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Development of Learning Tools with Project-Based Learning (PjBL) Model on Students' Creative Thinking Skills in Renewable Energy Material

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Abstract: This study aims to develop learning devices with a project-based learning model in order to improve students' creative thinking skills in physics subjects on renewable energy material. This type of research is research and development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). This research was conducted at SMAN 1 Semarang with the research subjects being a physics teacher and 10th grade students. The research instruments consist of three types, including 1). Feasibility test using a questionnaire sheet, 2). Practicality test using observation sheets and questionnaires, and 3). Effectiveness test using creative thinking skills questions on renewable energy material. Research data related to the effectiveness test in the form of pre-test and post-test were analyzed using the N-gain test. Based on the data analysis, the results obtained include 1). The results of the validation of the learning devices with an average percentage value of 79% (high), 2). The results of the physics teacher's response regarding the practicality of the learning devices obtained a percentage of 83% (very practical), and 3). The results of the effectiveness test using the N-gain test showed that there was an increase in students' creative thinking skills on the renewable energy material taught using the project-based learning (PjBL) model learning device. So it can be concluded that the use of project-based learning models can improve students' creative thinking skills in studying material about renewable energy.

Keywords: Creative thinking skills; Project based learning (PjBL); Renewable energy; Research and development (R&D)

Introduction

In facing global challenges, especially in the world of education, it is very important to prepare the golden generation of the future, which is not only focused on cognitive abilities but also skills and includes challenges related to environmental sustainability (Santika, 2021). The role of educators is expected to invite students to know the values of development perspectives and how sustainable development exists in Indonesia. Science is one of the learning contexts found in secondary schools and must be understood by students (Rizaldi et al., 2019). Teachers have a critical role, one of which is that teachers act as facilitators by creating a conducive learning atmosphere, in harmony with student development, so that teaching and learning interactions can take place effectively and optimally (Fauzi & Mustika, 2022). Active learning is a learning requirement that must be created by teachers, especially when the learning process occurs in the classroom. This is certain to increase the percentage of learning objectives achieved and provide an impressive meaning to

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students (Yu et al., 2022). Teachers have a responsibility to create a fun and valuable learning environment so that students do not feel bored. In Law No. 20 Article 40 paragraph 2 it is stated *that "teachers and education personnel are required to build a meaningful, exciting, creative, dynamic, and dialogical educational atmosphere"*(Iwani, 2022).

Learning is considered fun if it can attract students' interest. On the other hand, if learning is not fun, the class will feel boring and the delivery of the material will be uninteresting, which can lead to a decrease in students' learning motivation (Van et al., 2023). There are many ways that teachers can do to be able to create a pleasant learning condition for students. The selection and use of learning models are initial alternatives that can be applied by teachers to create a pleasant and meaningful learning condition for students (González-Pérez & Ramírez-Montoya, 2022; Mokhtar et al., 2023). One of the learning models that can be used in the science learning process is by implementing a project-based learning model (PjBL) (Hairunisa et al., 2019; Iswantari, 2021). This learning is able to integrate the principles of sustainable learning and prepare students with problem-solving skills such as critical and creative thinking, as well as awareness of the importance of maintaining environmental, social, and economic balance.

Learning that focuses on PJBL emphasizes the steps of information transmission, attitude change, and behavioral change because this learning does not only focus on the classroom environment but can also be applied in independent learning at home (Rizaldi et al., 2022). Sustainable development education produces knowledge through critical action and reflection, policy change, and implementation practices. Sustainable development education will produce active and critical citizens (Shohel & Howes, 2011). By developing learning tools using the PjBL model, students will not only learn about the concept of renewable energy but also be able to think creatively in planning and finding innovative solutions related to a topic to be studied, especially those related to the use of environmentally friendly energy. Creativity is the ability to solve problems that involve cognitive and affective characteristics. Affective aspects include daring to take risks, feeling challenges, curiosity, imagination, and intuition, and cognitive aspects include fluency, flexibility, originality, and elaboration (Putri & Alberida, 2022).

The project-based learning model is one of the cooperative learning models that is a recommended learning model to be applied to all subjects, one of which is physics. Physics is a process and product (Jalil & Shobrun, 2023). Process means the procedure for finding physics products (facts, concepts, principles, theories, or laws), which is carried out through scientific steps (Hanna et al., 2016; Widarti, Khoiri, & Roshayanti, 2023). Physics learning that has been discovered by researchers to date is mostly only conventional, theoretical, and informative, resulting in a lack of provision and training for students to improve skills, values, and attitudes that reflect concern and responsibility for the environment, so that learning objectives cannot be achieved optimally. According to research conducted by Muliani et al. (2021), using a project-based learning model can have a positive influence on students' cognitive, affective and psychomotor learning outcomes in Static Fluid material. In addition, other research has shown that the application of project-based learning has been proven to be able to improve students' creative thinking and collaboration skills during the physics learning process in class (Yanti et al., 2023).

Science and technology learning has contributed to improving students' understanding of the environment at SMAN 1 Semarang. However, the challenge faced is the lack of learning tools integrated with the Project-Based Learning (PjBL) model. Learning tools still tend to master theory, while aspects of creative thinking skills, problem solving, and practical application are still very lacking to be applied in daily learning at school.

