Effectiveness of Learning Outcomes through Problem-Based Learning Model Utilizing Augmented Reality (AR) Technology in Grade IV Material on the Form of Matter and its Changes in the Ki Hadjar Dewantara Group

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Abstract: The use of learning models and media that are not in accordance with the Process Standards contained in Permedikbudristek Number 16 of 2022. This type of research is experimental research with a Quasi Experimental design in the form of Nonequivalent Control Group Design. The population of this study was all students of class IV of SD Gugus Ki Hadjar Dewantara totaling 82 students. The sampling technique was purposive sampling. In this study, SD Muhammadiyah Purwodadi class IV Al-Majid as the experimental class and class IV Al-Qowiyuu as the control class. Data collection techniques were in the form of test techniques (pretest and posttest); non-test techniques, namely observation, interviews, questionnaires, and documentation. Initial data analysis techniques include normality and homogeneity tests and final data analysis with t-test and N-Gain. The output of the t-test is a sig. value of 0.002 (sig. <0.05), so H0 is rejected and Ha is accepted. The output of the N-Gain test for the experimental class is 0.67 and the control class is 0.42. In conclusion, the AR-assisted PBL model is effective in improving student learning outcomes compared to the PBL model version of the teacher assisted by the media of science images for grade IV SD Gugus Ki Hadjar Dewantara.

Keywords: Assemblr edu; Augmented reality; Effectiveness; Learning outcomes; Problem-based learning

Introduction

According to Law of the Republic of Indonesia No. 20 of 2003 concerning the National Education System. Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have spiritual religious strength, self-control, personality, intelligence, noble morals, and the skills needed by themselves, society, nation, and state. Education in Indonesia is currently undergoing a significant transformation through the implementation of the Independent Curriculum. This curriculum is designed to provide freedom and flexibility in the learning process, so that students can be more actively involved in their self-development (Müller & Mildenberger, 2021). Listed in the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 16 of 2022 concerning Process Standards. The education process standards for Elementary Schools are used as a reference to make the education process better than before. Education process standards are national standards related to the implementation of learning to achieve graduate competency standards. Article 7 paragraph (2) points a and b states that learning strategies are designed to provide learning experiences

carried out by providing opportunities to apply material to real problems or contexts, encouraging interaction and active participation of students.

This should be implemented with a problem-based learning model that can foster critical thinking skills in students which will later trigger interaction and active participation of students in the learning process (Ngatman et al., 2025). In addition, learning can integrate information and communication technology as a supporting tool in the teaching and learning process in accordance with the provisions stated in Article 7 paragraph (2) points a and d, to achieve the expected graduate competency standards (Wuryaningtyas & Setyaningsih, 2020). However, in reality, the real conditions in several schools do not match the expected learning. The implementation of learning in the classroom has not fully met the process standards set out in Permendikbudristek Number 16 of 2022, because not all teachers have carried out the directions of the process standards. Natural and Social Sciences (IPAS) is one of the subjects that still faces various problems in the teaching process at the elementary school level.

The problems that arise include the use of learning media that seems monotonous, as well as the limited facilities and infrastructure available. Many teachers tend to choose media that are considered easier, so they do not utilize information technology-based learning media. This results in the learning process being less interesting and not optimal in improving student understanding (Lodge et al., 2018). Another problem is that the learning model that takes place in schools is also not in accordance with the process standards and learning that is still centered on the teacher where students receive and listen more to explanations from the teacher without getting direct learning experience. Of course, this results in a lack of interest in students in understanding a material (Suparman et al., 2020). This makes students tend to be passive, such as students do not dare to ask questions, only certain students dare to speak when instructed by the teacher, this happens because the learning media used is less interactive and uninteresting, and the learning model is not in accordance with process standards so that the learning process is less interesting and boring (Syupriyanti et al., 2020; Khakim et al., 2022). The success of science learning is not only determined by the material taught, but also by student participation in the learning process, the use of interactive media, innovative learning models, and creative learning methods.

