RESEARCH ARTICLE

Framework problem solving based augmented reality media to empower scientific explanation skill

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Abstract: Development of scientific explanation abilities in students is an important aspect in science education. However, traditional learning methods such as textbooks and PowerPoint presentations are often less effective in improving skills due to lack of student interactivity and involvement in the learning process. This study aimed to analyze the effectiveness of using augmented reality media based on problem-solving frameworks to empower scientific explanation. The research design was used a Nonrandomized Control Group, Pretest-Posttest Design. The study used a quasi-experimental method with a factorial design of 2 x 2. The research sample was 72 students, one of senior high school in Indonesia. The sample was divided into two groups: the control group using two-dimensional learning media based on books, PowerPoints, and videos. The treatment group used augmented reality learning media based on problem-solving frameworks. The material used in the study is the human circulation system in biology subjects. The instrument used to obtain scientific explanation data is an essay test developed from scientific explanation indicators adapted from McKneill et al. Data analysis using ANCOVA (p=0.05%) with pre-test values as covariates. The results showed that augmented reality media based on problem-solving frameworks could empower and more significantly improve the ability of scientific explanation, this is evidenced by the average value of scientific explanation skills in the experimental class is higher than the control class.

Keywords: augmented reality; framework problem solving; scientific explanation

Introduction

Education is the learning experience of every human being in the continuity of life (Kolb, 2014). One of the educational processes takes place in the school environment. School education is formal education due to interactions between several people and people with non-living objects (Shaturaev, 2021). The interaction that occurs in the classroom is not only between teachers and students but teachers, students, and the learning media used. The interaction that occurs in learning is expected to meet the abilities and skills of students needed at this time.

The scientific explanation has three achievement aspects: claim, evidence, and reasoning. A claim is an answer or statement of a problem phenomenon that occurs, evidence is data or evidence used to support a claim, and reasoning is a justification used to link the evidence owned with the claim. Evidence to defend the claim can be accommodated by granting construction (Hoban & Nielsen, 2014). Construction compiled as evidence can be in the form of quantitative or qualitative data (Laksmi et al., 2021). Reasoning as a reinforcer of scientific explanation can be achieved by logical reasoning after observing visualization (Al-Balushi et al., 2017).

Scientific explanation preparation activities can encourage active participation in classroom interactions. However, the fact is that many students are not active and participate in the classroom, thus affecting the student's ability to explain a phenomenon (Rohwer & Rice, 2015). Facts found through several similar studies show that the level of scientific explanation is low, students' reasoning still cannot provide real evidence in natural phenomena that strengthen claims. According to Wijayanto et al (2020), In their research, students tend to be unclear in conveying the conclusions obtained through the observation process. Scientific explanations compiled by students cannot entirely write claims, evidence, and reasoning (Cari et al., 2022; Laksmi et al., 2021). Based on PISA scores in 2018, Indonesia occupies the low category for science (OECD, 2019). The average score of Indonesian students' science ability is 389 with an OECD average score of 489, Indonesian students who are able to achieve level 2 in science ability are approximately 40% while the OECD average is 78% (OECD, 2019). Level 2 in science skills includes, explanation of phenomena scientifically, being able to identify, and make conclusions based on data (OECD, 2019). The PISA results prove that most Indonesian students have not been able to write scientific explanations based on existing data or evidence.

Empowering scientific explanation can be done by training students through analytical thinking learning (Yeo & Gilbert, 2014). Students are required to observe and analyze a problem to create the correct reasoning power of a problem. Observing and analyzing one of the activities found in problem-solving activities (Chang et al., 2017). Problem-solving activities can be arranged through a framework.

The problem-solving framework is the process of achieving a solution to a problem (Hesse et al., 2015). The problem solving framework aims to help recognize abilities, solve problems through thinking, and take responsibility for choices (Chin & Wang, 2021). To be able to solve the problem of ability that must be possessed, among others, is to find keywords from the observed problem, compile data, and analyze fact reasoning (Alkhatib, 2019). The problem-solving framework has four stages: exploring and understanding information, describing and formulating solutions, planning and implementing solutions, and monitoring solution steps (Graesser et al., 2018).

