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Implementation of Augmented Reality Booklet Based on Problem Based Learning on Earth and Solar System to Increase Students' Scientific Literacy Skills

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ABSTRACT

Penelitian ini bertujuan untuk meningkatkan literasi ilmiah siswa tentang materi Bumi dan Tata Surya melalui penggunaan buku berbasis Augmented Reality (AR) yang terintegrasi dengan model Pembelajaran Berbasis Masalah (PBL). Literasi ilmiah merupakan kemampuan penting dalam pendidikan sains, terutama untuk memahami konsep abstrak dan fenomena alam secara ilmiah. Metode yang digunakan dalam penelitian ini adalah desain pra-eksperimental dengan pretest-posttest satu kelompok, melibatkan 32 siswa kelas tujuh di salah satu SMP negeri di Kota Malang. Instrumen yang digunakan adalah pertanyaan deskripsi literasi ilmiah berdasarkan kerangka PISA 2025, yang telah divalidasi oleh para ahli dan diuji lapangan. Hasil penelitian menunjukkan peningkatan yang signifikan pada rata-rata skor literasi ilmiah siswa setelah perlakuan, dari kategori "cukup" pada pretest menjadi "sedang" pada posttest. Hal ini menunjukkan bahwa integrasi teknologi AR dan pendekatan PBL dalam media buku dapat meningkatkan pemahaman ilmiah siswa, kemampuan berpikir kritis, dan minat belajar tentang materi Bumi dan Tata Surya.

This study aims to improve students' scientific literacy on Earth and Solar System material through the use of Augmented Reality (AR)-based booklets integrated with the Problem-Based Learning (PBL) model. Scientific literacy is an important ability in science education, especially to understand abstract concepts and natural phenomena scientifically. The method used in this research is pre-experimental design with one-group pretest-posttest, involving 32 seventh grade students in one of the public junior high schools in Malang City. The instrument used was a scientific literacy description question based on the 2025 PISA framework, which has been validated by experts and field tested. The results showed a significant increase in the average score of students' scientific literacy after treatment, from the "sufficient" category at the pretest to "moderate" at the posttest. This shows that the integration of AR technology and PBL approach in booklet media can improve students' scientific understanding, critical thinking skills, and interest in learning about Earth and Solar System material.

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INTRODUCTION

Scientific literacy is an essential skill for students in understanding scientific concepts and applying them in everyday life. This literacy includes an understanding of the scientific process, the ability to apply scientific knowledge, and the skills to make decisions based on scientific information (Alatas & Fauziah, 2020; Setiawan, 2023) . In the context of science education, scientific literacy is needed to equip students with critical and analytical thinking skills to face complex challenges in the modern era, including environmental issues related to the Earth and Solar System (Setiawan, 2019; Yuliati, 2017) .

The results of the PISA assessment show that the level of science literacy of students in Indonesia is still relatively low compared to other countries. In the 2018 PISA assessment, Indonesia ranked 70 out of 78 countries, with a score of 389 below the global average of 489 (Musyarofah et al., 2023) . This suggests the need for reform in science teaching and learning methods in schools, where a more interactive and inquiry-based approach is considered effective for improving students' science literacy (Matkarimov, 2022) . Research results (Setiawan et al., 2019) underline that one of the factors causing low scientific literacy is the lack of application of active learning methods that encourage student involvement in exploration and experimentation activities. In fact, methods such as the scientific approach and problem-based *learning* can improve students' understanding of scientific concepts while honing problem-solving and critical thinking skills (Andari et al., 2020; Dewi et al., 2024) .

Problem-based learning (PBL) has been shown to effectively improve literacy indicators of scientific literacy aspects, including context understanding, knowledge acquisition, competency development, and attitude improvement (Pakpahan, 2022). This approach has successfully improved students' ability to apply scientific concepts to real-life problems and improved their scientific attitudes (Prastika et al., 2019).

