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Supporting Students' Basic Science Process Skills by Augmented Reality Learning Media

Tiara Lestari Paembonan[1], Jaslin Ikhsan[2]
[1] Chemistry Education, Universitas Negeri Yogyakarta, Indonesia
Email: tiaralestari.2018@student.uny.ac.id
[2] Chemistry Education, Universitas Negeri Yogyakarta, Indonesia
Email: jihksan@uny.ac.id

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Abstract. Science process skills (SPS) are one of the skills needed in the chemistry learning process, in order to gain a complete understanding of the concepts. This skills categorized into two types; basic and integrated. This research aimed to develop a product of Augmented Reality (AR) learning media then to know its feasibility, practicality, and effectiveness on students' basic SPS on acid base learning. The research adopted Research and Development (R&D) with 4-D model consisted of define, design, develop, and disseminate stages. Questionnaire was used to measure the feasibility and practicality. Then, the obtained data were analyzed by qualitative and quantitative descriptive. In addition, SPS test was used to measure the effectiveness of AR learning media and the data were analyzed by the test of One-way ANOVA, Tukey's Post Hoc test, and General Linear Model (GLM) Univariate. The result showed that the AR learning media is feasible, practical, and effective with big influence to support students' basic SPS on acid base learning.

Keywords: Augmented Reality; Acid Base; Guided Inquiry; Science Process Skills.

INTRODUCTION

Indonesian Curriculum of 2013 emphasizes the implementation of ICT-based learning process (Permendikbud, 2016). Commonly, technology can be used in education as a learning media to support the learning process (Sirikaya & Sirikaya, 2020), especially in the chemistry learning to improve the students' knowledge (Moeller & Reitzes, 2011). However, learning media that used in class are usually books with two-dimensional (2D) form, so they are not always present all of the information for students (Pekdag, 2010) then it will make students difficult to learn.

The concept presented in a more tangible form using media can provide a more meaningful learning experience for students (Singhal, Bagga, Goyal & Saxena, 2012). Information that are commonly presented in 2D now can be transformed into 3D by utilizing Augmented Reality (AR) technology (Ko, Chang & Ji, 2013). AR has three main characteristics; 3D recognition, a mix of real and virtual worlds, and real-time interactivity (Azuma, Billinghurst & Klinker, 2011). AR implementation are increased in education (Akcayir, Akcayir, Pektas & Ocak, 2016) because it is considered to be capable to display information in 3D which are too abstract if presented on the real learning process (Chen & Wang, 2017). AR has many benefits and it can be used for all levels of education. AR can facilitates the learning process (Enyedy, Danish & DeLiema, 2015), improve students' learning achievement (Estapa & Nadolny, 2015), satisfaction (Giasiranis & Sofos, 2017) and especially in the chemistry learning can support practical skills (Yang, Mei & Yue, 2018) as well as conceptual understanding in inquiry-based scientific activities (Cheng & Tsai, 2013). It can be concluded that AR is very helpful to improve the students' learning outcomes on the affective, cognitive and psychomotor domains.

The success of learning process are complex because it also determined by the students, whereas the teacher only act as their mentor (Dimyati & Mudjiono, 2006). Thus, the teacher should create a good learning that can make students more active and explore their potential. Then, students are able to understand the science work methodology and develop their certain skills in scientific work or science process skills (SPS) and also have the competence to develop their own knowledge. SPS can affect the development of students' knowledge (Rezba, Sprague & Fiel, 2003). These skills provide a framework of how scientists act, think, and deepen the problem to find solution scientifically (Idiege, Nja & Ugwu, 2017). Students need to improve their process skills in order to understand the chemical concept completely. Students with high SPS will highly mastery the concepts as well (Cetingul & Geban, 2011). SPS is important for students when use scientific methods in develop science and are expected to acquire or develop their knowledge (Sihaloho, Sahyar & Simanjuntak, 2017).