Inadequacy in these three aspects can cause boredom in students, as well as unsatisfactory learning outcomes which are common problems faced at various levels of education (Milasari & Setyasto, 2023). Therefore, to improve students' learning motivation and

learning outcomes, learning that is in accordance with process standards and the use of interactive learning media is needed. Through these aspects, learning becomes interactive, educators can take advantage of students' interest in digital activities to improve their learning outcomes (Suminah et al., 2019). The schools studied were from the Ki Hadjar Dewantara cluster, Purwodadi District, Purworejo Regency. There were 3 schools studied, namely Muhammadiyah Purwodadi Elementary School, Purwodadi State Elementary School, and Purwosari State Elementary School. Based on the results of observations, interviews, questionnaires, documentation, and a list of grade IV grades at Ki Hadjar Dewantara Elementary School Cluster, Purwodadi District, Purworejo Regency.

The researcher found various problems, including teachers still predominantly using teaching with narrative (verbal) such as lectures, discussions, and questions and answers and the use of the Problem-Based Learning model by teachers is still not fully in accordance with the syntax that should be. Many teachers only include the term Problem-Based Learning on the learning device without explaining the syntax so that problem solving by students is not well structured. However, sometimes teachers have utilized technology as a teaching medium but it still tends to be monotonous, namely only displaying learning videos or image media in textbooks and have not integrated technology, even then only using it occasionally. So the lack of interactive learning makes students bored, such as students often do not pay attention to the teacher and often play with their desk mates so that learning becomes less meaningful, which results in students not understanding the material being taught. In simple terms, such a teaching situation can be described as listening, taking notes and memorizing.

Based on the results of observations, interviews with teachers, documentation, and questionnaires of class IV students in the Ki Hadjar Dewantara cluster, Purwodadi District, Purworejo Regency. The selection of learning resources is still too dependent on student handbooks and teacher books which are more often used. In the midst of the development of the era, the existence of learning media facilitates the teaching and learning process and has a significant role for students in participating in learning activities. With the existence of supporting learning media, students will not get bored quickly, it is easier to understand the material, and the teaching and learning process becomes more effective and efficient. As a result, learning objectives can be achieved as expected. Therefore, the role of learning media is very important for educators and students so that the teaching and learning process can take place better, improve understanding of the

material, and foster student interest in learning so that learning outcomes also increase. Therefore, teachers need to be more active in developing strategies for using more varied, more explorative, and effective learning media. Thus, students can gain broader and deeper knowledge, and improve their critical thinking and analytical skills.

Meanwhile, regarding facilities for the use of teaching media, schools in the Ki Hadjar Dewantara cluster have infrastructure such as wifi, speakers, LCDs and several chromebooks that can be utilized properly, but teachers only continue to rely on the use of uncomplicated teaching media during classroom learning procedures so that schools have not maximized their use properly. Meanwhile, if the infrastructure is used properly by teachers according to the questionnaire given, 65 out of 81 (80.24%) students choose interactive technology-based science learning media/teaching aids.

Based on the results of the smartphone ownership questionnaire by grade IV students in several elementary schools that are members of the Ki Hadjar Dewantara Cluster, there are 61 out of 81 (75.31%) students who already have smartphones that can be used to access the internet and there are 74 out of 81 (91.35%) students who like learning using smartphones. By looking at the questionnaire, there is a very large potential in the use of information and communication technology devices as learning supports that have not been fully optimized in learning by teachers.

The use of IT-assisted teaching media can actually make learning more varied, interesting, and illustrate the material being taught better. However, the activities carried out by teachers so far have mostly been limited to showing learning videos and image media only in textbooks, as well as information and communication technology devices as learning supports that have not been optimized which can cause boredom in students if the same learning pattern continues to be used and there is a lack of interactivity between teachers and students so that the material delivered is not conveyed well. The findings of the above problems indicate that teachers at SD Ki Hadjar Dewantara cluster still lack in implementing and adapting the learning model expected in Permendikbud RI Number 16 of 2022 concerning Process Standards. From the learning outcomes data of grade IV students at SD Ki Hadjar Dewantara cluster, Purwodadi District, Purworejo Regency. It can be seen that the learning outcomes, especially in the Science subject, are still low, because the KKTP of each school is different, namely 75 for SD Muhammadiyah Purwodadi and SDN Purwodadi and KKTP 70 for SDN Purwosari. At SD Muhammadiyah Purwodadi for class IV Al-Qowiyuu, there were only 11 students out of 26 (38.46%) who achieved the KKTP.

