Phi: Jurnal Pendidikan Fisika dan Terapan
Vol.11 No.2 (2025) 123-135
ISSN: 2460-4348, e-ISSN: 2549-7162
https://jurnal.ar-raniry.ac.id/index.php/jurnalphi/index

Article Type: *orginial research*

Application of the Project Based Learning (PjBL) Model Assisted by Augmented Reality to Increase Student Creativity on Solar System Material

Risma Andriani[1], Safriana[1]*, Fajrul Wahdi Ginting[1], Muliani[1], Widya[1]
[1]Physics Education, Malikussaleh University, Aceh, Indonesia

Correspondence E-mail: safriana@unimal.ac.id

ARTICLE INFO

Article History:
Submitted/Received: 09 March 2025
First Revised: 04 June 2025
Accepted: 15 June 2025
First Available Online: 01 July 2025
Publication Date: 01 July 2025

Keywords:
Project based learning; PjBL; Augmented reality, Creativity, Solar system

ABSTRACT

This study examines the impact of the Project-Based Learning (PjBL) model assisted by Augmented Reality on student creativity in the solar system material at SMP Negeri 5 Lhokseumawe. Using a Nonequivalent Control Group Design, the study involved two groups: a control class (Direct Instruction with Augmented Reality) and an experimental class (PjBL with Augmented Reality), each with 20 students. Data was collected through observations, questionnaires, and multiple-choice tests. Results show that the experimental class had a significantly higher creativity score (71.53%, "creative") than the control class (58.61%, "moderately creative"). Student responses were very positive, with an 85.78% satisfaction rate. The N-Gain score was also higher in the experimental class (0.64) compared to the control class (0.44), both in the "medium" category. This confirms that PjBL with Augmented Reality effectively enhances student creativity.

1. INTRODUCTION

One of the human efforts to answer the challenges of today's times is through education (Widarti & Roshayanti, 2021). Education is a conscious and planned effort to create a learning atmosphere and learning proccess so that students can actively develop their potential (Ginting et al., 2020). Education is very important for every human being, because it plays a big role in improving the quality of students learning, being able to make dreams come true and being able to make the nation's life more intelligent (Rexa & Anistyasari, 2017). A great nation is marked by educational progress. A good education system is expected to produce graduates and human resources (HR) professionals who are able to compete internationally with other developing countries throughout the world (Mahendra et al., 2019).

Currently, the government is promoting the development of quality human resources for the Industrial Revolution 4.0. The quality of competitive human resources is determined by the education

system. Teachers play an important role in educational development. Teachers are the spearhead of determining the quality of education outcomes in Indonesia (Safriana & Marina, 2019). The development of knowledge in the field of education in the current digital era requires teachers to be able to utilize technological advances so that they can play an active role in transferring learning material to students optimally and teachers are expected to be able to make learning more enjoyable through the various skills and creativity needed by students in participating in learning (Kimianti & Prasetyo, 2019).

One of the government's efforts to support the development of knowledge that students want to achieve is by developing a curriculum. The curriculum becomes a reference for educators in implementing the teaching and learning process. The curriculum currently being implemented by the government is the independent learning curriculum (Saaddiyah & Anjarwati, 2022). The independent learning curriculum is a curriculum that gives students the freedom to learn and seek their talents (Muliaman et al, 2022). By developing a curriculum in the education sector, the government aims to include learning elements that are fun, interesting, safe, active, creative and innovative so that teachers and students can interact with each other and explore their abilities so that they can achieve the desired learning goals (Alfath et al., 2022).

The independent curriculum gives teachers the freedom to use various teaching tools to adapt learning to the needs and interests of their students, especially in science learning (Kemendikbudristek, 2022). Natural Scientist (IPA) is a science that studies natural phenomena such as living things and inanimate objects. It can be seen that there is a lot of abstract material in science material, making it difficult for students to understand (Sari, 2020). Science learning requires students to think critically in understanding a concept. Therefor, science learning is very dependent on the teacher's role in implementing the learning model. This teacher's role can help increase student involvement in the teaching and learning process and improve their learning outcomes (Rahmi, 2017).

One of the main goals of using appropriate and effective learning models is to create a comfortable learning environment for students so that students can actively participate in the learning process. To achieve educational goals and successful learning, of course efforts are needed to increase creativity. Creativity is the ability to make things, think in different ways, and always find solutions to problems in ways that other people cannot think of (Suryanti, 2021). (Jagom, 2015) said that creativity is a person's ability to use information that has been collected to create new ideas or solutions. Student creativity must always be honed and developed because it makes students more critical and have new ideas for solving problems (Suryanti, 2021). Not only that, students can also make connections between problems and make appropriate analyzes (Haryati, 2003).