Problem-based learning (PBL) has been shown to improve students' scientific literacy indicators at various levels of education. Research has shown that PBL, especially when combined with other approaches, can improve science literacy competencies in junior high school students (Parno et al., 2020) . The application of PBL is also proven to improve scientific explanation ability in biology learning about the environment (Laksmi et al., 2021) . When integrated with flipped classroom techniques, PBL can produce better science literacy results compared to traditional PBL alone (Sholahuddin et al., 2023) . In addition, incorporating technology such as Prezi media into PBL can have a positive impact on science literacy and student independence (Kristiantari et al., 2022) . These studies suggest that PBL, especially when combined with other innovative teaching methods and technologies, can be an effective strategy to improve various aspects of students' scientific literacy across different subjects and grade levels.

The results of interviews with several students at one of the middle schools in Malang City show that students are more eager to learn in subjects that are considered exciting and easy to understand. In addition, students also mentioned that fun and interactive teaching methods from teachers can make them more interested in learning. Students also mentioned that learning is more effective with interactive media, both in the form of practice and through interesting visualization strategies. However, limited school facilities, lack of teaching aids, and the dominance of the lecture method are still the main obstacles in learning science. Teacher-oriented learning makes it difficult for students to understand the earth and solar system material because they can only hear and memorize words without seeing the visualization. As found in research (Sari et al., 2019) , students face difficulties in earth and solar system material, especially in making observations of celestial objects during the day. Students also face difficulties in understanding phenomena related to the solar system, such as the apparent annual movement of the sun. Furthermore, according to research conducted by (Salamah et al., 2023) , learners also have difficulty in imagining the position of celestial objects that are located very far away. As a result, they find it difficult to understand the difference between lunar and solar eclipses, and the difference between the rotation and revolution of the earth. Therefore, an innovative learning approach and the utilization of technology in the teaching-learning process are needed to make it easier for students to learn the topic of the earth and solar system.

Science is an abstract concept, one example is the solar system. Many parts of science cannot be observed directly by human senses, so they require the help of models or visualization. The solar system, for example, is often used as a learning context to help students understand scientific concepts that are difficult to understand concretely. According to research by Salim & Aryuni (2022) , the use of 3D learning technology can improve students' understanding of solar system concepts by visualizing abstract elements in a more concrete form. Other research shows that having students imagine planets in different ways can strengthen their understanding of complex science concepts such as planetary habitability (Nyhout & Ganea, 2022) . This suggests that innovative approaches are essential in helping students understand abstract concepts in science.

According to (Jayawardana, 2017) , teacher-oriented learning tends to make students passive, easily bored, and have difficulty in understanding the material. In fact, effective learning does not only focus on memorization, but also involves interactive learning experiences (Khumaidi, 2018) . One strategy that can be used to increase student engagement is a visualization strategy, which is the use of images and interactive media to strengthen concept understanding (K. Novita & S. Rahayu, 2021) . In this case, Augmented Reality (AR) technology has the potential to be an effective solution in visualizing abstract material, such as the Earth and Solar System.

Augmented Reality (AR) is a technology that integrates virtual objects in 2D or 3D into the physical environment in *real-time* (Habiddin et al., 2022) . AR can help present abstract concepts more concretely and interactively, thus improving students' understanding of the material (Yen et al., 2013) . Some studies show that the use of AR in learning can increase student learning motivation and improve academic achievement (Wang & Chi, 2012) . In the context of Earth and Solar System learning, AR can be used to display interactive models of planetary movements, Earth's rotation and revolution, and other astronomical phenomena, which are difficult to explain with text and 2D images alone.

One form of AR implementation in learning is through interactive booklets. Booklets are small-sized printed learning media that contain material that is presented concisely and systematically. *Booklets* are small A5-sized books with no more than 48 pages (Intika, 2018) . The structure of the *booklet* content is similar to a book, which includes an introduction, content, and closing section, but the material presented is much more concise than a book (Simamora, 2009) . AR-based booklets allow students to access additional information through scanning specific codes using digital devices, so the learning experience becomes more dynamic and in-depth (Lai et al., 2015) . Research (Lisnani & Irzawati, 2019) shows that the use of booklets as learning media can improve students' understanding of the concept of the solar system.

To make the application of AR in learning more effective, this technology needs to be combined with appropriate learning strategies. Some studies mention that the utilization of technology in learning will only be effective if supported by an appropriate approach (Bergdahl et al., 2020) . In this case, the Problem-Based Learning (PBL) model is one method that can be combined with AR to improve students' critical thinking skills and creativity, where students are given problems that must be analyzed and solved through exploration and teamwork (A. Isatunada et al., 2023; Agustin et al., 2021) . This method also allows students to better understand the connection between scientific concepts and their application in everyday life (Monsang et al., 2021) .

