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Analysis of Students' Multi-Representation Ability in Augmented Reality-Assisted Learning

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Abstract. Not all learning sources can directly and cheaply be presented, so augmented reality media is needed to be applied to students with various talents and intelligence. This study aims to analyze students' multi-representation ability through the use of augmented reality media. The research method was carried out through pre-experiment with one group posttest only design. Test question items were given to see the students' multi-representation ability. Data analysis was carried out through the percentage of the number of students achieving test scores of more than or equal to 80 on a scale of 100. The results showed that 88% (28 students) were around 88%, 28 students out of 32 students reached a score range of 80-100. A score achieved between 60-79 was 3% (1 student), and scores of less than 60 were around 9% (3 students). This shows that learning through augmented reality media is effective in improving students' multi-representation ability.

Keywords: Augmented Reality, AR Learning, AR Media

1. Introduction

The spirit of Natural Science learning lies in product, process, and scientific attitudes [1]. Science product here refers to a collection of concepts, principles, laws and theories which are systematically processed through discovery/investigation methods. This discovery process will build students' scientific attitudes, namely curoisity, courage, persistence in each individual [2]. The product of natural science knowledge will be more meaningful and having real benefits with multiple representations according to the characteristics of natural diversity manifestation. Multi representation is a technique of presenting a concept through various ways such as pictures, diagrams, words, graphics, computer simulations, mathematical equations, experiments, and so on [3]. Multi representation is best used in classes with multiple intelligence. The various representations will provide maximum learning opportunities for each type of intelligence. Multi representation is very well used to explain natural phenomena, explain experimental results, and disseminate findings. It also helps students solve, overcome and address problems.

Physics learning syntax is actually an up-to-date learning process towards any curriculum development and the times. The process of which is carried out by scientific methods in gaining knowledge in accordance with existing developments. Physics learning at schools and universities should reflect a learning model to find knowledge and introduce knowledge products [3]. In addition, it must train and develop students' abilities to face, respond to and provide solutions to problems arising both in learning process and in the real world. The development of Physics has also encouraged new discoveries in advances related to information technology. However, Physics has so far left a poor image. It is considered difficult and most students do not like it [4]. It only seems to be metamatic and theoretical subject, which is far from a real life.

The competences of graduates that students must achieve must be directed to skills supporting the development of the 21st century. Students need multi-representation skills in order to be able to compete in society. An understood concept needs to be represented in a real product. Authentic assessment needs to be done to figure out whether students' skills are really formed or not [5], [6]. This assessment will look at their psychomotor aspects in learning process. Assessment is conducted towards activities carried out by students during learning process, experiment completion, and ability to represent through the use of media in learning [7].

Natural Science subjects, especially physics and chemistry, are considered difficult subjects, both at schools and in universities [8]. Most concepts are abstract, so they are not always well understood, and not easy to visualize. Chemistry and physics learning need to be directed at finding concepts and their applied products. For this reason, a good visualization is needed so that a comprehensive understanding occurs. This visualization is one of the ways to represent the concepts which have previously been obtained [4]. This multi-representation uses computer simulation media through Augmented Reality (AR). AR technology provides a more real three-dimensional display so that it is expected to be able to develop students' multi-representation ability.

Multi-representation is used to study natural events, conduct experiments and communicate/visualize them through pictures, diagrams, words, graphics, mathematical equations, and computer simulations [3]. Some abstract physics concepts, such as quantum physics, modern physics, solar systems, electromagnetic waves, sound, temperature and heat, elasticity and so on, require simulation media to be well understood. These abstract concepts can be best understood when translated into more concrete symbolic representations [9], [10]. One of the media that can be used is Augmented Reality (AR). AR enables real and virtual objects side by side in the same space to interact with real time [11]. It also makes it easy to connect science concepts to everyday life [8]. The main pedagogical ability of AR is to alter scale virtual objects from molecules to planets. It can also link to learning resources which are considered expensive and impractical for schools [12]. These resources are such as large industries, expensive laboratories, and applied physics products on a large scale.