SPS categorized into two types; basic and integrated (Arabacioglu & Unver, 2016). Basic process skills is aimed at the primary school, while integrated can be achieved by medium and higher school students (Seetee, Coll, Boonprakob & Dahsah, 2016). Basic process skills is used in this research that include observing, classifying, communicating, measuring, predicting, and inferring (Shahali & Halim, 2010). Acid base is suitable for measuring SPS because it include complex calculations and abstract concepts (Gultepe, Celik & Kilic, 2013). Therefore, to understand the acid base concepts, students must be able to have a several of skills needed in learning chemistry such as SPS (Irwanto, Rohaeti & Prodjosantoso, 2018). This research is about to develop AR learning media then test the feasibility, practicality and effectiveness on students' basic SPS in acid base learning.

METHOD

Research and Development (R&D) with 4-D model include four stages namely define, design, develop, and disseminate (Thiagarajan, Semmel & Semmel, 1974) was adopted in this research. There were five analyzes conducted on define such as front end, learner, task, concept, and objectives analysis. On design, the flowchart and storyboard of product were designed. In addition, the research instrument, lesson plan and student worksheets were arranged for research purposes. On develop, the product was created, then validated by the expert. Besides, the instrument and learning tools were also validated before used on the next activity. Product trial was held after all the validation process were done. The final product was applied on learning process to test the effectiveness. On the disseminate stage, the AR learning media was published on schools or an article. The AR learning media development procedures can be seen in the Figure 1.

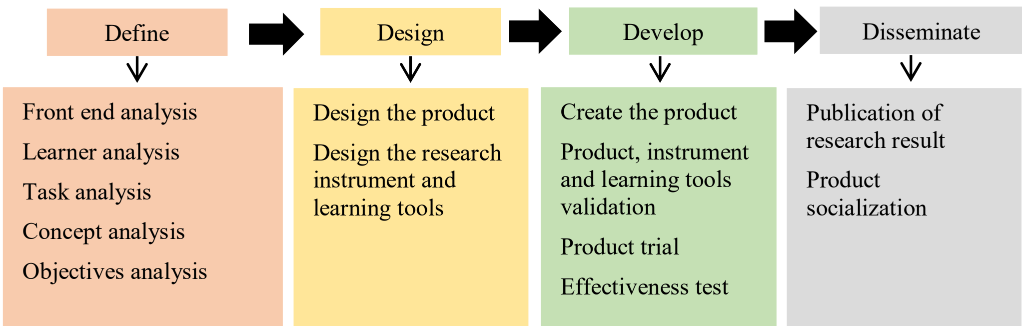

Figure 1. AR learning media development procedures.

This research was initially conducted on nine public senior high school in Toraja Utara

Regency who have the same of students' characteristics, such as were used Indonesian chemistry Curriculum of 2013, have a very good school accreditation, and have adequate facilities to support the learning process based on ICT. Two stages of purposive sampling were used to choose the school then determine the research samples. Two schools out of the population were selected on the first stage. After that, the research samples were determined by the need and learner analysis. The need analysis involved chemistry teachers and the learner analysis involved the eleventh grade students in both school. The results on both analysis revealed that there was no difference among the school. Hence, one school used on product trial; 7 students for small class and 28 students for large class, then the other used on effectiveness test (109 students). Effectiveness test was adopted a quasi-experiment with post-test only design. Three classes with different treatment are used on this research. The control class with direct instruction learning; experimental 1 class with guided inquiry learning; and experimental 2 class with AR learning media on guided inquiry learning. The independent variable of the research were the treatment that given on each classes. Meanwhile, the dependent variable measured was students' basic SPS.

Instruments were used on this research consisted in the form of questionnaire and test. Questionnaire was used to measure the feasibility and practicality of product. Feasibility data obtained from the questionnaire of media and subject-matter expert. Media expert assess based on the graphic, software engineering and visual communication (Munir, 2009; Wahono, 2006). Subject-matter expert asses based on the content, presentation and language (Arsyad, 2015; BSNP, 2010). Besides, practicality data obtained from the questionnaire of readability filled by students and practicality by chemistry teacher with assess based on the view, presentation and language. Effectiveness data obtained from SPS test consisted of 8 questions about acid base in the form of esay. The validity and reliability were carried out firstly. The validity consist of content and empirical validity. Content validity was conducted toward two expert from Chemistry Education Department. Revision according to the comments and suggestions of experts were made. Empirical validity was conducted toward 162 students who have completed the acid base lesson. The result showed that all of the items were valid. The reliability of SPS test was analyzed with Cronbach's alpha value with the result was reliable. The indicators distribution of SPS test are shown in Table 1.