While for class IV Al-Majid, there were only 10 out of 26 students (34.62%) who achieved the KKTP. For SDN Purwodadi class IV, there are 11 out of 24 students (45.83%) who have achieved KKTP. While for SDN Purwosari it is very good because there are 9 out of 16 (56%) who have achieved KKTP. From the sample of 3 elementary schools that are part of the Ki Hadjar Dewantara Cluster, with a total of 92 students, only 41 students (44%) whose scores are able to reach the KKTP limit.
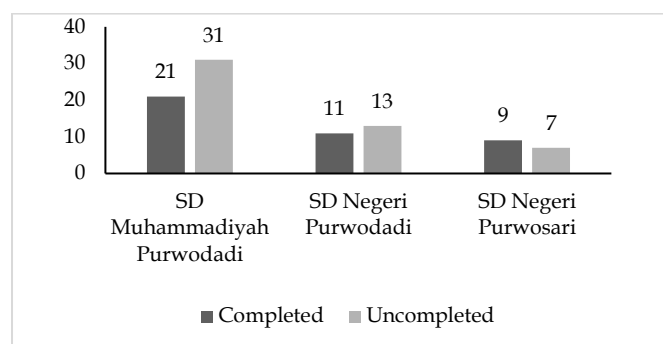

Figure 1. Table of completion of learning outcomes of IPAS

The findings of the above problems indicate that teachers at SD Cluster Ki Hadjar Dewantara still do not apply and adjust the expected learning model according to the Process Standards. Article 7 paragraph (2) points a and b states that learning strategies are designed to provide learning experiences that are carried out by providing opportunities to apply material to real problems or contexts, encouraging interaction and active participation of students in developing critical, creative, and collaborative thinking skills. One of the learning strategies used in training problem-solving skills is the problem-Based Learning model. The problem-Based Learning model is a learning model that begins by presenting real problems. Through solving these problems, students can obtain and build certain knowledge, as well as develop critical thinking skills and problem-solving skills (Ijirana et al., 2021; Nirwana et al., 2024).

The problem-Based Learning model has five syntaxes designed to organize students to learn independently, where the role of the teacher is as a facilitator and guide. The implementation of this model begins with problem orientation using media, followed by organizing students in groups, guidance and direction in conducting investigations, developing and presenting discussion results, and ending with analysis and evaluation using media. This problem-based learning model is in accordance with the needs of students because it encourages them to be more active and interested during the learning process. This model also places students as the center of learning, allowing

them to develop the desired knowledge (Suradika et al., 2023). This is in line with the results of previous studies which show that students who are taught through the use of the problem-based learning model help students understand the subject matter better because they are directly involved in solving real problems. Students who learn through problem-based learning develop better critical thinking, collaboration, and communication skills. In other research results, it was revealed that the problem-based learning model improves the learning process and encourages active participation of students. Students look enthusiastic in following the teaching and learning process provided. through problem-based learning creates a more meaningful experience, an interesting and relevant learning experience in the classroom. This contribution is very important in helping to improve student learning outcomes.

Digital technology is the most influential factor in the current global education system. This is due to increased efficiency, effectiveness, and innovation in education. Technology plays an important role in education, especially in the use of media during the learning process. Media functions as a tool that can facilitate the learning process. To implement learning that applies the use of digital technology in it, researchers use augmented reality media through Assemblr Edu as a learning medium. Augmented Reality is useful in visualizing abstract concepts to recognize and understand an object. Augmented reality applications are created to present users with more in-depth information about real objects. With the advancement of technology that continues to develop, the application of augmented reality is now one of the choices of learning media available (Putra et al., 2020; Yusa et al., 2023). Augmented Reality is a technology that can integrate the virtual world and the real world, so that it can be used by teachers to project abstract concepts interactively. This technology is able to combine the two worlds, allowing projections from various directions as desired, and communicating objects from the virtual world with an attractive appearance, thus creating a more real experience.