The Nuclear Energy Power Plant (PLTN) is one of the rare learning sources and cannot directly be presented in learning. In addition to its limited numbers, there are only three locations in Indonesia, namely the Kartini Research Reactor in Sleman, Yogyakarta Special Region, the MPR RSG-GA Siwabessy Research Reactor in Serpong, Banten, and the Triga Mark III Research Reactor in Bandung, West Java. The anxiety of being affected by radiation is also of the factors for not being able to conduct a direct learning [13]. For this reason, augmented reality media is needed, so that learning about the Nuclear Energy Power Plant (PLTN) resources can easily be done, wherever they are. Referring to the background above, this study was conducted as an effort to improve students' multi-representation ability in understanding the concept and process of Nuclear Energy Power Plant (PLTN) through augmented reality media.

2. Research Methods

This study is a quantitative research with pre-experimental type, one group posttest only. The samples were the sixth semester students of Physics Education Study Program, totaling 32 students. The learning process through the use of augmented reality was carried out in the Environmental Physics subject, Sub-theme of alternative sources of electrical energy for Nuclear Energy Power Plants (PLTN). Wonosobo village, which is far from big cities, requires a lot of time and money to have an excursion class in the location of the Nuclear Energy Power Plant (PLTN). Therefore, a cheap and affordable learning resource is needed, that is, through augmented reality. At initial stage, students were given an explanation of how to use the Nuclear Energy Power Plant (PLTN) learning application, namely nucleAR (Figure 1 via Zoom). They were then given opportunities to download the application and install it on their respective smart phones.

After that, they tried the application by following the manual which had previously been distributed. Having successfully tried the application without any obstacles, the students were then given test questions to see their ability to present the concept of nuclear energy power plant (PLTN) which has been studied. There were 15 test questions with representation type in the form of phenomenology with 3 pictures and 3 verbal questions. The model representation was in the form of 3 simultaneous pictures and verbal questions, and 1 mathematical question. The symbol representation type was given in 3 questions, which were the decomposition of the fission reaction of nuclear reactor fuel and the energy produced.

Figure 1. nucleAR Application

The effectiveness of using a multi-representation approach through augmented reality media in instilling an understanding of Nuclear Energy Power Plant (PLTN) concept in students was determined based on the percentage of the students achieving test scores of more than or equal to 80 on a scale of 100 [14], using the criteria as shown in Table 1.

Table 1. Criteria for assessing the effectiveness of learning

The number of students reaching scores ≥ 80 in scale of 100	**Criteria for learning effectiveness**
> 75%	The learning effectiveness is high
50 % - 75%	The learning effectiveness is fair
<50%	The learning effectiveness is low

3. Results and Discussion

The multi-representations used in this study were phenomenological types, models, and symbols. The phenomenological questions were in the form of pictures (figures) showing phenomena or events resulting from radioactive rays and answers in the form of verbal short essays, as well as verbal questions which must be answered verbally as well as picture 2.

Figure 2. Atomic Bomb

The model presents images of core, reactor, moderator, control bar, and turbine. The questions are presented in the form of pictures and verbally and mathematically answered as shown in figure 3.

Figure 3. The reactor core contains uranium materials in the form of bars, water moderators, and cadmium control bars.

Meanwhile, the symbol to train the students' abilities was to present the core reaction of uranium fuel in the core reactor and the energy produced. One of the fission reactions is the reaction between Uranium and neutrons, that is

$$U + n \rightarrow Ba + Kr + 3n + E \tag{1}$$

with reactant mass and products as follows:

m_u=235, 125 sma. m_n=1,009 sma, so the total reactant mass of m_{reak}=236, 134 sma. Whereas for the product, m_{Ba}=140,958 sma, m_{Kr}=91,926 sma, m_{3n}=3,027 sma. So, the total product mass m_{prod}=235,911 sma. However, from the total reactant mass and products, there is a difference which then becomes the energy used in power plants.

$$E = \Delta m. c^2$$
$$E = \left(m_{reactant} - m_{product}\right)c^2$$
$$E = \left(m_{reactant} - m_{product}\right)[sma].931\left[\frac{MeV}{sma}\right]$$
$$E = 235{,}911[sma].931\left[\frac{MeV}{sma}\right]$$
$$E = 207\ MeV$$

The multi-representation using augmented reality media in studying the Nuclear Energy Power Plant (PLTN) was carried out through stages in Table 2 as follows.

