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ENHANCING ELEMENTARY SCHOOL STUDENTS' ABSTRACT REASONING IN SCIENCE LEARNING THROUGH AUGMENTED REALITY-BASED INTERACTIVE MULTIMEDIA

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ABSTRACT

Elementary school students' rational skill is terminated on concrete situations; therefore, enhancing abstract reasoning becomes a prompt for students to be more critical in solving science problems. The objective of the study was to improve abstract reasoning in science learning using interactive multimedia based on augmented reality (AR) for fifth-grade students. This study used a Classroom Action Research conducted in two cycles consisting of Plan, Act & Observe, and Reflect stage each. Data collection techniques used tests and observations involving 28 students. The credibility of the research data was examined based on technical triangulation and source triangulation while the collected data were analyzed descriptively. The results of the study on process aspect showed that the use of interactive multimedia based on augmented reality gave positive changes to the learning processes on earth and rock structure topic in the fifth grade of elementary school. The students' enthusiasm during the learning processes thus strengthened student-teacher interaction as they enjoyed the learning processes actively, independently, and collaboratively. The interactive multimedia based on augmented reality facilitates the students to reason by exploring more realistic visual objects to eases student understanding of science concept, associating inter-concepts and implementation of information analysis, and problem-solving. The success of the product showed that students' abstract reasoning in science learning enhanced by 24.20% (in the first cycle) and 23.08% (in the second cycle). The results of this study concluded that the use of interactive multimedia based on augmented reality could enhance abstract reasoning skill of the fifth-grade elementary school students.

Keywords: abstract reasoning, augmented reality, elementary school, interactive multimedia, science learning

INTRODUCTION

Science is the knowledge that deals with natural phenomena not only a collection of facts and concepts, but also about how to work, how to think, and how to solve problems. Science learning is a medium for students to learn about themselves and their surroundings, and the prospects for further development in applying science concepts in their daily lives (Djojosoediro, 2010). The earth and the universe is one of the topics for fifth-grade science learning, including earth structure and rock formation. In this study, students are expected to master the concepts of earth structure, rock formation, and analyze various types of rocks.

The study of the earth belongs to a real object; yet due its massive size and depth (for earth structure and underground phenomena), it is finally categorized as an abstract topic. As a

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result, students, particularly fifth graders, find it difficult to understand it.

The majority of children in elementary school are in the operational stage of Jean Piaget's stages of cognitive development (Piaget et al., 1964). At this stage, students are mature enough to use logical or operating thinking, but only for existing physical objects (Ibda, 2015). They could classify, order the construction of the numerical idea, the fundamental operations of classes and relations, basic mathematics, and elementary physics (Piaget et al., 1964). By understanding children's ways of thinking and problem solving, educators can elaborate more practical ideas to help students acquire and apply their knowledge (Brouse & Chow, 2009).

Students process basic requirements as a form of abstract reasoning (Markovits et al., 2018). In particular, ages 11-14 years old (grade fifth of elementary school students) is a transition phase to their cognitive development from concrete operational to formal operational (Susac et al., 2014). Considering this situation, teachers need to facilitate students to develop logical reasoning and the ability to reason abstractly to achieve learning achievements in learning earth structures and rocks. The overall learning outcomes of the fifth-grade elementary school students, according to the 2013 Curriculum content standards, is at Level 3 or Relational categories (BNSP, 2013). At this level, students address a point, make sense in light of their contribution to the topic as a whole (Biggs & Tang, 2007).

Research on young children's reasoning shows the complex correlations of knowledge, theories, and evidence in their decision-making and problem-solving (Kim, 2016). The reasoning is part of an abstract reasoning process. Abstract reasoning refers to the ability of information analysis, detect patterns and relations, and problem-solving skill on complex levels (Datta & Roy, 2015). Moreover, abstract reasoning is an outcome of brain maturation (Piaget, 1952). This ability acts to think, analyze information, solve problems, and make rational decisions (Psychometric Canada, 2019). Ability to reason abstractly in science learning at elementary school strengthens scientific reasoning in achieving student learning success that requires data analysis and problem-solving skill by identifying the correlations.