Table 1. The indicators distribution of SPS test.

Indicator	Number Item
Observing	3, 8
Classifying	4
Communicating	6
Measuring	2
Predicting	1
Inferring	5, 7

Qualitative and quantitative analysis technique were used in this research. Qualitative analysis was used to describe the process of product development such as comments and suggestions obtained from expert judgment and product trial. Meanwhile, quantitative analysis was used to analyze quantitative data from questionnaire of expert judgment, students and chemistry teachers and also the result of SPS test. The questionnaire were analyzed quantitatively by calculated the total scores. Scores were converted in percentage form, then the feasibility and practicality criteria of learning media was customized with the percentage (Arikunto, 2009). Feasibility and practicality criteria of learning media are shown in Table 2.

SPS test answers data should be converted into scores based on scoring guidelines that have been compiled with the lowest score is 0 and the highest is 5. The SPS data were analyzed in three steps (Field, 2009; Walpole 1995). First, the data tested by One-way ANOVA to know the difference of students' SPS average value in the control, experimental 1 and experimental 2 classes as research hypotheses. Second, Tukey's Post Hoc test to detect which classes have the specific difference. Third, Genereal Linear Model (GLM) Univariate was used to know the effectiveness and the size of developed AR learning media influence based on the obtained value of partial eta squared (Richardson, 2011).

Table 2. The product criteria of learning media.

Percentage (%)	Criteria
90 – 100	Very Good
75 – 89	Good
65 – 74	Moderate
55 – 64	Low
0 – 54	Very Low

RESULTS AND DISCUSSION

Result

The research results obtained on each 4-D development model stages were presented in this part. The define stage results are shown in Table 3.

Table 3. The result on define stage.

Type of Analysis	Result
Front end analysis	Optimization of smartphone and needs of AR learning media in chemistry learning process.
Learner analysis	Visual learner 46%, auditory learner 19%, kinesthetic learner 35% and most of students were enthusiastic about ICT-based learning media.
Task analysis	Core and basic competencies were reviewed and eight indicators of competence achievement were compiled.
Concept analysis	Concept maps of theory and indicator of acid base were made.
Objectives analysis	Eight instruction objectives were determined based on the indicators of competence achievement.

The design stage were done the flowchart and storyboard in order to give detailed overview of AR learning media components. In addition, instruments to measure feasibility, practicality, and effectiveness of product were arranged. Moreover, learning tools such as lesson plan and student worksheets were also arranged in this stage.

The develop stage results showed that the product of AR learning media was successfully created based on the flowchart and storyboard. Then, this product validated by media and subject-matter expert. The percentage of media expert was 84% while subject-matter expert was 81%. Based on both percentage, the AR learning media was in the good criteria so it is feasible to use in acid base learning. The revision based on the comments and suggestions of experts were made. Instruments and learning tools were also feasible to use in this research. Meanwhile, practicality of the product was calculated on the product trial. Based on the obtained percentage from students and chemistry teachers' questionnaire, the product was practical to use. The percentage were obtained on this step are shown in Table 4.

Table 4. The percentage of questionnaire on product trial.

Aspect	Student (%)	Chemistry Teacher (%)
View	85	83
Presentation	88	89
Language	86	92

The last step on develop stage was conducted effectiveness test by calculate the students' SPS score data with One-way ANOVA. There were six prerequisite assumptions that must be met before use this test. The treatment on each group as the independent variable was categorical. Meanwhile, SPS as the dependent variable was numeric. The compared samples on each group were not related and no outlier was found on the dependent variable data. Dependent variable data of the tested group was normally distributed. The normality tested by Shapiro-Wilk with the basic of decision making was the Sig. $>$ .05. The tested group also had homogeneous dependent variable data with the Sig. of .068. The homogeneity was tested by Levene with the basic of decision making was the Sig. $>$ .05. The result of normality test by Shapiro-Wilk are shown in Table 5.

Table 5. The result of normality test by Shapiro-Wilk.