Based on the results of observations and interviews conducted by researchers at SMP Negeri 5 Lhokseumawe, it is know that the school has implemented an independent curriculum which requires teachers to have the ability to utilize learning technology, but the science learning process is still less effective in using learning technology. Thearhers only use Power Point when using technology-based learning media. Meanwhile, the Ministry of Education and Culture government has done many new things to improve the quality of education in the 21st century as it is today. This means that the government has provided many opportunities for the world of education to use other technology-based learning resources. This is due to the teacher's inability to use technology-based learning media.

This causes the learning atmosphere in the class to become passive, students become sleepy, bored, and not interested in following the lesson fully. As a result, student creativity will be hampered. Science learning requires students to use all their abilities to achieve leaning goals, so that a lack of student involvement in the learning process can lead to poor learning outcomes and low creativity (Rahmi, 2017). Most of the learning models applied by teachers at SMP Negeri 5 Lhokseumawe are discovery learning models. Discovery learning is a model for developing active learning in students by finding and considering problems so that the results obtained are remembered for a long time and are

not easily forgotten by students (Prasetyo & Abduh, 2021). However, the obstacle that teachers often face when using the discovery learning model is the inability to identify problems or misunderstanding between teachers and students.

Are a result, this model does not apply to all learning topics. Based on the problems above, efforts are needed to increase the use of learning models and learning media. One possible learning model is the project-based learning model (PjBL). PjBL is a learning model through project activities that involves complex projects absed on questions and problems. This project involves students in designing, solving problems, making decisions, and conducting research. This provides students with the opportunity to work together to create a predetermined project and produce a presentation or product (Muliani et al., 2021). According to Rais (2013), project-based learning is an innovative learning model that emphasizes situational learning. This model includes complex activities that invole students in the learning process and help students build their own thinking patterns, solve problems, and find solutions independently.

This project-based learning method uses activities or projects as media (Salamun et al., 2023). Having a projects as a learning activity will of course help students hone and develop their creativity. Apart from that, students are also required to work together and communicate well in groups to be able to solve the problems posed. In line with Suryanti's (2021) research, it is stated that project-based learning will train students to become responsible, communicative and collaborative individuals, as well as increase creativity in problem solving. That is in line with previous research conducted by Bramantya et al (2024), Retnosari & Mediatati (2023), Arshita et al (2023), Aiman et al (2024), Pitaloka (2024) by applying the Project Based Learning (PjBL) learning model cn increase students creativity. The development of digital technology has had a significant impact on the world of education, including in efforts to improve the quality of the learning process at the junior high school (SMP) level(Kim et al., 2025). One form of technology that is growing rapidly and is starting to be widely applied in learning is Augmented Reality (AR). AR is an interactive technology that can combine two- or three-dimensional virtual objects into a real-time real environment, creating a hybrid space that allows students to interact directly with the visualized learning material in a more realistic and interesting way (Guntara et al., 2025). In the context of Natural Sciences learning in junior high school, especially in the solar system material, many concepts are abstract and difficult for students to understand only through conventional media such as textbooks or flat pictures. Materials such as planetary movements, orbits, and relationships between celestial bodies require good visualization so that students are able to imagine these concepts in their entirety (Wang et al., 2024). AR technology is present as a potential learning medium in helping students understand the material through interactive visualizations that are close to reality (Fidan & Tuncel, 2019). AR can boost students' creativity and imagination by allowing them to interact with both digital and physical aspects at once. It can assist pupils in developing fresh ideas and creative solutions to the issues at hand.(Kim et al., 2025; Wen et al., 2022; Zubir et al., 2018). AR enables more interactive learning, allowing students to actively participate in the learning process rather than passively receiving information. This can improve student involvement and participation in the classroom (Cózar Gutiérrez et al., 2015; Sofiadin, 2025).

In addition to understanding concepts, science learning is also required to be able to grow 21st century skills, including students' creativity in solving problems and producing works. To achieve this goal, the application of the Project-Based Learning (PjBL) model is a relevant strategy. This model emphasizes the active involvement of students in solving a project based on real problems, which requires collaboration, exploration, and innovation. The collaboration between PjBL and AR technology is believed to create a more fun, contextual, and creative learning environment for students.

Based on this background, the researcher is interested in conducting research at SMP Negeri 5 Lhokseumawe regarding the application of a project-based learning model with the support of Augmented Reality technology on the theme of the solar system. This research aims to examine the

effectiveness of this approach in increasing student creativity, as well as contributing to the development of science learning strategies that are more innovative and in accordance with the needs of the times.