The application of this technology aims to enable students to conduct experiments, which can increase motivation and learning outcomes (Faria, 2024; Majid et al., 2023). Assemblr Edu is an augmented reality application specifically designed to meet the needs in the field of education, especially in the teaching and learning process. This application is equipped with various features, such as classes, topics, scanning, and profiles. With an augmented reality base, this application makes learning more interactive for students (Lino Padang et al., 2022). In this study, the problem-based learning model assisted by augmented reality is a

learning model that integrates augmented reality technology to improve students' learning experience. In this model, students are faced with real situations or problems that are relevant to the subject matter, and students use augmented reality technology to explore, analyze, and solve these problems. By using augmented reality, students can see additional objects or information that cannot be accessed directly, thereby increasing their understanding and involvement in the learning process (Boekaerts, 2016).

Other research results show that the application of a problem-based learning model assisted by augmented reality can increase student engagement, so that the learning process becomes more qualified and meaningful, which ultimately has a positive impact on improving student learning outcomes (Mayasari et al., 2022). Another relevant study is a study by Rizqia et al. (2024) entitled "Effectiveness of Using Augmented Reality-Based Social Studies Learning Media to Improve Students' Knowledge Competence." shows that augmented reality media is effective in improving the knowledge competence of fourth-grade students at SDN Karang Entang, especially regarding the variety of traditional Indonesian clothing. This study aims to utilize interesting and interactive learning media, so that students are more enthusiastic in learning the material "State of Matter and Its Changes," with augmented reality that helps visualize abstract concepts concretely.

The novelty in this study is combining the application of a problem-based learning model assisted by augmented reality, especially in the subject of social studies, the material of the state of matter and its changes for fourth-grade elementary school, where the use of this technology is expected to increase the active participation of students and help them understand complex social studies material. By adopting this model, students not only become recipients of information, but also play an active role in the learning process through exploration and collaboration. Problem-based learning encourages students to identify problems, formulate questions, and find solutions independently or in groups, while augmented reality provides an interactive and engaging visual experience. This allows students to see abstract concepts in a more concrete form, making it easier for them to understand and remember the material. In addition, the combination of problem-based learning and augmented reality can also increase students' learning motivation (Fidan & Tuncel, 2019), because they feel more involved and have control over their learning process.

Thus, this study not only contributes to the development of innovative learning methods, but also has a positive impact on students' learning outcomes in understanding science material. The application of

augmented reality media is carried out on the syntax of organizing students to learn and on the syntax of guiding individual and group investigations, in both steps, there are Student Worksheets (LKPD) equipped with QR codes that can be scanned using a smartphone which will later appear three-dimensional objects related to the material form of matter and its changes, then students are asked to work on LKPD in groups by searching for information through augmented reality media after scanning the QR code. For example, the application of augmented reality media is carried out on the material of the state of matter and its changes, where augmented reality helps to visualize in detail the characteristics of solids, liquids, and gases. This visualization includes the arrangement of particles, shape, mass, volume, and examples of objects that represent each of these states of matter. Not only that, augmented reality also plays an important role in visualizing schemes and various types of changes in the state of matter, such as melting, freezing, evaporating, condensing, sublimating, and crystallizing. By using augmented reality, students can see these processes interactively and dynamically, so that they can better understand how each change occurs in a real context.

This visualization not only makes learning more interesting, but also helps students relate abstract concepts to phenomena they encounter in everyday life. In augmented reality, there are also explanations in the form of text and sound that describe in detail the parts of the characteristics of matter and changes in the state of matter. Students can also rotate 360°, enlarge, and reduce three-dimensional objects as desired, so that students can more easily observe them from various angles. The use of problem-based learning models that are in accordance with process standards and using augmented reality media can encourage students to think critically and collaboratively in solving real problems, which can reduce misconceptions about the material being studied. Based on the existing description, the research that will be conducted by the researcher aims to test the effectiveness of the problem-based learning model assisted by augmented reality on the learning outcomes of science subjects on the state of matter and its changes in class IV in the Ki Hadjar Dewantara Cluster, Purwodadi District, Purworejo Regency.

Method

This study is an experimental study with a quasi-experimental design and uses the nonequivalent control group design method. The first step in this study was to provide a pretest to the experimental class and the control class to measure the initial abilities of students.