Technological advances cannot be separated from the development of learning media that must be used in delivering material until learning objectives are met (Rashed & Hanipah, 2022). Today's learning media must accommodate the differences in the diverse ways students learn (Newton & Miah, 2017). Students will find it easier to understand learning if the learning media can provide audio and visual material. Media that can accommodate audio and visual include two-dimensional (2D) and three-dimensional (3D) media. PowerPoint is a 2D learning media that provides a learning tool that can see and hear. Augmented reality is a 3D learning media that provides a learning tool that can see, point, and manipulate a structure (Newman et al., 2018), So that students can go through the stages of the problem-solving framework on abstract material to achieve scientific explanation.

In this research, previously developed learning media to empower scientific explanation, 2D-PowerPoint media based on problem-solving framework and 3D-Augmented Reality media based on problem-solving framework for contributed biology learning materials education. The developed media will be used in two research groups. The novelty in this study is to prove that 3D-Augmented Reality media based on problem-solving frameworks can increase scientific explanation skills more significantly than 2D-PowerPoint media based on problem-solving frameworks.

Method

Research design

This study used a quasi-experiment method with two research groups. The control class uses two-dimensional learning media through PowerPoint, and the treatment class uses the application of augmented reality learning media based on the problem-solving framework. The research design used is a Nonrandomized Control Group, Pretest-Posttest Design. The research design used a factorial design of 2×2. Factorial design research can be seen in Table 1.

Table 1. Research design

Group	Pretest	Independent variabel	Posttest
Control	Y1	-	Y2
Experiment	Y1	X1	X1Y2

Note:
Y1 = Scientific explanation before treatment
Y2 = Scientific explanation after treatment
X1 = 2D-Powerpoint based on the Framework Problem Solving of circulating system material to scientific explanation
X2 = Augmented Reality based on the Framework Problem Solving of circulatory system material to scientific explanation

Sample and sampling technique

The population in this study was students of Science Class, one of Senior High School in Indonesia. The target population is 108 students divided into 3 randomly grouped classes, including Science 1 Class, Science 2 Class, and Science 3 Class. A sample of 2 categories was extracted from the population using the cluster random sampling technique. This technique takes a group of individuals rather than taking individual members of the population into a research sample. Thus, all population members are equally likely to be elected to the sample. The class used as a sample has been pre-tested using an equivalence test. The results of the equivalence test show that the population classes do not differ significantly, so that each class group can be used as a research sample. The research samples used by researchers are class Science 1 Class and Science 3 Class. The sample used was 72 students, with each group comprising 36 students.

Instrument for data collection

The research instrument to obtain scientific explanation data uses a written test of 9 cognitive questions with a maximum score of 2. The questions are used to determine the student's scientific explanation ability. The question of scientific explanation ability is developed from indicators of scientific explanation ability. The scientific explanation written test instrument designed is validated by expert question developers, piloted to students, and analyzed for feasibility using RASCH analysis. RASCH is a method of analyzing the validity and reliability of questions whose results state that the questions used are valid and able to measure the dependent variables correctly. The validity of the questions shows that the results of the analysis of the question items from the nine scientific explanation questions meet three conditions. It can be stated that each question item has good quality and can be used to measure students' scientific explanations. The questions have been tested for reliability and declared feasible and reliable.

Method and data analyses

Scientific explanation value data were statistically tested using ANCOVA or covariance analysis. Covariate analysis tests treatment differences against a group of post-test result data after adjusting to the covariate influence, namely pre-test. The results of the description of inferential statistical analysis are used to test the effectiveness of using augmented reality learning media based on problem-solving frameworks to empower scientific explanation. The ANCOVA test in this study used SPSS software version 16 for Windows at a real rate of 5%. The ANCOVA test assumption is that the data is normally distributed and has a homogeneous variance. The ANCOVA test can be carried out after prerequisite tests, namely normality and homogeneity.

Results

Development of augmented reality learning media

This framework mostly meets the needs put forward by Fikriana et al (2023) of more design guidelines and holistic models to improve Scientific Communication Skills. In particular, our framework defines the components that must be possessed by AR applications to effectively support Scientific Communication Skills, so that software developers, educational technology researchers, teachers, and other stakeholders can create effective and motivating AR learning experiences.

Augmented reality media based on problem-solving frameworks has advantages over two-dimensional media, such as books, PowerPoints, videos, and so on, in empowering students' scientific explanations (Nielsen et al., 2016). Augmented reality media based on problem-solving framework shows more significant scientific explanation results than control classes that use 2D-powerpoint based on problem-solving framework.

