responses in the learning process using augmented reality achieved a perfect category, with a portion of 92.76 %.

It can be concluded that the augmented reality media have fulfilled the criteria of students' reasoning and response so that this media can be said to be useful for use. Additionally, in line with the vision of the industrial revolution 4.0, which has been discussed in the introduction and the development of online learning, distance learning as well as digital learning, this PicsAR application in the future can be used as a tool for learning nuanced massive and online course [12, 17, 18].

4. Conclusion

After developing PicsAR, the authors claimed that the PicsAR had fulfilled the criteria of valid, practice, and effective through their preliminary research. Then, regarding the two main issues in this research: (1) the features performed at PicsAR of atomic models and (2) the students' thinking skills in the abstract concepts, the following are the conclusion. Firstly, as a physics representation, an atomic model was illustrated as an abstract concept in physics due to the proposed application. The research findings described the feature of PicsAR through the performance of Augmented Reality (AR) of atomic models. The representation of AR started from the Dalton to the Bohr atomic model. Secondly, students' abstract thinking skill of atomic models, including "proportional reasoning, probabilistic reasoning, combinatorial reasoning, and correlational reasoning," was also deliberated. The students achieved 100 % on proportional reasoning indicators, 66.67 % on probabilistic reasoning indicators, 75.76 % on combinatorial reasoning indicators, and 66.67 % on correlational reasoning indicators with very good categories.

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