Group	df	Sig. Value
Control	37	.063
Experimental 1	36	.211
Experimental 2	36	.272

One-way ANOVA was used to testing the research hypotheses if there was a significant difference between students' basic SPS on the three compared group or not with the basic of decision making was the Sig. $<$ .05. The result obtained Sig. value was .001 means that the H_0 rejected and H_1 accepted. Based on the obtained result, it concluded that with the level of significant of 5%, there was a significant difference between students' basic science process skills on control, experimental 1 and experimental 2 classes. The significant difference in those classes could be seen in detail through the result of Tukey's Post Hoc test. The result are shown in Table 6.

Table 6. The result of Tukey's Post Hoc test.

Group		Mean Difference	Sig. Value
Control	Experimental 1	-4,.320	.351
	Experimental 2	-11.820*	.001
Experimental 1	Control	4.320	.351
	Experimental 2	-7.500*	.048
Experimental 2	Control	11.820*	.001
	Experimental 1	7.500*	.048

The partial eta squared value obtained from GLM Univariate test was .151 means that the AR learning media was effective and give big influence to support the students' basic SPS. The GLM Univariate test result can be seen in Figure 2.

Tests of Between-Subjects Effects

Dependent Variable:KPS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1629.056a	2	814.528	9.455	.000	.151
Intercept	503594.457	1	503594.457	5.846E3	.000	.982
KELOMPOK	1629.056	2	814.528	9.455	.000	.151
Error	9131.495	106	86.146			
Total	513825.000	109				
Corrected Total	10760.550	108				

a. R Squared = ,151 (Adjusted R Squared = ,135)

Figure 2. The result of GLM Univariate test.

The effectiveness of AR learning media is also can be known from the percentage of SPS average score calculated in each indicator that can be seen in Figure 3.

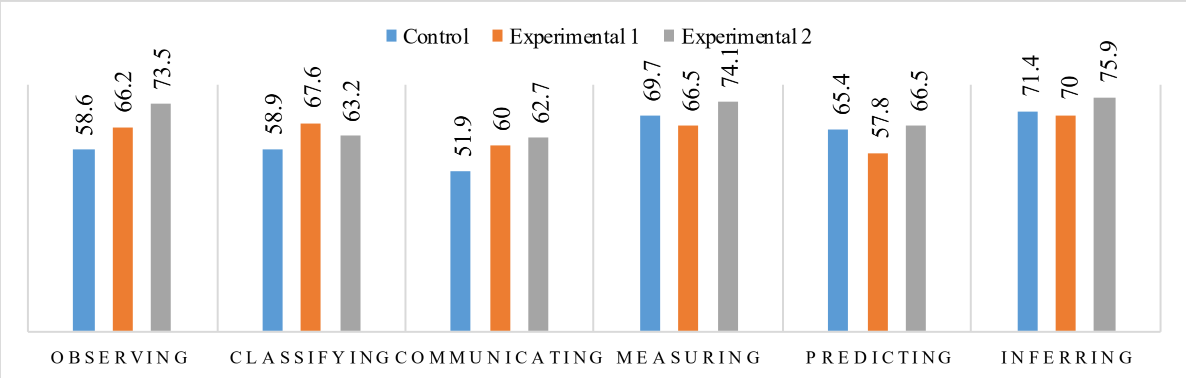

Figure 3. The average score percentage of SPS indicators.

The disseminate stage results were done by carried out the product with applying AR learning media to students of two public senior high school in North Toraja Regency. Google Drive link was given to chemistry teacher for download the application which later can be used in acid base learning. This process was also continued by publish the product through writing article related to the research.

Discussion

The final product was developed on this research is AR learning media for acid base learning made with three supporting applications such as Unity to create and display AR mode; Vuforia to create markers for 3D objects appeared; and CorelDRAW to create a design look. This product is an application that can be downloaded on a laptop or smartphone and includes 3D animation that helps in the visualization of acid base concepts. This product is applied in the learning process using guided inquiry model that can facilitate students in finding concepts independently and can further improve their thinking skills (Llewellyn, 2011). AR learning media is equipped with 14 markers includes acid base concepts specifically for the Arrhenius theory; the Bronsted-Lowry theory; Lewis theory; litmus paper; indicator solution; pH meter; and natural indicators. AR learning media contains exercises in the form of 3D animations that are displayed on the application and students should write the answers of the question on their worksheets.