By combining AR and PBL, the learning process not only becomes more interactive, but also more in line with the demands of 21st century education that emphasizes critical thinking skills, problem solving, and collaboration (Hasanah & Haryadi, 2022; Rahmadita et al., 2021) . Previous research conducted by (Fidan & Tuncel, 2019) shows that the integration of AR in PBL-based learning can significantly improve student learning achievement. Research by Idris et al. (2024), shows that the combination of augmented reality media with PBL learning models can improve students' literacy competencies.

Based on the description above, this study aims to apply *Problem-Based Learning-based* Augmented Reality booklets on Earth and Solar System materials to improve students' scientific literacy skills. Through this research, it is expected to obtain an effective learning model in improving students' understanding of scientific concepts and encouraging their active involvement in the learning process.

METHOD

This study aims to determine the increase in students' scientific literacy after the application of *Problem-Based Learning-based Augmented Reality booklets* in the learning process of Earth and Solar System material. To achieve these goals, this study uses a *Pre-experimental* method, researchers deliberately provide treatment in the form of using PBL-based AR *booklets*, then observe the impact on increasing students' scientific literacy (Arikunto S., 2013) .

The number of samples used in this study were 31 students taken from the population of seventh grade students in one of the Malang city SMPN through random sampling, namely the drawing of classes with diverse ability levels. The instrument used was a multiple choice question of 15 questions that were tested for content validation through expert validators. The scientific literacy questions given followed

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the 2025 PISA framework guidelines. The description of the scientific literacy indicators can be seen in Table 1.

Table 1. Scientific Literacy Indicator

Explain phenomena scientifically	Recall and apply appropriate scientific knowledge;
	Use different forms of representations and translate between these forms;
	Make and justify appropriate scientific predictions and solutions;
	Identify, construct, and evaluate models;
	Recognise and develop explanatory hypotheses of phenomena in the material world;
	Explain the potential implications of scientific knowledge for society
Construct and evaluate designs for scientific enquiry and interpret scientific data and evidence critically	Identify the question in a given scientific study;
	Propose an appropriate experimental design;
	Evaluate whether an experimental design is best suited to answer the question;
	Interpret data presented in different representations, draw appropriate conclusions from data and evaluate their relative merits.
Research, evaluate and use scientific information for decision making and action	Search, evaluate and communicate the relative merits of different sources of information (scientific, social, economic and ethical) that may have significance or merit in arriving at decisions on science-related issues, and whether they support an argument or a solution;
	Distinguish among claims based on strong scientific evidence, expert vs. nonexpert, and opinion, and provide reasons for the distinction;
	Construct an argument to support an appropriate scientific conclusion from a set of data;
	Critique standard flaws in science-related arguments using epistemic and procedural knowledge e.g., poor assumptions, cause vs. correlation, faulty explanations, generalisations from limited data;
	Justify decisions using scientific arguments, either individual or communal, that contribute to solving contemporary issues or sustainable development.

In this study, the results of students' Scientific Literacy in the competency and knowledge domains will be obtained. Therefore, the first step in analyzing the instrument is to group the questions based on each aspect in the competency and knowledge domains first. After that, the percentage of correct scores obtained on each indicator in the domain of competence and knowledge is calculated, so that the average value of the percentage of correct scores from all students is obtained. The percentage is obtained from equation (1).

The percentage results are then interpreted according to the criteria interpreted by Arikunto presented in table 1.

Table 2. Percentage Interpretation

Percentage (%)	Category
80 - 100	Excellent
66 - 79	Good
56 - 65	Simply
40 – 55	Less
0 – 39	Failed

The research design used is pre-experimental with *one-group pretest- posttest design*, In this method, no control group is needed to compare with the experimental group, does not use equalization of characteristics in one treatment group, and does not require variable control (Creswell, 2014) . The research design is presented in the table 3.