2. METHODS

This research uses a combination method or mix methods of the concurrent embedded type (a mixture of reinforcement/second method strengthens the first method). In this research, researchers emphasize quantitative data, where qualitative data is used to strengthen and support the results of quantitative data. This research design uses a nonequivalent control group design (Sugiyono, 2014) . The design of the nonequivalent control group is:

Table 1. Nonequivalent Control Group Design

O_1	X	O_2
O_3		O_4

Information:
O_1 = Giving an initial test in the experimental class
X = Providing treatment in the experimental class
O_2 = Giving the final test in the experimental class
O_3 = Giving an initial test in the control class
O_4 = Giving the final test in the control class

This research was carried out at SMP Negeri 5 Lhokseumawe which is located on JLN. Sultanah Nahrasiyah No. 5, Lancang Garam, Kec. Banda Sakti, Lhokseumawe City. This research took place in the even semester of the 2023/2024 academic year. According to Sugiyono (2020), population is a generalized area consisting of subjects or objects that have certain qualities and characteristics that are chosen by researchers to study and then draw conclusions. The population in this study were all class VII students at SMP Negeri 5 Lhokseumawe. The sample is part of the number and characteristics of the population (Sugiyono, 2020). The sampling technique in this research uses nonprobability sampling using purposive sampling type. The samples chosen by the researches were class VII-5 as a control class with 20 students and class VII-6 as an experimental class with 20 students.

This research has two variables, namely the dependent variable and the independent variable. The dependent variable in this research is student creativity and the independent variable is the Project Based Learning (PjBL) model assisted by Augmented Reality. The steps in using the Project Based Learning (PjBL) learning model have 6 stages/phases. The first stage is basic questions, at this stage students are involved in the learning process by observing Youtube videos presented by researchers through shows from Infocus which touch on solar system material. Then the researcher and students asked each other questions and answers regarding the video that had been presented, namely with qusetion (1). What is the center of the solar system?, (2). Why is the sun at the center of the solar system?, (3). What happens if the planets move out of their orbits?. In the second stage, namely designing the project, at this stage the researcher provides an overview of the project that will be created.

The researcher informed the students about the project that would be created, namely in the form of making a simple miniature about the solar system on the Assemblr Edu or Assemblr Studio website which would produce Augmented Reality. Augmented reality is an interactive technology that can combine 2 or 3 dimensional virtual objects into a real environment. The combination of the two creates a hybrid space that is mixed, which can be

projected into real time. The use of augmented reality media to create projects is very suitable in collaboration with the PjBL model which is believed to increase student creativity. The third stage is developing a timetable, at this stage the researcher allocates the time needed for students to design and complete a simple tiny solar system for 40 nminutes and divides the students into 4 groups.

The fourth stage is monitoring project progress or monitoring students. At this stage the researcher guides students to understand each image item in the Assemblr Edu or Assemblr Studio menu through guided steps in the LKPD. The fifth stage is testing the results, at this stage the researcher helps students measure achievements in the project work process, one of which is whether the project created by the student complies with the rules and concepts. In the sixth stage, namely evaluating, at this stage the researcher and students reflect on the project activities that have been carried out by the students. The students work on posttest questions as a result of evaluation in learning after making the project.

3. RESULT AND DISCUSSION

3.1 Result

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily. The discussion can be made in several sub-sections.

Table 2. Data from pretest and posttest results

Class	Average Pretest	Average Posttest
Control	37	65
Experiment	41	79,33

The research results obtained were based on quantitative data analysis through students creativity tests. The trial was carried out in the experimental and control classes, each consisting of 20 students, by giving 15 multiple choice questions. The following is a table of decriptive statistics for the pretest and posttest for the control and experimental classes as follows:

Table 3. Descriptive statistics of pretest and posttest for control and experimental classes

Descriptive Statistics				
	N	Minimum	Maximum	Std. Deviation
Pretest Control	20	13,33	60	12,699
Posttest Control	20	26,67	86,67	15,578
Pretest Experiment	20	26,67	66,67	10,657
Posttest Experiment	20	66,67	93,33	8,349

Based on the table above, the minimum pretest score for the control class is 13,33 and the maximum score is 60. Meanwhile, the minimum pretest score for the experimental class is 26,67 and the maximum is 66,67. Based on the table above, the minimum posttest score for the control class is 26,67 and the maximum score is 86,67, while the minimum posttest score for the experimental class 66,67 and

the maximum is 93,33. The following diagram shows the average results of the N-Gain test scores in the control class and experimental class, which can be seen below:

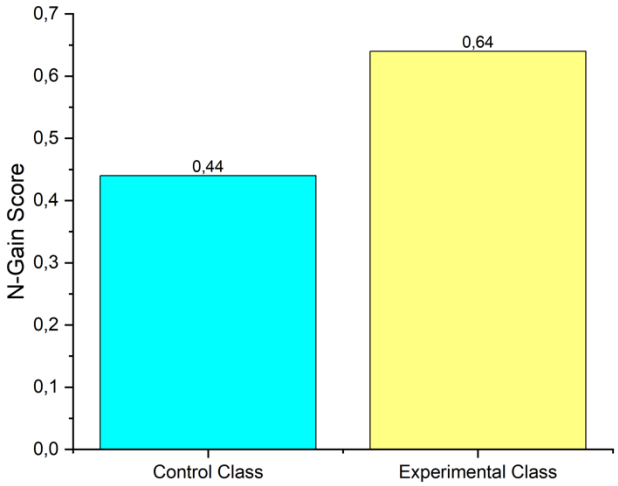

Figure 1. Diagram of N-Gain Test Results for Control Class and Experimental Class

In this research, students' creativity was observbed. This observation aims to determine the level of student creativity when the Project Based Learning (PjBL) model assisted by Augmented Reality is applied in the experimental class and the level of creativity of students in the control class when the Direct intruction model assisted by Augmented Reality is applied. The following are the results of observations of student creativity in the control and experimental class, which can be seen below:

Table 4. Nilai Observation Values of Control Class Students Creativity

Indicator	Petcentage (%)
Fluent Thinking	60,83
Flexible Thinking	62,92
Elaboration	58,60
Original Thinking	52,11
Average	58,61 (quite creative)

Based on the results of the observations that the research made during the classroom learning process, the students creativity results were obtained according to table 4 above. The control class on the fluent thinking indicator obtained a score of 60,83%. The flexible thinking indicator obtained a value of 62,92%. The elaboration indicator obtained a value of 58,60%. The original thinking indicator received a score of 52,11% and the average student creativity score 58,61% with the criteria being quite creative, where the learning used the Direct Instruction model by assisted Augmented Reality.

Table 5. *Observation Value of Experimental Class Students Creativity*

Indicator	Petcentage (%)

Fluent Thinking	76,25
Flexible Thinking	72,92
Elaboration	68,13
Original Thinking	68,83
Average	71,53 (creative)

Based on the results of observations that the researcher made during the learning process in class by making a miniature solar system project, the results of student creativity were obtained according to table 5 above, the fluent thinking indicator for the experimental class obtained a score of 76,25%. According to Sinta (2022), fluent thinking is the ability to generate many relevant ideas, answers and problem-solving in a short time. In this aspect, many students were able to come up with lots of ideas and answers, namely in ordering the planets in the solar system that have the have the most natural satellites to the fewest natural satellites, many students came up with answers about how long the earth has evolved and came up with answers about the outermost planets this time after the exit of pluto.

The flexible thinking indicator obtained a value of 72,92%. According to Sinta (2022), flexible thinking is the ability to produce varied ideas, answers or questions, but must still refer to the problem given, be able to see problems from different points of view and be able to apply concepts, properties or rules in solving examples problem. In this aspect, many students can produce thr right answer from a variety of answers, many students produce answers by looking at the problem from diffepoints of view, and many students can apply the concepts and rules contained in the solar system material. The detailed thinking indivcator obtained a value of 68,13%. According to Sinta (2022), detailed thinking is the ability to improve and develop an idea or product by adding or detailing the details of a thing, idea or situation so that it becomes more interesting.

In this aspect, students apply it in making projects and apply their own creativity. The original thinking indicator obtained a value of 68,83%. According to Sinta (2022), original thinking is the ability to generate problems, ideas or things that other people have not thought of and create different and newest ideas or work. In this aspect, students can look for errors in questions given by the teacher regarding the arrangement of the solar system correctly and clearly in their own way or idea that no one else has thought of. The average creativity score of experimental class students obtained a score of 71,53% using creative criteria, Where the learning used the project based learning (PjBL) model assisted by augmented reality. So it can be concluded that using the project based learning (PjBL) model assisted by augmented reality is more effectively applied to increase student creativity compared to the Direct Instruction learning model assisted by augmented reality. The following are various student project results regarding miniature solar system assisted by augmented reality which can be seen in the image below:

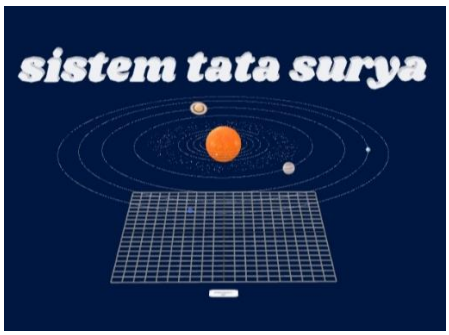

Figure 2. Poor Project

Figure 3. Poor Project

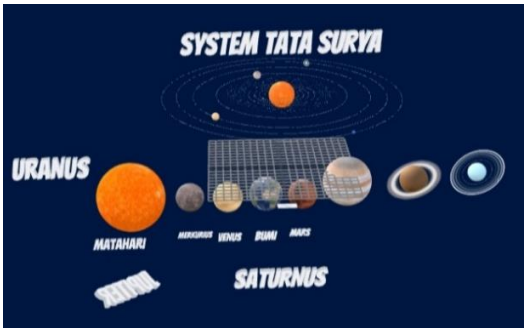

Figure 4. The Project Is Quite Good

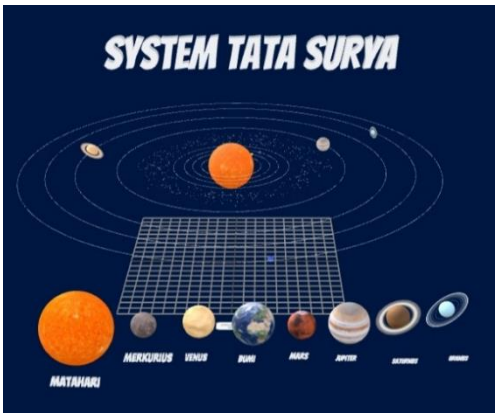

Figure 5. The Project Is Quite Good

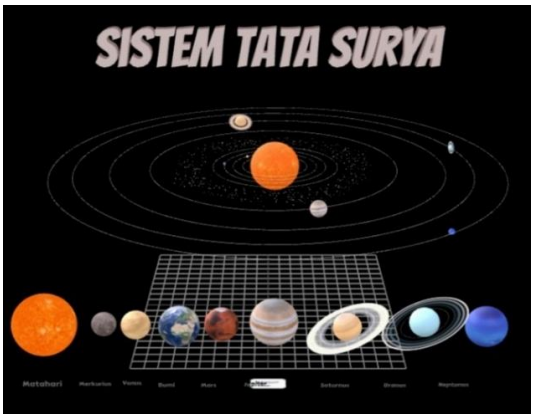

Figure 6. Verry Good Project

Figure 7. Verry Good Project

Figure 2 and Figure 3 show the results of student projects which are not good and not yet perfect because there are still many planetary items that have not been completed and giving names to each planet has not been completed, this is because students do not understand the concept (think flexibly) which causes students are less fast in doing many things from making projects (thinking fluently). Figure 4 and Figur 5 show the results of the student project are quite good. Students work faster and do more than others (fluent thinking). In this project, students have begun to understand the concept of the solar system (thinking flexibility). Figure 6 and Figure 7 show the results of the student project are verry good and perfect. Students already understand concepts (flexible thinking), work faster and do more than others (fluent thinking), create detailed and different problem solutions for the project (detailed thinking), create different and newest work (original thinking). The diagram of the results of observing students creativity in the control class and experimental class can be seen below:

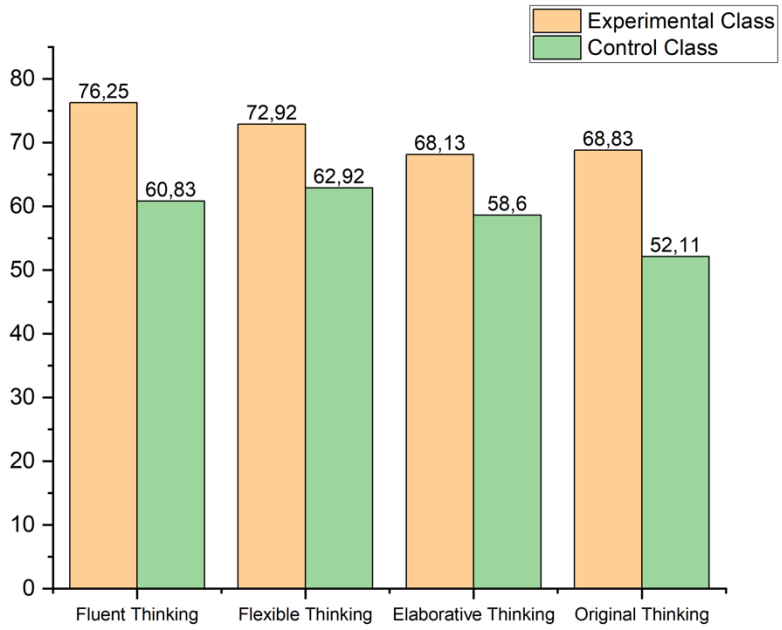

Figure 8. Diagram Percentage of Student Creativity Observations in the Control and Experimental Class