The results of pre-test on abstract reasoning on earth and rock structures topic for fifth graders of Surakarta Public Schools showed unsatisfactory results. The mean of interpretation ability was 51.79, the analytical ability was 46.43, and the problem-solving ability was 41.96, and the overall mean aspect of abstract reasoning was 46.73. These results indicated that the students' abstract reasoning on the topic was low. Fifth-grade students are in the transition from concrete thinking to abstract thinking; hence, efforts to improve abstract reasoning are needed to help them in further processes such as analysis and problem-solving.

The limitations of learning aids and the unavailability of science labs at elementary school are classic reasons that are less relevant for nowadays digital era when computer-based technology enables learning to be possibly carried out both in and outside a class (Smaldino et al., 2019). Utilization of Information and Technology (IT) facilities as a smartphone could be an alternative to overcome the limitations of space and the media and also stimulate abstract reasoning of students in earth and rock structures topic. Smartphone has the potential to enhance efficiency and effectiveness in teaching and learning in addition to improving learning outcomes and working skills (Morris & Lambe, 2017).

The development of science and technology leads to the development of innovative and effective learning media. Features of a smartphone with sophisticated operating systems are capable of providing users access to a variety of attractive multimedia content and applications that fulfill daily needs, including interactive media-based Augmented Reality (AR). AR Technology is the latest technology for teaching, learning and creative research (Tekedere & Göke, 2016) that has three characteristics: (1) real and virtual combines; (2) interactive in real time; and (3) registered in 3-D (Information Resources Management Association, 2018). AR technology allows virtual objects to be produced by computers to be placed on physical objects in real time (Ozdemir et al., 2018). Through AR technology, students can study the objects of the earth's structure and phenomena that occur visually to form various types of rocks actively. In other words, AR enhances the perception of the user, helps them to understand better (Iftene & Trandabăt, 2018).

Related researchers have applied AR technology as multimedia in various types of teaching topics and educational levels such as

use of AR in middle-level students and universities as an interactive media on human anatomy, geomorphology, and astronomy learning (Jamali et al., 2015; Kurniawan et al., 2018; Turan et al., 2018; Yen et al., 2013). The researchers at elementary school have applied AR media as learning media ecology system, increase motivation and critical thinking skills (Chang & Hwang, 2018; Tarng et al., 2015). If the other researchers focused on motivation, mastery of concepts, and the basis of critical thinking skills, this study focused on enhancing the abstract reasoning of the fifth-grade elementary school students whose role is essential in classifying, identifying the relationship between concepts, analyzing problems, and eliminating problems.

The earth and rock structures topic would be easily understood by fifth-grade students if delivered with proper media suitable for the students' characteristics, in this case, relating to the thinking stage as mentioned upfront. The AR combines 3-dimensional (3D) objects as a visualization of the earth structures. Students will actively find a picture of the structure of the earth and rocks through their smartphone camera by scanning markers on teaching materials. Visualization of the concept of earth structure that is still abstract for fifth-grade students can help students to identify traits, understand interconcept relationships so that they can help to analyze and solve problems as manifestations of abstract thinking skills. Therefore, the use of AR-based media is suitable for the characteristics of fifth-grade elementary school students.

Based on the problems regarding the low ability of fifth-grade students in abstract reasoning, this study aims to enhance the abstract reasoning skill of fifth-grade students in learning earth and rock structures through the use of AR-based multimedia.

METHODS

This study is qualitative research employing Classroom Action Research method. Many teachers practice personal reflection on teaching, others conduct formal empirical studies on teaching and learning, and Classroom Action Research is more systematic than personal reflection (Stringer, 2008). Classroom Action Research intends to find out what works best in the classroom to improve abstract student reasoning on the earth and rock structures topic.