Furthermore, the two classes received different learning treatments. The experimental class received treatment through learning that applied the problem-based learning model with the help of augmented reality media, while the control class used the problem-based learning model with the help of simple power point media. After different learning treatments in each class, a post-test was conducted to evaluate whether there was an effect on learning outcomes in the two classes. The following is a table that describes the research design conducted by the researcher.

Table 1. Research Design

Class	Pre-test	Treatment	Post-test
Experiment	O_1	X_1	O_2
	O_3	X_2	O_4

Description:
O1: pretest experimental class
O2: posttest experimental class
O3: pretest control class
O4: posttest control class
X1: learning treatment in the experimental class using a problem-based learning model assisted by augmented reality.
X2: learning treatment in the control class using a problem-based learning model assisted by simple image media.

This study was conducted by providing treatment to the experimental group and providing a control group as a comparison. The treatment in this study was carried out in the Science Subject with the material on the state of matter and its changes in phase B with Learning Outcomes (CP) namely Students identify the process of changing the state of matter and its changes in everyday life. The population used by the researcher was all students in grade IV of SD Gugus Ki Hadjar Dewantara, especially at SD Muhammadiyah Purwodadi as many as N students. Therefore, the sample used in this study was 26 students of grade IV of Muhammadiyah Purwodadi Elementary School in the 2023/2024 academic year, 28 students of grade IV Al-Majid of Muhammadiyah Purwodadi Elementary School in the 2024/2025 academic year, 28 students of grade IV Al-Qowiyuu of Muhammadiyah Purwodadi Elementary School in the 2024/2025 academic year. There are two variables in this study, namely the independent variable (X) and the dependent variable (Y).

In this case, the independent variable (X) is the problem-based learning model assisted by augmented reality. Meanwhile, the dependent variable (Y) is the results of learning science. The hypothesis in this study is that the problem-based learning model assisted by

simple power point media does not affect the results of learning science on the material of the state of matter and its changes at Ki Hadjar Dewantara Elementary School (H0). The problem-based learning model assisted by augmented reality affects the results of learning science on the material of the state of matter and its changes at Ki Hadjar Dewantara Elementary School (Ha). Data collection techniques in this study include the use of test and non-test techniques. The test technique is carried out by providing a pretest and posttest. In this study, by providing a pretest and posttest, it is necessary to test the validity, reliability, discrimination power, and level of difficulty of 50 questions that have been made with the following test results.

Table 2. Results of the Validity Test of Question Items, Reliability Test, Distinction Power, and Level of Difficulty

Analysis Aspect	Results
Question Validity	All 28 questions were declared valid
Question Reliability	0.969 (High)
Difficulty Level	6 Questions (Easy)
Question Distinction Power	17 Questions (Medium)

Based on Table 2 above, the conclusion of the study related to the analysis of pretest posttest questions for grade IV of SD Muhammadiyah Purwodadi. A total of 28 questions (56%) were considered valid and 22 questions (44%) were considered invalid. So it can be concluded that overall the pretest posttest questions are valid for testing. The reliability value of the questions is 0.969. So it can be concluded that the exam questions have very good reliability. A total of 12 questions (42%) are in the good differentiation category, 17 questions (60%) are in the sufficient differentiation category. Based on this, it can be concluded that the questions have good differentiation quality. A total of 6 questions (21%) are in the easy category, 17 questions (60%) are in the moderate category, and 5 questions (17%) are in the difficult category. So it can be concluded that the majority of questions are in the moderate category so it is recommended that there is an increase in the difficulty of the questions. While non-test techniques are carried out by interview, observation, documentation, and distributing questionnaires. This study also applies preliminary data analysis and final data analysis. The preliminary analysis consists of prerequisite tests that include normality tests and homogeneity tests, while the final data analysis is carried out using the t-test and the N-Gain test.

Result and Discussion

Referring to the results of the experimental research that has been conducted at SD Muhammadiyah Purwodadi, class IV Al-Majid as the experimental class and class IV Al-qowiyuu as the control class in Gugus Ki Hadjar Dewantara, Purwodadi District, Purworejo Regency, there are several things that will be studied in the results and discussions, namely: pretest and posttest learning outcomes of students; normality test of pretest and posttest data for experimental and control classes; homogeneity test of pretest and posttest data for experimental and control classes; hypothesis test for experimental and control classes using the independent t-test; N-Gain test for experimental and control classes. The achievement of learning in science in this study is a learning outcome based on the results of the pretest and posttest of the experimental and control classes. Below are the learning outcomes based on the results of the pretest and posttest of the experimental and control classes.