Augmented reality media based on problem-solving frameworks has been proven to improve the results of the three scientific explanation indicators. 3D visualization is a future improvement that is able to clarify objects and help the preparation of construction (Shojaei et al., 2018). While in 2D media such as PowerPoint and printed books are not able to display the clarity of objects. In fact, material about human body systems requires clarity of structural physiology that is not obtained through 2D media (Štampar et al., 2019). 2D media is only able to display images and videos that are often difficult for students to understand, so researchers developed Augmented Reality-based 3D media based on a literature review that states that the use of 3D media can empower students' scientific explanation.

The learning media developed is an augmented reality based on a problem-solving framework. Augmented Reality media was chosen because it is highly recommended in anatomy materials to achieve student understanding and able to accommodate interactions with abstract objects in the real world (Abdinejad et al., 2020).

Media Augmented Reality based on a problem-solving framework comprises competency menus, materials, augmented reality features and 3D animation, games, videos, and evaluations. The competency menu is presented based on national learning objectives for class XI high school students in Indonesia, namely analyzing and presenting the results of the analysis of the human circulation system. The material menu is given with the following topics: understanding blood, blood components, blood clotting, blood type, blood transfusion, and blood circulation (Figure 1).

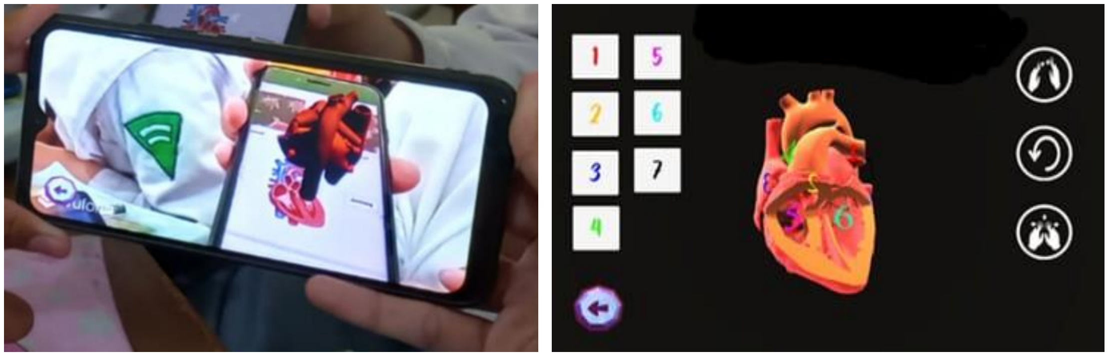

Figure 1. Augmented Reality Fitur page

Augmented reality is used to visualize the shape of blood cells, blood vessels, and the heart. The shape of blood cells needs to be imagined because they cannot be seen in real-time, so they require a picture similar to the original to be easily understood by students and to be able to distinguish the characteristics between erythrocytes, leukocytes, and platelets (Hong et al., 2020). Blood vessels are visualized so that students are able to distinguish arteries, venous vessels, and capillary vessels based on their physical characteristics (Gnidovec et al., 2020). The heart is visualized with the aim that students can understand the parts of the heart with AR facilities that can visualize parts of the heart they can see. The heart is visualized with the aim that students can understand the parts of the heart with AR facilities that can visualize parts of the heart so that they can be seen (Nuanmeesri, 2018).

There are also games based on problem-solving frameworks in the learning media. The game in this media is about a characteristic disease or disorder, its causes, and how to overcome problems in the human circulation system. Video is used to accommodate students' way of learning through audio and visuals. The material provided through the video includes blood types of the ABO system and human blood rhesus. At the end of the learning media, students can use the evaluation menu to find out the extent of their understanding of the entire material of the human circulation system (Figure 2).