The study was conducted in the form of cycles. Each cycle has three stages consisting of a plan, act and observe, and reflect (Eriksson & Kovalainen, 2015). The research was initiated with "Plan" by compiling learning devices using AR media, planning data collection, students' worksheet, test, and observation sheets for learning activities and teacher performance. "Act and Observe" is an implementation of the planned activities. Simultaneously, at this stage, observation of student learning activities, and the teacher performance determines the quality of the learning process in the classroom. Each cycle is evaluated using tests for revealing the learning achievement and abstract reasoning. Furthermore, the stage of "reflect" focuses on a period of continuous reasoning through discussion activities with the teacher about the meaning of the observational data. This stage determines the new strategy in deciding whether the next cycle needed to be performed or not referring to the performance indicators. The formulation of performance in determining the success of the research was measured by the acquisition of abstract reasoning test scores with a percentage of classical completeness of 75% on 55 of minimum score completeness.

The subjects were 28 fifth grade students of primary school in Surakarta. Data were collected through tests and observations. The students' abstract reasoning were assessed based on three aspects including: (1) the ability to identify inter-conceptual relationships; (2) information analysis; and (3) problem-solving abilities about the structure of the earth, convection, tectonic phenomena, volcanic, and the formation of various types of rocks. Observations were carried out during the implementation of the learning process using interactive multimedia based on augmented reality.

The validity of the data was examined using the triangulation technique. Triangulation is a way of checking data from various sources in various ways and at multiple times (Sugiyono, 2015). This study used data validity testing techniques in the form of source and technique triangulation. The collected data were analyzed descriptively to reveal the effectivity of interactive multimedia based on augmented reality to the improvement of learning outcomes and abstract thinking skill.

The data analysis phase was identified after the data were collected. All of the collected research data were selected and reduced on what should be presented and used (Miles & Huberman, 1994). The valid data were used as a basis for drawing conclusions which focused on

enhancing the quality of learning processes and abstract student reasoning in science learning.

RESULTS AND DISCUSSION

The Use of Augmented Reality-Based Interactive Multimedia in Science Learning at Elementary School

This research was conducted in three stages consisting of pre-, first, and second cycle. The pre-cycle step is a preliminary study aimed to identify problems in learning the earth and rock structures in the fifth grade of elementary school. Observations of the science learning process in the pre-cycle stage showed that learning was not student-centered (Student-Centered Learning). The learning method only emphasized on memorization. The students had not been trained to explore their problem-solving skill. As a result, they were bored and ended up playing their stationary, drawing, or folding paper that had nothing to do with the topic being studied. The observations of student activities intended to examine 5 aspects consisting of: (1) students' readiness to learn; (2) enthusiasm in learning activities; (3) activeness in discussion; (4) student activities in solving problems; and (5) participation in the closing activities. The observations results of the student activities in the precycle are presented in table 1.

Table 1. Results of Student Activity Observation

No	Rated Aspect	Score	Category
1	Students' readiness to learn	2.33	Fair
2	Enthusiasm in learning activities	1.33	Poor
3	Activeness in discussion	1.67	Poor
4	Student activities in solving problems	1.33	Poor
5	Participation in the closing activities	2.00	Fair
	Mean	1.73	Poor

Table 1 identifies that the readiness of students during the while and closing activities were in a fairly good category, while other aspects in the category were insufficient. The students had not been enthusiastic in learning activities, actively involved in discussions, and activities in solving problems. Obtaining an average score of was 1.73, it shows that student learning activities in learning the structures of the earth and rock was classified as poor. The teacher applied many verbal learning methods and had not used any amusing media primarily to present visual objects that aid students' abstract reasoning in studying the topic. This condition caused unattractive learning and less satisfying learning outcomes.