This research also uses a student response questionnaire based on the application of a project based learning model assisted by augmented reality, the aim of which is to see an increase in student creativity. The student response questionnaire was taken from 20 experimental class students. This response was obtained from filling out a questionnaire by students during the learning process carried out by the researcher. The following students questionnaire results can be seen in the following table:

Table 6. Results of Student Questionnare Responses

Student Code	Number of Scores	Percentage %	Criteria
AIA	52	81,25	Verry Good
AD	58	90,63	Verry Good
AR	54	84,38	Verry Good
AU	52	81,25	Verry Good
AR	58	90,63	Verry Good
AK	52	81,25	Verry Good
AI	49	76,56	Good
DCR	56	87,5	Verry Good
DYA	58	90,63	Verry Good

IM	57	89,06	Verry Good
IK	51	79,69	Good
IA	58	90,63	Verry Good
KW	56	87,5	Verry Good
KS	61	95,31	Verry Good
MTO	61	95,31	Verry Good
NA	51	79,69	Good
NN	56	87,5	Verry Good
NA	51	79,69	Good
TWS	58	90,63	Verry Good
T. Alhaz Fathan	49	76,56	Good
Average	**54,9**	**85,78**	**Verry Good**

According to the statistics in Table 6, the student response questionnaire yielded an average percentage score of 85.78% in the "Very Good" category.

3.2 Discussion

The research findings indicate that the implementation of the project-based learning (PjBL) model, supplemented by augmented reality, enhances student creativity about solar system material at SMP Negeri 5 Lhokseumawe. The results of the average N-Gain score in both the experimental and control classes substantiate this claim. The experimental class achieved an average N-Gain value of 0.64, categorized as medium, whereas the control class attained an average N-Gain of 0.44, also classified as medium. The data indicates that the enhancement of student creativity was more pronounced in the experimental class than in the control class, evidenced by a comparison of N-Gain values of 0.2 points. The experimental class demonstrates a greater enhancement in student creativity due to the implementation of the Project Based Learning (PjBL) model, augmented by Augmented Reality, whereas the control class utilizes the Direct Instruction model, also supported by Augmented Reality.

The increase in student creativity can also be seen from the results of observations that researchers have made during the classroom learning process. The results of observations of students creativity in the control class obtained an average score of 58,61% with the criteria “Creative Enough”. Meanwhile, in the experimental class, students creativity observation results obtained an average score of 71,53% with the “Creative” criteria. This proves that using the project based learning (PjBL) model assisted by augmented reality can increase student creativity at SMP Negeri 5 Lhokseumawe on the topic of the solar system. The results of the student response questionnaire about the implementation of the project-based learning (PjBL) model, augmented by augmented reality, yielded an average percentage score of 85.78%, categorized as "Very Good." Augmented reality, combined with virtual reality in physics education, can enhance students' visual literacy skills (Permana et al., 2025). This enhancement occurs because augmented reality is a facet of computer technology that displays a real-world image of an imaginary realm in three-dimensional (3D) format, accompanied by audio simultaneously (Ubaidillah, 2024).

This means that the application of the Project Based Learning (PjBL) learning model assisted by Augmented Reality on the solar system material is very well implemented in the learning process. By implementing the Project Based Learning (PjBL) model assisted by Augmented Reality, it can not only increase student creativity, but make learning more fun, make the material easier to understand, make students more courageous and confident in proposing new ideas, both to the teacher as well as fellow friends. So it can be concluded that by implementing the Project Based Learning (PjBL) model assisted by Augmented Reality, it can increase student creativity. This is in line with research conducted by (Bramantya et al., 2024), (Retnosari & Mediatati, 2023), (Arsitha et al., 2023), (Aiman et al., 2024), (Pitaloka & Purwanti, 2024), where the results of the research they conducted show that the implementation The Project Based Learning (PjBL) model can increase student creativity and make the learning process more fun, interactive and not boring.

What differentiates this research from previous research lies in the learning media, learning materials, target population and sample. Researchers used the the Project Based Learning (PjBL) model assisted by Augmented Reality to increase students creativity in the solar system material, where previous research had never researched using Augmented Reality is a learning medium. The augmented reality learning media that researchers use can be accessed in the Assemblr Edu or Assemblr Studio applications. By using augmented reality media, students can hone their abilities in using learning technology to create simple miniature solar system projects and can practice each student's creations. One of the obstacles faced by researchers during the research process was at the first meeting in the experimental class.