Table 2. The Stages of Multi-Representation Learning Using Augmented reality

No.	**Learning Stages**	**Students Activities**
1.	Orientation on the use of nucleAR application	After listening to the lecturer explanation regarding the importance of learning nuclear power plants using AR, the students

downloaded and installed the nucleAR application, and operating it based on the manual.

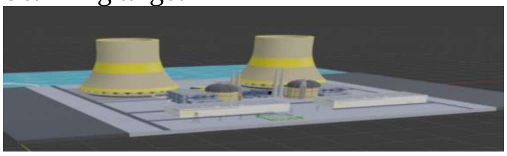
2. Orientation on fission phenomena

The students pressed the start button, videos of various phenomena and events occurring in the world as a result of the inappropriate use of radioactive rays would appear. Among of which were the atomic bombs occurring in Nagasaki and Hiroshima.

3. Orientation on 3D Nuclear Reactor Model

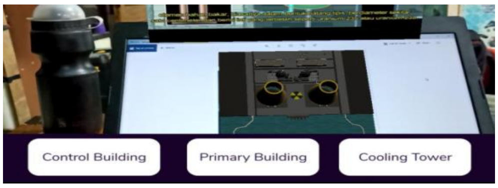
After exploring the world, looking at the phenomena of the impact of radioactive rays, the students were directed to see the positive impact of these radioactive rays on the Nuclear Energy Power Plant (PLTN) by pressing the scan button. At this stage, they explored the process of making electrical energy.

a. Scanning target



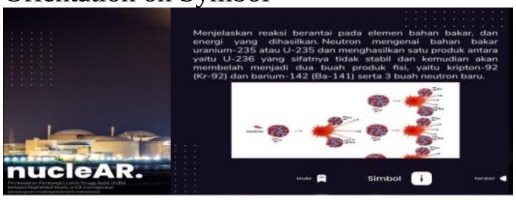
After the students pressed the scan button, the camera on smart phone was directed at the target image, and they would see a 3-dimensional images and an explanation video of the Nuclear Energy Power Plant (PLTN).

b. Nuclear Reactor



After the 3D images and videos appeared, the students pressed Button 3, the writing in the middle of which functions to show the PLTN sections consisting of the main building (reactor core), the control section, and the cooling section. This section should be clicked first and the animation would start then.

4. Orientation on Symbol



After looking at the Nuclear Energy Power Plant (PLTN) sections, the students pressed the button symbol, and a video explaining the materials on the nuclear fission process that occurred in the reactor core from the uranium bars would appear. This video also includes an explanation of the energy produced.

Thus, augmented reality invites students to virtual adventures as if they exist in the real world. It helps to present objects which cannot directly be presented in the learning process, so that it is more contextual [15]. The augmented reality application which we know only from children's games is now proven to be used in learning and is very helpful in increasing students' motivation in pandemic era.

To provide monitoring, enrichment, and follow-ups, test questions were given to see the students' multi-representation ability in understanding the material on Nuclear Energy Power Plants (PLTN). The test results given to 32 students are shown in Figure 4 below.