The first cycle consisted of two meetings having 70 minutes each. The early stage of the cycle began with planning everything needed during the action such as: determining learning achievement; compiling learning devices; preparing augmented reality (AR) media; preparing observation sheets for student learning activities, and examination sheets. The AR-based interactive multimedia referred to the 2013 Curriculum's scientific approach for elementary school, aiming at acquiring a scientific, systematic knowledge that gives priority to more active and participatory methods (Baars, 2011; Hernawati et al., 2018; Simonneaux, 2014).

Implementing the first cycle's activities began with the formation of groups consisting of 4-5 heterogeneous students. The teacher had prepared a smartphone that already has AR-based interactive multimedia. The teacher introduced AR media and explained how to use it in learning activities on the structures of the earth and rock. Each group got AR media, and alternately, the students used it for tracing every layer of the earth, the structure of the earth, volcanic processes, tectonics, rock formation, and observing various types of rocks. This led to the role of AR that could be used as a learning resource for students. The information obtained by the students through multimedia became the primary data for analyzing and solving problems that the teacher had prepared on a worksheet. The students seemed enthusiastic in using the media and active in discussion activities.

Observations on student activities were carried out during learning activities to determine the quality of learning using AR -based multimedia. The observation results of student activities in learning the structures of the earth and rock in the first cycle are presented in table 2 below.

Table 2. Activities of Students in the First Cycle

No	Rated Aspect	Score		Mean	Category
		Learning 1	Learning 2		
1	Students' readiness to learn	2.67	3.00	3.00	Good
2	Enthusiasm in learning activities	2.00	2.67	2.34	Fair
3	Activeness in discussion	1.67	2,33	2.00	Fair
4	Student activities in solving problems	1.67	2.00	1.83	Fair
5	Participation in the closing activities	2.33	2.67	2.50	Good
Mean		**2.07**	**2.53**	**2.33**	**Fair**

The observation results in Table 2 indicated that the student learning activities in the first cycle belonged to a fairly good category. The enthusiasm of students in learning and student activities in discussions has enhanced than previous learning the structure of the earth using AR-based interactive multimedia. However, aspects of student activity in problem solving still have the lowest score compared to other aspects. The students' interest in new AR-based media makes them excitedly told each other what objects they see and discussed them in an interactive learning situation. The observation results of the learning process quality in the first cycle are presented in Table 3.

Table 3. The Quality of Learning Process in the First Cycle

No	Rated Aspect	Score		Mean	Category
		Learning 1	Learning 2		
1	Consistency of learning activities with the curriculum	4	4	4.00	Very good
2	Implementation by educators	2	3	2.50	Fair
3	Implementation by students	2	3	2.50	Fair
4	Student learning motivation	3	4	3.50	Good
5	Student activeness in learning activities	3	3	3.00	Good
6	Teacher-student interaction	2	3	2.50	Fair
7	Educators' teaching skill	3	3	3.00	Good
Mean		2.71	3.29	3.00	Good
Percentage (%)		67.86	82.14	75.00	

Table 3 showed that the quality of the learning process has enhanced from meeting I to meeting II. Cycle 1 has fulfilled the consistency of learning activities with the curriculum aspects. The student learning motivation, student activeness in learning activities, and educators' teaching skill had good scores. Meanwhile, points that need to be enhanced include implementation by educators, application by students, and interaction between students and teachers. The teachers remained to face problems in controlling students when they teach science using AR media for the first time. The excessive enthusiasm of the students made the class condition quite noisy because they actively scanned into various AR markers to see visual objects following their curiosity regardless of what it was written in the instructions. The second cycle's procedures were similar to the first one. The second cycle was identified with activities to prepare an action plan with improvement (the results of reflection activities in the previous cycle). This action was carried out in accordance with the second cycle planning procedure. There are various types of rocks added to interactive multimedia to broaden the students' references in getting to know the types of rocks in Indonesia. At the beginning of learning, the teacher explained the procedure for using AR interactive multimedia to support analysis and solve problems that the teacher had prepared through a worksheet. The use of AR media presented more tangible objects so that it could be a source for students to know the concept of earth structure (which cannot be seen directly) and phenomena about the earth. The observation results of student activities carried out during the second cycle of learning are presented in Table 4.