Table 3. Cognitive Learning Outcomes

	N	Min.	Max	Average	Completed (%)
Pre-test					
Experiment	28	60	78	69.57	32.10
Control	28	57	78	69.25	28.50
Posttest					
Experiment	28	75	100	89.42	100
Control	28	71	96	82.17	78.50

Based on Table 3, it can be concluded that the learning outcomes of students taught using the problem-based learning model assisted by augmented reality have an average of 89.42 and a completion percentage of 100%. This result is higher than that of students taught using the problem-based learning model assisted by image media only, which has an average of 82.17 and a completion percentage of 78.5%. In this study, normality analysis was carried out with the help of the SPSS 25 program. The pretest was carried out before the researcher gave treatment to the experimental class and the control class. After the treatment was given, the researcher continued by giving a posttest. The normality test aims to assess the distribution of initial data and final data on the results of learning science regarding the material of the state of matter and its changes in grade IV students of SD Muhammadiyah Purwodadi located in the Ki Hadjar Dewantara Cluster, Purwodadi District, Purworejo Regency, to determine whether the data is normally distributed or not. The results of this normality test are very important to ensure that the statistical analysis carried out later can be interpreted correctly. Table 4 presents the results of the normality test for the

pretest and posttest data, which provides an overview of the characteristics of the data distribution obtained.

Based on the results of the normality test of the pretest and posttest data in Table 4, the pretest significance value of the experimental class was 0.128 and the control class was 0.097 which was tested using the Kolmogorov-Smirnov method. Meanwhile, the pretest significance value using the Shapiro-Wilk method for the experimental class was 0.064 and the control class was 0.118. Then, the posttest significance value of the experimental class was 0.151 and the control class was 0.190 which was tested using the Kolmogorov-Smirnov method. Meanwhile, the posttest significance

value using the Shapiro-Wilk method for the experimental class was 0.135 and the control class was 0.121. It can be concluded that the significance value of all pretest and posttest data for both the experimental and control classes is greater than 0.05 in the Kolmogorov-Smirnov and Shapiro-Wilk methods, so that H0 can be accepted or the pretest data and posttest data are normally distributed. In the homogeneity test in this study, it was assisted by the SPSS 25 program. The homogeneity test uses the pretest and posttest scores of students to determine whether the data is homogeneous or not. Table 5 is the result of the homogeneity test.

Table 4. Output of the Results of the Normality Test for Pretest and Posttest Data

			Tests of Normality				
Class		Statistic	df	Sig.	Statistic	df	Sig.
Results	Pretest A (Control)	0.152	28	0.097	0.941	28	0.118
	Posttest A (Control)	0.137	28	0.190	0.941	28	0.121
	Pretest B (Experiment)	0.147	28	0.128	0.931	28	0.064
	Posttest B (Experiment)	0.143	28	0.151	0.943	28	0.135

Table 5. Output of the Pretest and Posttest Data Homogeneity Test

Learning outcomes		Statistics	df1	df2	Sig.
Based on Mean	Pretest	0.322	1	54	0.572
	Post-test	1.955	1	54	0.168

Based on the results of the homogeneity test of the pretest and posttest data of the experimental and control classes in Table 5, the significance value of the pretest data of the two classes is 0.572. Meanwhile, the significance value of the posttest data of the two classes is 0.168. It can be concluded that the significance value of the pretest and posttest data of the two classes are respectively 0.572 and 0.168 or the significance value is greater than 0.05. Thus, it can be concluded that the

pretest and posttest data of the two classes are homogeneous. Based on the results of the normality test and the homogeneity test which are prerequisite tests, it can be concluded that the data in this study are normal and homogeneous. So that the hypothesis can be tested using the independent sample t-test. In this study, a hypothesis test was conducted to determine the effectiveness of the Problem-Based Learning model assisted by augmented reality in the experimental class and the Problem-Based Learning model assisted by image media through the posttest values of the two classes. The tests used in the hypothesis test in this study are the independent sample t-test and the N-Gain test. Table 6 below is the result of the independent sample t-test that has been carried out using the SPSS 25 program.