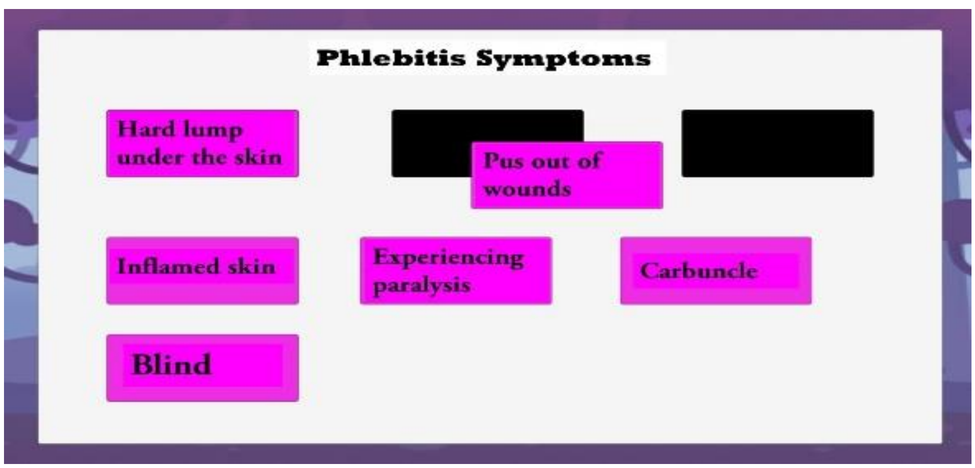

Figure 2. Game Problem Solving Page

Augmented reality features are given on specific topics with detailed erythrocyte material, leukocytes, platelets, arterial, venous, and capillary vessels, and the heart. 3D animation strengthens visualizations regarding the heart organ and blood vessel system. The augmented reality feature embedded in the media supports problem-solving frameworks and empowers students' scientific explanations. Some of the benefits of augmented reality to help problem-solving frameworks are as follows: (1) Able to provide authentic 3D content so students can explore and understand problems well (Hoban & Nielsen, 2014); (2) Accommodating interactions with abstract objects in the real world (Abdinejad et al., 2020); 93) Increase learning effectiveness compared to two-dimensional media (Štampar et al., 2019); 94) The concept carried out by AR is in line with learning, which is a problem-based situation (Nikolai et al., 2019); and (6) Improve students' ability to think higher (Al-Balushi et al., 2017).

Augmented reality enhances the construction of knowledge with technologies that better describe theoretical concepts, such as visualization of organs looking like real. The development of Augmented Reality-based 3D media can facilitate problem solving framework-based activities so that students are able to explain and reason problems to achieve scientific explanation.

The characteristics of AR support students to be able to compile scientific explanations. Some of the characteristics of AR that can empower scientific explanation are helps connect the content and context of learning materials (Kamarainen et al., 2018). The content and context of the learning material depicted through AR media make it easier for students to find evidence related to problems or learning that takes place. AR media is a bridge so students can describe the relationship between the content and the context of the material being studied (Fonseca et al., 2014).

Support student reasoning and the investigation of phenomena (Kyza & Georgiou, 2019). Reasoning and investigation of phenomena are the main keys to successful scientific explanations. Students can use AR media assistance to reason through the visualizations presented.

AR media can make it easier to collect hard-to-reach data (Georgiou & Kyza, 2018). The data obtained is evidence that can then be compiled as a logical reason in the form of a scientific explanation.

AR media is capable of studying organ matter because it brings to life invisible, abstract, and complex concepts (Pellas et al., 2019). The clarity of concept is beginning to build a claim to a phenomenon being studied. The clarity of a concept is beginning to develop a claim to a phenomenon being studied. Help the demonstration when the teacher or student explains (Chen & Liu, 2020). March through AR media can be depicted compared to other media, even 3D media. A demonstration can make it easier for a person to understand what is going on to find the information used in preparing scientific explanations.

Enabling students in authentic learning (Chin & Wang, 2021). The sources used in preparing AR media use sources so that students can compile evidence based on valid data or information.

The problem-solving framework aims to help recognize abilities, solve problems through thinking, and be responsible for choices (Chin & Wang, 2021). In the developed media, the problem-solving framework is in the game section. Games are designed using a problem-solving framework with activities 1) identifying problems, 2) analyzing the information provided, 3) understanding what is needed to be solved, 4) suggesting problem-solving initiatives in the developed media, and the problem-solving framework in the game section. Games are designed using a problem-solving framework with activities 1) identifying problems, 2) analyzing the information provided, 3) understanding what is needed to be solved, and 4) suggesting problem-solving initiatives.

In the first stage of the game, students are asked to identify problems regarding symptoms in diseases related to the human circulation system, then analyze several symptom options based on the information obtained during learning. Identifying and analyzing is a way of empowering scientific explanations to compile claims and present evidence appropriately (Berland et al., 2016; Dichev & Dicheva, 2017; Tracy, 2019). Understanding and suggesting problem-solving is carried out in the second stage, after students can solve problems regarding symptoms in the human circulation system. Students are given several choices regarding how to cope with the disease presented in the first stage. Problem-solving requires students to achieve sound reasoning in finding solutions. Reasoning compiled through understanding and suggesting problem-solving activities can empower reasoning indicators in scientific explanation (Ceberio et al., 2016).