Table 4 . Student Activities in the Second Cycle

No	Rated Aspect	Score		Mean	Category
		Learning 1	Learning 2		
1	Students' readiness to learn	3.33	3.67	3.50	Very good
2	Enthusiasm in learning activities	3.00	3.33	3.17	Good
3	Activeness in discussion	2.50	3.33	2.92	Good
4	Student activities in solving problems	2.33	3.00	2.67	Good
5	Participation in the closing activities	3.00	3.00	3.00	Good
Mean		**2.83**	**3.27**	**3.05**	**Good**

The observation results in Table 4 reveal that the activities students learning activities in the second cycle were categorized as good, having a score enhancement in meeting 1 to meeting 2. When compared to the previous cycle, there was an enhancement in all aspects in the second cycle. Learning the structure of the earth by using AR-based interactive multimedia in class has proven to increase the students' enthusiasm so that it strengthened student-teacher interaction. Also, the students were more active in class discussion to solve problems collectively.

On the other hand, the quality of the learning process in the second cycle was assessed based on the mean score of the first and second cycle, as displayed in Table 5. It is seen in Table 5 that there are six aspects categorized as very good, and one aspect as good. Enhancement almost occurred in all aspects but was not significant on student-teacher interaction. Thus, it is evidenced that AR has interactive characteristics when accessed by users. The students (as users) were enthusiastic in using this new media, which had an impact on increasing student-media interaction.

Table 5. The Quality of Learning Process in the Second Cycle

No	Rated Aspect	Score		Mean	Category
		Learning 1	Learning 2		
1	The Consistency of Learning Activities with the Curriculum	4.00	4.00	4.00	Very good
2	Implementation by educators	3.00	4.00	2.50	Fair
3	Implementation by students	3.00	4.00	2.50	Fair
4	Student learning motivation	4.00	4.00	3.50	Good
5	Student activeness in learning activities	3.00	4.00	3.00	Good
6	Teacher-student interaction	3.00	3.00	2.50	Fair
7	Educator's teaching skill	3.00	4.00	3.00	Good
Mean		3.29	3.86	3.57	Good
Percentage (%)		82.14	96.43	89.29	

The use of interactive multimedia based on augmented reality gave positive changes to the learning process of earth and rock structures in the fifth grade of elementary school. Students' interest in AR media made them enjoyed the learning process. Most students were interested in continuing to explore other markers by hoping that other 3D objects will appear. Learning earth and rock structures became more contextual with students actively, independently, and collaboratively involved in it. This result is in accordance with the results of previous studies that visualize objects related to the structure of the earth in 3D help students in the process of concept analysis (Amir, 2017), understand the relationship of their parts (Deshpande & Kim, 2018), enhance student motivation in dimensions of attention dan self-confidence (Cai et al., 2014; Chiang et al., 2014), and strengthen student spatial skills (Escudero et al., 2016). Also, the use of AR media in science learning is suitable for the 21st-century learning process (Sungkur et al., 2016).

Enchancing Abstract Reasoning Skill in Science Learning through Augmented Reality-Based Interactive Multimedia

Measurement of students' abstract reasoning was carried out in the pre-cycle, the end of the first and second cycle. The abstract reasoning skill was measured through tests on aspects of relationship identification, information analysis, and problem-solving. The results of the abstract reasoning test in the pre-cycle are presented in Figure 1, which indicates that the students' abstract reasoning skills were not good enough. The pre-test

mean on the aspect of relationship identification had the highest score among other aspects. These results indicated that the students had the initial ability to interpret data and look for relationships between data, yet have not been able to apply it in analyzing and solving problems. Besides, one student obtained a zero score at the information analysis and problem-solving stage because he could not provide an answer.