When researchers showed how to make a simple miniature solar system project on the Assemblr Edu or Assemblr Studio website in the form of Augmented Reality, many students felt down (gave up) because they still had difficulty using modern learning technology. The efforts that the researcher made to overcome this problem were that the researcher provided 3x training in the experimental class in using digital-basel learning technology outside of researcher hours. The aim of conducting training was so that during project creation process the desired results were in accordance with the plan. At the second meeting in the experimental class, there were no problems or obstacles that the researcher experienced, everything went well and optimally according to the results desired by the researcher, resulting in gigher student creativity in the experimental class compared to the control class. Meanwhile, in the control class, at the first meeting, the obstacle experienced by the researchers was that many students did not understand the material about the solar system, so the class became passive and unpleasant. The second meeting in the control class, the obstacles faced were still the same a in the first meeting, the student's focus was less than optimal in following the learning process, resulting in lower student xreativity results compared to the experimental class.

4. CONCLUSION

Based on the results of the research and discussion described above, it can be concluded that the application of the Project Based Learning (PjBL) learning model assisted by Augmented Reality on the solar system material is very well applied in the learning process. By implementing the Project Based Learning (PjBL) learning model assisted by Augmented Reality, it can not only increase student creativity, but also make learning more fun, make the material easier to understand, make students more courageous and confident in proposing new ideas, both to teacher and fellow friends.

REFERENCES

Aiman, U., Lasmawan, I. W., & Suastika, I. N. (2024). Pengaruh Model Pembelajaran Project Based Learning Untuk Meningkatkan Kreativitas Siswa Sekolah Dasar Berdasarkan Potensi Daerah. *Jurnal Ilmiah Pendidikan Citra Bakti*, *11*(1), 116–123.

Alfath, A., Azizah, F. N., & Setiabudi, D. I. (2022). Pengembangan Kompetensi Guru Dalam Menyongsong Kurikulum Merdeka Belajar. *SOSHUMDIK*, *1*(2), 42–50.

Arsitha, D. R., Setyawan, K. G., & Larasati, D. A. (2023). Pengaruh Model Pembelajaran Project Based Learning Menggunakan Media Scrapbook Dalam Meningkatkan Kreativitas Dan Hasil Belajar Siswa. *Dialektika Pendidikan IPS*, *3*(2), 226–238.

Bramantya, A., Untari, S., & Nafsiyah, F. (2024). Penerapan Model Pembelajaran PjBL Untuk Meningkatkan Kreativitas SSiswa SMK Kelas X-3 Berbantuan Poster Kebudayaan Di SMAN 1 Tumpang. *Jurnal Tinta*, *6*(1), 105–113.

Cózar Gutiérrez, R., Del Valle De Moya Martínez, M., Hernández Bravo, J. A., & Hernández Bravo, J. R. (2015). Emerging technologies in social sciences teaching. An experience using Augmented Reality in teacher training. *Digital Education Review*, *27*, 138–153.

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers and Education*, *142*. https://doi.org/10.1016/j.compedu.2019.103635

Ginting, F. W., Novita, N., & Rahmadani, Y. (2020). Penerapan Model TGT Melalui Simulasi PhET Terhadap Peningkatan Pemahaman Siswa Pada Alat-Alat Optik. *RELATIVITAS: Jurnal Riset Inovasi Pembelajaran Fisika*, *3*(2), 1–9.

Jagom, Y. O. (2015). Kreativitas Siswa SMP Dalam Menyelesaikan Masalah Geometri Berdasarkan Gaya Belajar Visual-Spatial Dan Auditory-Sequential. *Jurnal Pendidikan Matematika*, *1*(3), 176–190.

Kim, J.-S., Choi, Y., & Kim, S.-H. (2025). Review on the Use of Augmented Reality Technology on Computational Thinking Education. *Springer Proceedings in Business and Economics*, 59–71. https://doi.org/10.1007/978-3-031-77975-6_5

Kimianti, F., & Prasetyo, Z. K. (2019). Pengembangan E-Modul IPA Berbasis Problem Based Learning Untuk Meningkatkan Literasi Sains Siswa. *Jurnal Teknologi Pendidikan*, *07*(02), 91–103.

Mahendra, Y., Nuha, U., Suryani, R., & Agyus, V. (2019). Pengembangan pendidikan karakter menuju transformasi abad 21. *Prosiding Semnasfip*, 187–191.

Muliani, Faradhillah, & Maya, S. (2021). Penerapan Model Pembelajaran Project Based Learning Terhadap Hasil Belajar Siswa Pada Materi Statis Di SMA Negeri Unggul Subulussalam. *RELATIVITAS: Jurnal Riset Inovasi Pembelajaran Fisika*, *4*(2), 59–67.