Table 6. Output of Independent Sample T-Test Results

	Levene's Test for Equality of Variances				t-test for Equality of Means			95% Confidence Interval of the Difference	
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.955	0.168	-3.246	54	0.002	-7.250	2.233	-11.728	-2.772
Equal variances not assumed			-3.246	50.337	0.002	-7.250	2.233	-11.735	-2.765

Based on the output table of the independent sample t-test results in Table 6, the sig. (2-tailed) value is 0.002 or less than 0.05. This means that the t-value is significant (0.002 <0.05). So it can be concluded that H0 is rejected and Ha is accepted. This means that there is a significant difference in the average learning outcomes between students in the class that was given the problem-based learning model treatment assisted by augmented reality and students in the class that was

given the problem-based learning model treatment assisted by image media. Thus, it can be concluded that the problem-based learning model assisted by augmented reality is effective in improving science learning outcomes on the material of the state of matter and its changes at SD Gugus Ki Hadjar Dewantara, Purwodadi District, Purworejo Regency. The N-Gain test was conducted to determine the increase in cognitive learning outcomes of students before and after

treatment in both research classes. The N-Gain test was assisted by the SPSS 25 program. Table 7 below is the result of the N-Gain test that has been carried out.

Table 7. Average Gain Results (N-Gain)

Class	Average			Category
	Pretest	Posttest	N-Gain	
Experiment	69.57	89.42	0.6736	Currently
Control	69.25	82.17	0.4265	Currently

Based on the results of the N-Gain test in Table 7, it can be seen that both research classes have almost the same initial abilities. However, after being given different treatments, both research classes have different average increases (N-Gain) in learning outcomes. In the experimental class, the N-Gain value is 0.6736 which is included in the moderate category. While in the control class, the N-Gain value is 0.4265 which is included in the moderate category. This means that the results of learning science on the material of the form of matter and its changes of grade IV students of SD Gugus Ki Hadjar Dewantara, Purwodadi District, Purworejo Regency who received learning treatment with the problem-based learning model assisted by augmented reality had an average increase (N-Gain) higher than the learning outcomes of students who received learning treatment with the problem-based learning model assisted by image media. After implementing the problem-based learning model combined with augmented reality media through the Assemblr Edu application on the material of the Form of Matter and Its Changes, there is a questionnaire response from teachers and students as follows.

Table 8. Results of Teacher and Student Response Questionnaire

Respondent	Percentage (%)	Criteria
Teacher	93%	Very Positive
Students	87%	Very Positive

Based on the questionnaire results in Table 8 showed very positive results related to the application of learning models and media as many as 14 questions. The questionnaire covers three aspects, namely models, learning media, materials and language. The assessment of this questionnaire uses a Likert scale calculation of 1-4 which must be filled in by teachers and students based on their experiences when observing and receiving treatment. Students expressed that the use of these media makes the learning process more interesting and interactive. Students feel more involved in learning because they can see the concepts taught visually and in real terms through augmented reality. In addition, students also stated that this model helps them understand the material better, because they can interact

directly with the objects being studied. Thus, the use of problem-based learning and augmented reality not only increases students' interest in learning, but also deepens their understanding of the material being taught. Meanwhile, the teacher response questionnaire to the Teaching module assisted by augmented reality on the material on the state of matter and its changes showed positive results.

Teachers appreciate the use of augmented reality technology which makes learning more interactive and interesting for students. Teachers noted that this module not only helped explain complex concepts but also increased students' motivation to learn (Gunawardena et al., 2024; Jääskä et al., 2022). In addition, teachers felt that this module made it easier to deliver material and allowed students to better understand changes in the state of matter through clear visualization. Thus, the use of augmented reality-assisted teaching modules is expected to be an effective innovation in the learning process in the classroom. From the results of data analysis and questionnaire responses from students and teachers which showed very positive results, it can be concluded that this study is effective in improving learning outcomes for science material for grade IV elementary school. This effectiveness is further strengthened by several factors. First, through the application of the problem-based learning model, it is effective in improving learning outcomes because it encourages students' motivation and self-confidence by confronting them with real problems that must be solved. This process not only helps students solve problems but also makes students more active and participatory in learning. Thus, problem-based learning contributes to increasing student engagement, overcoming various challenges in learning, and facilitating the achievement of better learning outcomes (Gumartifa et al., 2023; Manurung & Pappachan, 2025).