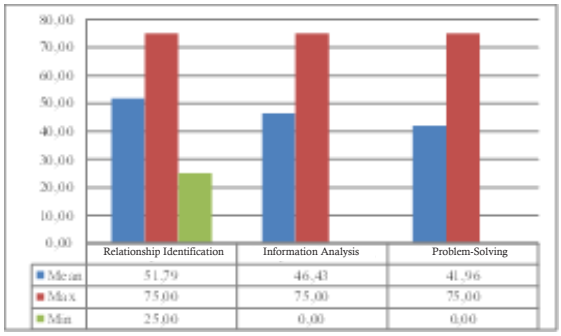

Figure 1. The Results of Abstract Reasoning Test in the Pre-Cycle Stage

The percentage of classical completeness in the pre-cycle stage was measured at 21.43%, which assured that the abstract reasoning of the fifth-grade students needed to be enhanced to assist them in solving scientific problems about the structure of the earth through effective learning and attracting media. At the end of the first cycle, a test was conducted to determine the ability of students to reason abstractly in learning the structure of the earth and rock after using AR media. The test results of the first cycle are presented in Figure 2.

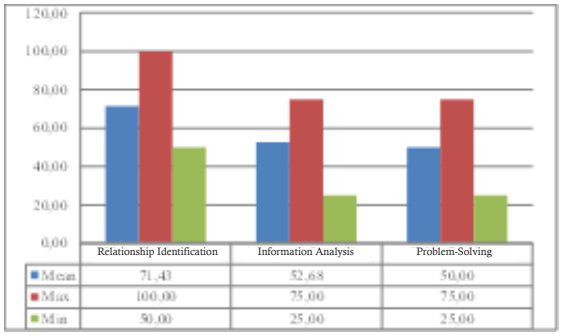

Figure 2. The Results of Abstract Reasoning Test in the First Cycle

Figure 2 showed that there is an enhancement of the students' abstract reasoning after learning the structure of the earth using AR-based interactive multimedia. Compared with the pre-cycle conditions, the aspect of relationship identification enhanced by 37.93%, while the aspect of information analysis enhanced by 13.46%, and aspect of problem-solving enhanced by 19.15%. The use of AR-based interactive multimedia has a useful effect in increasing the students' ability to interpret visual objects about the structures of the earth and rock and their connection. Such skills help them analyze the information they get to solve problems. Trying new things in learning activities was seen as fun and engaging for the students. Directly, they were interested in being active in science learning. This condition is different from the pre-cycle in which the students were reluctant to study the topic.

The reflection phase was conducted to get consideration in planning further action. Hinge on the classical completeness in the first cycle, which was 64.29%; thus, the study had to continue in the second cycle. Referring to observations of student activity and the quality of learning during cycle 1, it was identified that deficiencies or constraints faced in the first cycle generally include teachers who have difficulty in controlling students when scanning using AR media. The students were too happy to operate the AR media outside the worksheet instructions so that they were not focused on solving problems on the worksheet. Some efforts to handle the problems in the first cycle were: (1) giving training to the teachers in how to explain and operate the media in a systematic and procedural way; (2) dividing tasks to each of the group; and (3) setting up time limitation for each group to solve the problems and explain the results of the students' group work to be given a response by other groups. At the end of the second cycle, the students worked on the abstract thinking test and the results at the stage of the second cycle are presented in Figure 3.