Table 3. One group pretest-posttest design

Pre test	**Treatment**	***Post test***
O1	X	O2

With:
O1= Observation before treatment
O2 = Observation after treatment
X= Treatment of the experimental group

Before being given the treatment, students were given a pretest. Furthermore, based on the consideration of the given learning topic, the treatment (in this case the learning topic is delivered using the scientific approach) is given for 2 face-to-face sessions. After the treatment was completed, the students were given a post-test. Furthermore, the posttest-pretest results were used by researchers as a source of data to determine the results of the treatment. as for the treatment results in this study, namely the increase in scientific literacy in the competency domain. The data obtained in the form of *pretest* and *posttest* scores were processed using normalized gain <g> to describe the value of posttest improvement against pretest (Hake, 1998) . The normalized gain value is interpreted based on table 2.

Table 4. Results of Scientific Literacy Competency Domain

Normalized Gain Value	**Category**
g>0.7g>0.7	High
0.7>g<0.30.7>g<0.3	Medium
g<0.3g<0.3	Low

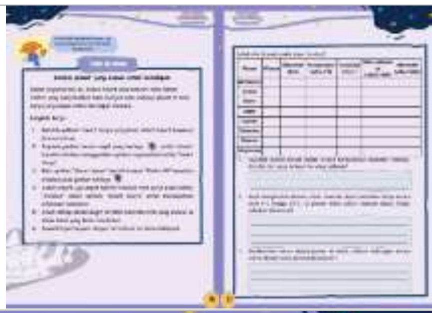
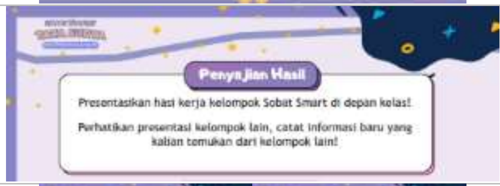
RESULT AND DISCUSSION

This study aims to determine the effect of using PBL-based AR booklets on Solar System material on improving students' scientific literacy skills. Pretest and posttest were given to one group of students as research subjects. *Pretest* was used to measure the initial ability of students' scientific literacy related to Solar System material before being given learning treatment.

After the learning process using AR *booklets* based on *Problem Based Learning*, students were given a *posttest* to measure the extent to which their scientific literacy skills improved. The AR *booklet* used contains a visual display based on *augmented reality* technology that is able to display 3D objects of the Solar System interactively. This supports student understanding through direct observation and a more meaningful learning experience.

Table 5. Stages of Problem Based Learning Model

Syntax	**Learning Activities**	**View**
Problem orientation	Presented with problems or information sourced from news/articles/reading sources. Learners understand the problems discussed. This can be seen in the "*Awesome News"* feature.	
Organizing Learners	In groups, learners formulate problems obtained from news/articles/reading sources. Additional information can be accessed on the *hyperlinks* contained in the "*Awesome News"* feature.	

Guiding the Investigation	In groups, learners will conduct investigations related to the problems in stage 1. Discussion materials are presented that help learners be more directed. This can be seen in the "Let's Investigate" feature.	
Presenting the Work	Learners present the results of group investigations and respond to the results of other groups' investigations. This can be seen in the "Presentation of Results" feature.	
Analysis and Evaluation	Learners analyze the problems that occur and provide alternative efforts to solve the problems discussed. The evaluation of the activity is in the QR Code presented. This can be seen in the "Analysis and Evaluation" feature.	

Science literacy skills were measured through *pretest* and *posttest*. The improvement of science literacy skills was measured by N-Gain analysis. Before calculating N-Gain, normality test and paired t-test were needed to check whether there was a significant difference between before and after learning. Table 1 presents the results of the normality test.

Table 6. Normality Test Results

Test	df	Sig. (Shapiro-Wilk)
Pre-Test	31	0,53
Post-Test	31	0,12

Based on Table 6, it can be seen that the significance value in the Shapiro-Wilk test for pretest (0.752) and posttest (0.372) > 0.05. Thus, the data is normally distributed and H_0 is accepted, which means there is no deviation from normal distribution. So, further statistical testing using paired sample t-test is presented in table 7.

Table 7. The paired sample t-test.