The result of application augmented reality media based on framework problem-solving on scientific explanation

Based on the analysis of the normality test with SPSS 16 on the pre-test and post-test scientific explanation scores of students, it was found that the two groups used in the study had a significance value of >0.05. A significance value was declared normally distributed. the results of parametric statistical tests will be more valid and accurate. The normality test is carried out as an initial step in data analysis to ensure that the normality assumption is met before proceeding to other statistical tests. The results of the normality test of the three groups can be seen in Table 2.

Table 2. Normality test result

Class		Shapiro-Wilk		
		Statistic	df	Sig.
Pretest	FW Problem Solving based PowerPoint	.958	36	.184
	FW Problem Solving based Augmented Reality	.965	36	.303
Posttest	FW Problem Solving based PowerPoint	.960	36	.211
	FW Problem Solving based Augmented Reality	.940	36	.051

Based on the analysis of the homogeneity test with SPSS 16 on the pre-test and post-test scores of students' scientific explanation ability, the result was that the significance value was 0.362. A significance value of >0.05 means that H0 is accepted, so the sample used in the study has a homogeneous variance. The results of the homogeneity test as a prerequisite for the ANCOVA test can be seen in Table 3.

Table 3. Homogenity Test Result

F	df1	df2	Sig.
.841	1	70	.362

Based on the ANCOVA prerequisite test, the samples used in the study were declared normally distributed and had homogeneous variance. So that it can be further tested using the ANCOVA parametric statistical test. Scientific explanation data in the study were analyzed using the ANCOVA test with the help of the SPSS 16 program. The results of the ANCOVA test from the scientific explanation value and the type of learning media used can be seen in Table 4.

Table 4. ANCOVA scientific explanation student test result

Source	Type III Sum of Squares	df	F	Sig.
Corrected Model	1798.905a	2	5.847	.005
Intercept	19542.052	1	127.029	.000
Pretest (covariat)	726.288	1	4.721	.033
Class	1048.303	1	6.814	.011
Error	10614.901	69		
Total	372121.290	72		
Corrected Total	12413.807	71		
a. R Squared = 0,145 (Adjusted R Squared = 0,120)				

Based on the ANCOVA test results, the group significance value was 0.011 (<α = 0.05), so H0 was rejected, which means that there are differences in the results of students' scientific explanation scores on the use of learning media.

Teaching media that has a major influence on empowering students' scientific explanation is Augmented Reality media based on problem-solving framework. This can be seen in the results of the difference in the average post-test results of students and the lowest and highest scores of students' post-test results in Table 5.

Table 5. Advanced test results

Class	Average	Std. Error (SE)	95% Average Accuracy	
			Lowest	Highest
FW Problem Solving based PowerPoint	66.866	2.067	62.742	70.990
FW Problem Solving based Augmented Reality	74.498	2.067	70.374	78.622

Learning experiences based on our framework have succeeded in attracting students, creating curiosity, and helping students focus on key information from learning content. These results support previous studies that report the positive impact of AR applications on the Dimension of Attention (Yamani, 2021). The dimensions of self -confidence, students in the experimental group report a higher level compared to those who use traditional learning materials. These results are in line with other studies that show that the AR application is useful to support Scientific Communication Skills (Wahyu al., 2020), and may show that students feel able to succeed in activities learning and have greater control over their learning process. These results can be explained by the fact that the components of the framework implemented in the AR application allows students to learn with their own speed and in this chemical learning domain, allowing them to explore various possibilities to solve problems and get automatic feedback, which cannot be achieved directly with traditional learning material. These results indicate that the components that are defined in our framework are useful to support the dimensions of self-confidence at a higher level than the use of traditional learning materials.

Based on the description above, it can be concluded that the use of augmented reality media based on problem-solving frameworks in the circulation system material of biology subjects can effectively empower students' scientific explanation. Augmented reality media based on problem-solving frameworks has an influence on students' scientific explanation skills.

Conclusion

This research concludes that the development of augmented reality-based learning media with a problem-solving framework has significant potential to improve students' abilities in scientifically explaining human circulatory system material compared to PowerPoint learning media based on a problem-solving framework. Augmented reality media based on a problem-solving framework significantly improves students' scientific explanation skills.

Conflicts of Interest

We have no conflicts of interest to disclose. All authors declare that they have no conflicts of interest.

Author Contributions

L. V. W. Widiana: methodology, analysis, writing original draft preparation; **B. A. Prayitno,** and **B. Sugiharto:** review and editing.

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