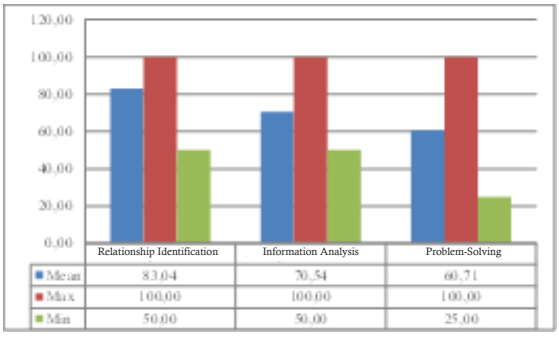

Figure 3. The Results of Abstract Reasoning Test in the Second Cycle

Figure 3 makes clear that there was an enhancement in all aspects of abstract thinking skills which were tested after the fifth-grade students experienced learning using AR-based multimedia. The students' ability to understand

concepts and identify the correlation between structures of the earth again increased in the second cycle. Also, their ability in analyzing information relating to phenomena on earth, volcanic events, and rock formation enhanced as well. The increase of abstract reasoning in all aspects was 71.43. The percentage of classical completeness in the second cycle was measured at 82.14%. By considering the results of observations of student activities, the learning process, and the performance indicators, the action research was already done until the second cycle.

Effective teaching includes the latest strategies that help to support alternative ways to understand the world while developing scientific explanations (National Research Council, 1996). Adopting interactive multimedia based on AR as new technology in science learning gives a positive impact on enhancing the ability of students to understand the concept with the help of abstract reasoning about the earth and rock structures. AR learning media can visualize abstract concepts so that they could provide an understanding of the structures through realistic models (Mustaqim, 2016; Yuliono et al., 2018). Furthermore, the comparison of the students' abstract reasoning is presented in Figure 4.

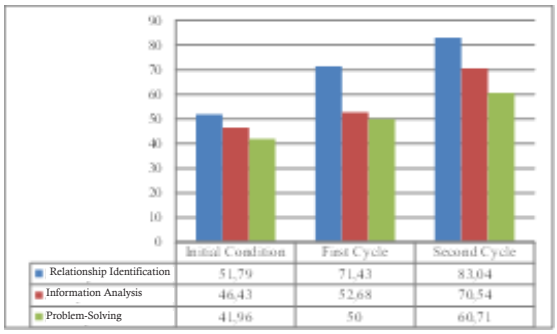

Figure 4. The Results of the Inter-Cycle Abstract Reasoning Test

The data in Figure 4 reveal that all aspects of abstract reasoning that were tested on the students have increased at each stage of the cycle. The spatial ability of students in comprehending the structures of the earth makes it easier to understand the correlation between parts that can be applied in further reasoning, such as analyzing and solving problems with critical thinking. These results are in accordance with related studies suggesting that AR-based tutoring approaches benefits students in increasing learning motivation and critical thinking (Chang & Hwang, 2018). Through the use of the AR app for environmental science learning, students could achieve a deep understanding of the concepts (Georgiou & Kyza, 2018). Furthermore, the AR could make students familiar with technology to access learning resources for independent learning (Garrett et al., 2015).

The students' enthusiasm towards the learning process has enhanced significantly through the use of interactive multimedia AR, yet it was not in line with the interaction between students and lecturers. The fifth-grade elementary school students have a high curiosity about new things, including the use of AR-based interactive multimedia. Thus, teachers were advised to explain clear procedures to the students in groups for using teaching materials with AR-based interactive multimedia through problem-solving activities. As a result, they actively participated in discussions. This fact is parallel with a study by Kim (2016), who revealed that when students participate in discussions, their intellectual realm appears to build new ideas, reasoning, and problem-solving skill. Thus, their motivation in analyzing and problem-solving activities could gradually enhance.

CONCLUSION

The research findings showed that the student activities in learning activities, quality of the learning process, and learning outcomes gradually enhanced at each stage of the cycle. These results indicated that the adoption of AR in science learning could improve the interest and help students provide abstractions about natural phenomena that occur within the structures of the earth. Visualization of the structures of the earth, volcanic events, tectonics, and the formation of various types of rocks makes it easier for the students to master the materials, connect between concepts in understanding other concepts, and apply them in analyzing and solving problems so that student learning outcomes in science learning were better.

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