Comparison	Mean Difference	t	df	Sig. (2-tailed)
Pre-Test - Post-Test	-22,000	-9,290	31	0,000

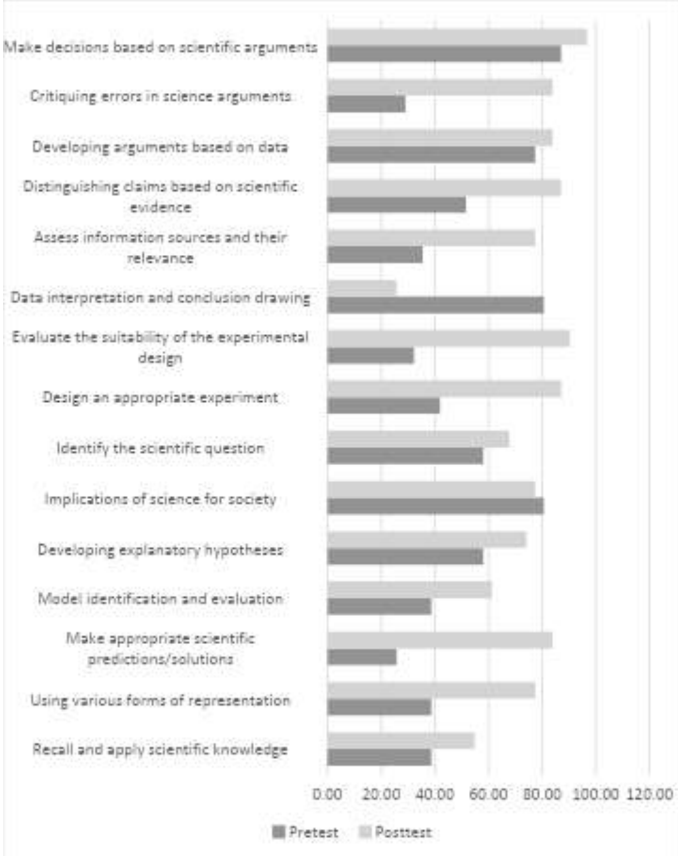
The *paired sample t-test* test criterion is if the significance value (Sig. 2-tailed) <0.05 then H_0 is rejected, which means that there is a significant difference in students' scientific literacy skills after learning using AR booklets based on *Problem Based Learning* (PBL) on Solar System material. Based on the *paired sample t-test* results displayed in Table 2, the Sig. (2-tailed) of 0.000 (<0.05). Thus, H_0 is rejected and H_a is accepted, which indicates that there is a significant average difference between the pretest and posttest scores. This means that learning using PBL-based AR booklets has a significant effect on improving students' scientific literacy skills.

The three indicators of scientific literacy skills measured include the ability to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and phenomena scientifically. The improvement of these skills is then calculated using the N-Gain value to determine the effectiveness of learning. The increase in scientific literacy skills is determined by the difference in test scores obtained before and after treatment. Calculations using Normalized Gain (N-Gain) were carried out to evaluate the effectiveness of PBL-based AR booklets as printed learning resources in study groups. The following table shows the results of the N-Gain calculation.

Table 8. Average score of students science literacy

Pretest Average	Posttest Average	N-gain	Criteria
51.61	75.27	0,49	Medium

Based on Table 8, it can be seen that the average score of students' science literacy has increased from 51.61 during the pretest to 7 during the posttest. The number of students who were used as research samples was 32 people. The N-Gain value of 0.47 is in the medium category, which indicates that the use of *Problem Based Learning* booklets assisted by *Augmented Reality* (AR) is able to have a positive impact on increasing students' scientific literacy in the Solar System sub chapter.



Based on the results of the pretest and posttest analysis of the fifteen indicators grouped into three PISA science literacy domains, it can be seen that most indicators have increased significantly. In the Explain Phenomena Scientifically domain, the most striking improvement occurred in indicator 2 (using various forms of representation) and indicator 3 (making scientific predictions/solutions). This shows that learning has successfully improved students' ability to understand scientific concepts visually and think logically in the context of predictions. However, indicator 6 (implications of science for society) actually experienced a slight decrease, possibly because students have not been able to fully relate learning materials to social life concretely.