Second, the use of augmented reality in elementary school science learning has significant potential to improve learning outcomes and student interest (Al-Ansi et al., 2023; Chang et al., 2022). Augmented reality helps students understand abstract concepts in a more concrete and real way, and encourages active interactions that deepen understanding of the material. Current technological developments have given birth to software that carries the theme of augmented reality. This software is very suitable for the needs of students because this software presents a 3D image display. One of the software that carries AR is the Assemblr Edu software (Chu & Ko, 2021). This software can be downloaded for free on the Play Store and App Store, making it easier for students and teachers to use technology in the learning process. By using Assemblr Edu, students can better understand learning concepts

through more realistic and interesting visualizations, which can ultimately increase student motivation and engagement in learning.

Augmented reality technology creates an interactive and fun learning experience, and expands innovative teaching methods (Câmara Olim et al., 2024). In addition, augmented reality supports a constructivist approach in education, which makes students more active and participatory in learning. With the presence of these two factors, it is in line with previous research, namely research from Sholikhah et al. (2023) with their research showing that the application of the problem-based learning model based on augmented reality media has effectiveness on student learning outcomes (Salsabila et al., 2023; Nafi'ah & Asih, 2024). This is evidenced by student learning outcomes are able to achieve minimum completion criteria, students who use problem-based learning with augmented reality media get better learning outcomes than those who use the lecture method. In line with Sapira et al. (2024), with their research showing that the problem-based learning model assisted by augmented reality media can improve student learning outcomes.

The implementation of the problem-based learning model can be combined with appropriate media so that learning objectives can be achieved, the application of the problem-based learning model can train students' critical thinking skills in solving contextual problems, and teachers must maximize each syntax contained in the problem-based learning model so that the application of the problem-based learning model based on augmented reality media has effectiveness on student learning outcomes (Wiraha & Sudarma, 2023; Pamorti et al., 2024). The use of problem-based learning models assisted by augmented reality has proven effective for student learning outcomes in science learning on the material of the state of matter and its changes for grade IV elementary school (Wiraha & Sudarma, 2023; Su & Cheng, 2019). This is indicated by the achievement of completion criteria and better learning outcomes compared to previous methods and media. The problem-based learning model can be combined with 3D virtual object visualization media in augmented reality so that it can facilitate understanding (Nurlaily Z et al., 2021; Küçük - Avcı et al., 2024), attract students' attention, and increase student involvement in the learning process, as well as train students' critical thinking skills in solving contextual problems (Retiyanto et al., 2023).

Conclusion

Based on the results and discussions that have been carried out in this study, it can be concluded that the problem-based learning model assisted by augmented reality is effective in improving the science learning outcomes of grade V students of SD Gugus Ki Hadjar Dewantara, Purwodadi District, Purworejo Regency. Based on hypothesis testing by conducting an independent sample t-test. It is known that the sig. value is 0.002 (sig. <0.05), so H0 is rejected and Ha is accepted. The N-Gain test for the experimental class is 0.67 and the control class is 0.42. The experimental class is included in the moderate category, while the control class is in the moderate category. Thus, students in the experimental class who use the problem-based learning model assisted by augmented reality from the results of research and practice are more effective than the problem-based learning model assisted by images. In addition, the science learning outcomes of students who use the problem-based learning model assisted by augmented reality experience a higher average increase in learning outcomes. This shows that the integration of augmented reality technology in learning not only makes the learning process more interesting, but also encourages students to be more active in participating in learning activities. With this model, students can more easily understand the material being taught, as well as develop critical thinking and problem-solving skills.

Conflicts of Interest
The author's interest in publishing this article is as a research output requirement in the form of scientific journal publication as evidence of required performance. In this study, there is no conflict of interest.

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