Permana, F., Guntara, Y., & Saefullah, A. (2025). The Influence of Visual Thinking Strategy In Augmented Reality (ViTSAR) to Improve Students' Visual Literacy Skills on Magnetic Field Material. *Phi: Jurnal Pendidikan Fisika Dan Terapan*, *11*(1), 71–81. https://doi.org/10.22373/P-JPFT.V11I1.28790

Pitaloka, D., & Purwanti, K. Y. (2024). Pengaruh model pembelajaran project based learning berbantuan mind mapping terhadap kreativitas siswa kelas V SDN Ungaran 01. *Jurnal Pendidikan Ke-SD-An*, *10*(2), 119–129.

Prasetyo, A. D., & Abduh, M. (2021). Peningkatan Keaktifan Belajar Melalui Model Discovery Learning Di Sekolah Dasar. *Jurnal Basicedu : Research & Learning in Elementary Education*, *5*(4), 1717–1724.

Rahmi, H. (2017). *Penerapan Model Project Based Learning Untuk Meningkatkan Kreativitas Siswa Dalam Tema Berbagai Pekerjaan Pada MIN Mesjid Rya Banda Aceh*.

Retnosari, E., & Mediatati, N. (2023). Penerapan Model Pembelajaran Project Based Learning Berbantuan Media Interaktif Untuk Meningkatkan Hasil Belajar Dan Kreativitas Siswa. *Jurnal Ilmiah Pendidikan Dasar*, *08*(03).

Rexa, B. T., & Anistyasari, Y. (2017). Pengembangan Lembar Kerja Siswa (LKS) Berbasis Augmented Reality Pada Model Pembelajaran Project Based Learning Di SMKN 2 Lamongan. *Jurnal IT-EDU*, *2*, 9–18.

Saaddiyah, L. I., & Anjarwati, A. (2022). Model Project Baseed Learning (PjBL) Dengan Augmented Reality (AR) Untuk Meningkatkan Kreativitas Siswa Digital Natives. *Journal of Physics and Science Learning*, *06*(phase 1), 85–92.

Safriana, & Marina. (2019). Analisis Kemampuan Pedagogical Content Knowledge (PCK) Calon Guru Fisika Pada Mata Kuliah Microteaching. *Jurnal Pendidikan, Sains, Dan Humaniora*, *7*(3), 312–320.

Salamun, Widyastuti, A., Syawaluddin, Iwan, R. N. A., Simarmata, J., Simarmata, E. J., Suleman, Y. N., Lotulung, C., & Arief, M. H. (2023). *Model-Model Pembelajaran Inovatif* (A. Karim, Ed.). Yayasan Kita Menulis.

Sari, E. P. (2020). *Meningkatkan Hasil Belajar Siswa Melalui Penerapan Media Augmented Reality Materi Sistem Tata Surya Dalam Pembelajaran IPA Kelas VI MI Al-Mursyidiyyah*.

Sofiadin, A. (2025). INNOVATIVE EXPERIENTIAL LEARNING THROUGH THE IMPLEMENTATION OF OUTCOME-BASED EDUCATION. *Proceedings of the International Conferences on Mobile Learning 2025 and Educational Technologies 2025*, 231–234. https://www.scopus.com/inward/record.uri?eid=2-s2.0-105003417644&partnerID=40&md5=c7d519bd6c83179105026c5d3415c802

Sugiyono. (2014). Desain Penelitian. *Metode Penelitian Kuantitatif, Kualitatif Dan R&D*, 8.

Suryanti. (2021). *Penerapan Model Pembelajaran Project Based Learning (PjBL) Terintegrasi STEM (Science, Technology, Engineering And Math) Untuk Meningkatkan Kreativitas Siswa Kelas XI MIA Di SMA N 10 Kota Jambi*.

Ubaidillah, U. (2024). Visualisasi Pembelajaran Fisika Menggunakan Virtual Reality Pada Materi Ajar Hukum Hooke di Kelas XI-MIPA MAN 2 Aceh Barat. *Phi: Jurnal Pendidikan Fisika Dan Terapan*, *10*(1), 55–62. https://doi.org/10.22373/P-JPFT.V10I1.19347

Wang, Y., Liu, W., Yu, X., Li, B., & Wang, Q. (2024). The impact of virtual technology on students' creativity: A meta-analysis. *Computers and Education*, *215*. https://doi.org/10.1016/J.COMPEDU.2024.105044

Widarti, R., & Roshayanti, F. (2021). Potensi Implementasi STEAM (Science, Technology, Engineering, Art and Mathematic) berorientasi ESD (Education for Sustainable Development) dalam Pembelajaran Fluida. *Unnes Physics Education Journal*, *10*(3).