In the second domain, Construct and Evaluate Scientific Enquiry, very significant improvements were seen in indicators 8 (design experiments) and 9 (evaluate experimental designs), indicating that students were increasingly able to design and assess the effectiveness of scientific experiments. However, there was a sharp decline in indicator 10 (data interpretation and conclusion drawing), from 80.61% in the pretest to only 25.80% in the posttest. This needs to be a special concern, because although students can design experiments well, they actually have difficulty when analyzing data and concluding the results. Most likely, the learning approach has not been effective enough in equipping students with in-depth data interpretation skills

Meanwhile, in the third domain, Evaluate Scientific Information for Decision Making, very positive improvements were seen in almost all indicators. Indicator 14 (criticizing errors in science arguments) experienced a significant jump from 29.02% to 83.83%, indicating that students' critical thinking skills had developed rapidly. Similarly, indicators 11 and 12 relating to the assessment of

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information sources and scientific claims also showed sharp improvements. Indicator 15 (making decisions based on scientific arguments) has even been high since the beginning and continues to increase, indicating that students have a strong foundation in linking science to everyday decision-making.

Overall, this data shows that the learning approach has successfully improved students' overall science literacy skills, especially in the aspects of representation, argumentation and evaluation of scientific information. However, the decline in the ability to interpret data indicates the need for improvement in the delivery of material that involves analyzing experimental results. Therefore, in the next stage, teachers need to strengthen the data understanding aspect through project-based learning strategies, case studies, or data-based simulations so that students can not only design experiments but also interpret the results appropriately.

The results of research in learning using *Problem-Based Learning (PBL)* based *Augmented Reality (AR) Booklet* media on Solar System material as a whole show the implementation of active, interactive, and fun learning. This is indicated by the enthusiasm of students during the learning process which is full of enthusiasm and curiosity. Thus, it can be categorized that students give a positive response to science learning by using PBL-based AR *booklets*.

Student response questionnaires in the form of closed questionnaires are used as instruments to measure student responses to learning with this media. The results of the questionnaire data processing that has been given by students can be seen in the following table

Indicator	**% Score (P)**	**Score Category**
Students' opinions on learning using PBL-based AR media	90,00	Positive
Students' ease of understanding Solar System material through solving habitable planet cases	83,00	Positive
Students' interest in PBL-based LKPD media and AR visualization	82,00	Positive
Students' ability to solve scientific cases through group work	85,00	Positive
Students' enthusiasm for problem-based learning approach	80,00	Positive
Students' views on the role of the PBL method in building scientific understanding	85,00	Positive
Average	84,17	**Positive**

Based on student responses, the majority of learners showed high interest in learning with AR-assisted PBL LKPD, especially because it allows them to see planets in 3D, recognize planetary characteristics, and work together in groups. They feel happy and more interested in learning because this method is fun and game-like, and the material becomes easier to understand through visualization and interaction. Some students also appreciated the interesting LKPD and poster-making activities, as they gave them a deeper understanding of habitable planets and encouraged group discussions. This shows that contextual and visual approaches in science learning can increase students' enthusiasm and scientific literacy.

However, some challenges also arose from the implementation of this activity. Some students complained about technical constraints such as limited cellphone memory to download the application, difficulty opening the application, or lack of group cooperation. In addition, some students had difficulty in distinguishing terms such as meteorite, meteor, and meteoroid, or found it difficult during the test. For improvement, students suggested that learning should be made simpler, interactive, and accompanied by clearer teacher explanations and a conducive learning atmosphere. They also suggested a variety of methods, such as learning through games, quizzes, or more discussions to make learning more exciting and easy to implement. This is an important input for teachers in developing adaptive, fun and inclusive learning strategies.

CONCLUSION

This study shows that the application of *Augmented Reality-based booklets* combined with the *Problem-Based Learning learning* model is proven effective in improving students' scientific literacy on Earth and Solar System material. Through the *pre-experimental* method with a *one-group pretest-posttest* design, the data showed that there was an increase in the average percentage of correct scores of all scientific literacy indicators. Students' scientific literacy scores increased from the "Fair" category in the pretest to "moderate" in the posttest based on Arikunto's percentage interpretation criteria. This increase reflects students' better ability to explain phenomena scientifically, build hypotheses, and evaluate data and design scientific investigations. These results indicate that the use of technology-based interactive media and active learning approaches can overcome the challenges of learning abstract material and at the same time increase student motivation and involvement in the learning process.

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