The instrument were used in the development process is to measure the feasibility, practicality and effectiveness of AR learning media. Product feasibility is based on the results of validation by media and subject-matter experts as well as practical tests by teachers and students. The results of media and subject-matter experts' validation show that AR learning media is feasible to use in acid base learning. The results of expert validation are also supported by the results of the product practicality which show that the product is practical to use. The feasibility and practicality of the media produces suggestions that are used as a reference for revising the product before being used in the effectiveness test.

The effectiveness test of the product is based on the results of the dependent variable data analysis. One-way ANOVA test is used after analyze the fulfillment of the prerequisite assumptions for the test. The test results show the rejection of H_0 and acceptance of H_1 which means that there is a significant difference between the students' basic science process skills in the control, experimental 1 and experimental 2 classes. The test was continued with the Tukey's test to determine the differences between treatments from the research results. The results of this test showed a significant difference between the students' basic science process skills in the control and experimental 1 and the experimental 1 and experimental 2.

The significant difference of science process skills in several classes caused by the given treatment. Based on Table 6, the difference in the average of SPS obtained in the Tukey's test shows that the experimental class 2 has the highest average because both values are positive, so the treatment in this class using AR learning media in guided inquiry learning is the best because it provides greater positive effect on SPS than other classes. This research uses six indicators of basic SPS namely observing, classifying, communicating, measuring, predicting and inferring. Based on Figure 3, the percentage of the SPS average score in the experimental class 2 is highest in almost all indicators except classifying. The highest indicator in the three classes is inferring. While the predicting is the lowest in the experimental 1 and communicating in the control and experimental 2. The inferring present two questions about identifying a solution that acts as a proton acceptor through litmus paper experiments and linking the acidity of the solution with the results of the acid base indicator experiment. The predicting indicator presents a question about estimating the color change that occurs in a solution through the pH range of the indicator solution. The communicating indicator presents the problem of constructing a natural indicator experiment.

The results obtained are suitable with the research of Cheng & Tsai (2013) that AR learning media is suitable for use in inquiry learning. The inquiry used is guided inquiry with seven learning steps, namely developing questions, making hypotheses, designing experiments, collecting data, analyzing data, making conclusions, and communicating results (Dell'Olio and Donk, 2007). One of the characteristics of guided inquiry is students are directed to develop their thinking skills (Kuhlthau, Maniotes & Caspari, 2007). Guided inquiry provides opportunities for students to apply the scientific method, so that they are indirectly trained to acquire science process skills and further have the competence to develop their own knowledge (Rezba, Sprague & Fiel, 2003; Sihaloho, Sahyar & Simanjuntak, 2017).

Students in guided inquiry are required to actively learn the certain material independently. The material referred in this research is acid base which includes complex calculations and abstract concepts (Gultepe, Celik & Kilic, 2013). Learning complex and abstract concepts is not easy, so the development of AR learning media is done as an alternative solution to these problems. AR learning media in education is considered to have many benefits, such as facilitating the learning process (Enyedy, Danish & DeLiema, 2015) and being able to display material in 3D which is too abstract if presented in real learning (Chen & Wang, 2017).

Students are necessary to improve SPS in order to gain a complete understanding of chemical concepts (Osman, 2012). SPS is not only about psychomotor abilities but also about cognitive mastery (Ozgelen, 2012). Students with high SPS will also have a high mastery of concepts (Cetingul & Geban, 2011). The results is same with research of Yang, Mei & Yue (2018) that showed AR learning media can also support the practical skills of students in the chemistry learning process.

CONCLUSIONS AND SUGGESTIONS

Based on the result and discussion of the research above, it can be concluded that the media and subject-matter validation show the developed AR learning media is feasible to apply for eleventh grade students on acid base learning. In addition, the AR learning media is also practical to use based on the assessment of students and chemistry teacher. Moreover, the AR learning media is effective to support the students' basic SPS. We suggest that this AR learning media is appropriate to use in chemistry learning process.

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