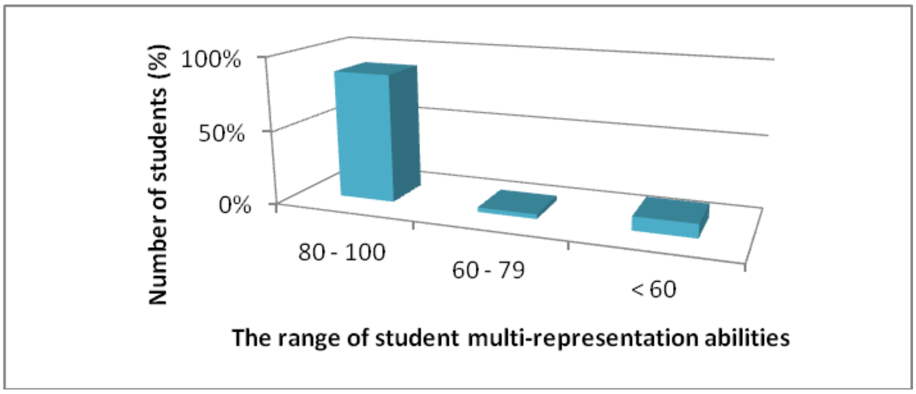


Figure 4. The bar diagram of the percentage of students' understanding of the Nuclear Energy Power Plant material

In Figure 4, it can be seen that students achieving a score range of 80-100 are around 88%, 28 students out of 32 students. Score of 60-79 reaches 3% (1 student), and scores of less than 60 are around 9% (3 students). This shows that the students' understanding of the Nuclear Energy Power Plant (PLTN) material is good. Learning Nuclear Energy Power Plant (PLTN) using augmented reality media is effective in increasing students' understanding of concepts. Augmented reality directs learning in the real world outside students into virtual world. Presenting concept with various presentations makes it easier for students to understand the material. Fission reaction which has so far been understood as a formula and symbol can systematically be visualized through augmented reality to clarify how the fission reaction occurs [16].

The 3-dimensional images of the nuclear reactor make them to not be afraid of being exposed to radioactive radiation. The important parts in the nuclear reactor can clearly be seen. Explanation videos when scanning camera is turned on, high-lighting the key parts of the nuclear reactor core make the process of uranium fission reaction which produces energy. The moderator sections are, water slowing down the motion of the neutrons and the control bar in the form of cadmium. The process of which is clearly visible so that the controlled fission reaction can be understood well by the students. Energy generated from the core of the reactor through 3D images and videos is visualized systematically. The energy is used to heat the water until steam comes out, and this steam drives the turbine to produce electricity. From the 3D images, it can also be seen a picture showing how electricity is supplied into houses. Thus, students can gain a correct understanding of how science may provide solutions to problems in society. This is in line with Sila Kaya et all's study which explains certain social aspects of the nature of science (NOS), such as economics, and entrepreneurship in science, studied in science education research [17].

In addition, it also shows how science works in society by shifting theoretical knowledge into practical applications in science teaching and learning process. The integration of interdisciplinary and trans-disciplinary science makes it easier for science to work on providing solutions to problems in society. The students' ability to present the concept studied has been given an example in the nucleAR application media. Thus, students have a concrete picture of concept visualization to be presented again in sharing models, either in the form of pictures, verbal, mathematical, symbols, or in computer simulations. Multiple-representation sharpens the understanding of the materials and can improve the students' learning activities [18]. Students have ample opportunities to convey thoughts in various ways and styles according to their talents and intelligence. Thus, the multi-representation approach through augmented reality media is very effective in increasing their multi-representation ability in showing how science works in society.

4. Conclusion

From the description of the discussion and data analysis, it can be concluded that multi-representation in learning is effective in developing various students' intelligence and talents. This study made use of nucleAR application as a simulation. It is an augmented reality media application which can be used in learning, so that science appears more real. Multi-representation through augmented reality media is able to direct how science works in solving problems in society.

A multi-representational approach to learning needs to often be conducted so that students have opportunities to express their intelligence in various ways. Augmented reality media needs to be applied in other materials, so that it is good enough to be used in learning process in this pandemic era. Science learning needs to be directed at practical applications, so that science is better known as non-theoretical knowledge.

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