Based on the results of observational research on creative thinking skills on renewable energy material conducted at SMAN 1 Semarang using a sample of 20 students, data on creative thinking skills were obtained, which were still low. This renewable energy material is one of the relevant topics in physics learning. Given the importance of using renewable energy in dealing with the global energy crisis and climate change. The material is very much in sync with the application in everyday life because of environmental sustainability. However, in reality, learning about renewable energy is often delivered theoretically and is less able to develop students' creative thinking skills.

To develop critical and creative thinking of students towards sustainable life related to the availability of energy sources for the present and the future, the suggestion given is that schools are expected to be able to introduce students to meaningful learning by involving the students' surroundings. Based on the initial analysis, it is necessary to develop learning tools that not only enrich students' knowledge but also train them to think creatively and innovatively. Through project-based learning, students are expected to be able to connect the concept of renewable energy with sustainability issues that are currently important issues in everyday life so that they have a holistic understanding and skills that are relevant for the future.

Therefore, this study aims to develop learning devices with a project-based learning model on renewable energy material, which is expected to

improve the creative thinking skills of students of SMAN 1 Semarang. This development is expected to be a real step in supporting sustainable education efforts and creating a young generation who care about environmental problems. This study also tests the effectiveness of the device in improving students' creative thinking skills so that it can become an innovative and relevant learning model for future challenges.

Method

This study uses research and development (R&D) and is equipped with a quasi-experimental design to test the effectiveness of the developed learning devices. This approach was chosen because it aims to produce a product, namely a learning device oriented to the Project-Based Learning Model (PjBL) related to the material "Renewable Energy," which can improve creative thinking skills. The type of development research used is the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation), which consists of five main stages that are interconnected (Almomen et al., 2016; Spatioti et al., 2022). The ADDIE model can develop more systematic and structured learning device development.

This research was conducted at SMAN 1 Semarang which has implemented the Merdeka Curriculum since 2022. The selection of this school was based on the availability of supporting facilities for the trial of the developed learning devices, as well as student characteristics that were in accordance with the targets of this research. In this study, three tests were conducted to determine the feasibility, practicality, and effectiveness of learning devices with the project-based learning model (PjBL).

The subjects used in this study were a physics teacher and 68 grade 10 students who were divided into two groups (experimental 34 students and control 34 students). While the objects in this study were the feasibility, practicality, and effectiveness of learning devices with project-based learning models (PjBL) SMAN 1 Semarang.

The instruments used in this study are divided into three types, namely 1) testing the feasibility of learning devices with questionnaire sheet, 2) testing the practicality of learning devices with observation sheets and questionnaires, and 3) testing the effectiveness of learning devices by giving tests in the form of pre-test and post-test creative thinking skills questions to obtain N-gain values. The feasibility and practicality test data were obtained using the following equations:

$$\% \text{ Validity} = \frac{sum\ of\ scores\ from\ assessors}{maximum\ score} \times 100\% \quad (1)$$

The validation level of learning device instruments is determined based on the criteria in the following table.

Table 1. Validity Criteria for Learning Tools (Arikunto, 2013)

Validity % Value Range	Validity Level
0–20	Very Low
21–40	Low
41–60	Quite Low
61–80	High
81–100	Very high

The practicality test of the learning device was carried out using a questionnaire on the implementation of learning in the classroom and analyzed using the following equation.

$$\text{Score} = \frac{percentage\ amount\ of\ the\ assessor}{number\ of\ assessors} \text{x } 100\% \quad (2)$$

After being analyzed, data interpretation will then be carried out based on practicality criteria by referring to the following table.

Table 2. Criteria for Practicality of Learning Tools (Arikunto, 2013)

Value Range	Level of Practicality
0-20	Very impractical
21-40	Less practical
41-60	Quite practical
61-80	Practical
81-100	Very practical

The last test conducted was the effectiveness test of the learning device of the project-based learning model (PjBL) of SMAN 1 Semarang. This test was conducted using pre-test and post-test data from students in the experimental and control classes, then analyzed to obtain the N-gain value so that the increase in creative thinking skills in each treatment class could be compared.

Table 3. Research Design Plan for Effectiveness Test

Group	Initial conditions	Treatment	Final condition
Experiment	Pretest	Learning with the PjBL Model	Postest
Control	Pretest	Conventional learning	Postest

The data analysis technique in this effectiveness test includes an instrument test consisting of administering pretest and posttest treatments between the experimental and control groups to obtain an N-Gain value to measure the effectiveness of the treatment by looking at the increase from pretest to posttest.

$$\text{N-Gain} = \frac{Skor\ Posttest - Skor\ Pretest}{Skor\ maksimal - Skor\ Pretest} \quad (3)$$

The N-gain values obtained are then interpreted according to the categories in the following table.

Table 4. N-gain Categories (Irhamna et al., 2017)

Score Value	Category
(g) < 0.30	Low
0.7> (g) < 0.3	Currently
(g) > 0.7	High

The flowchart of this research can be seen in the following image.

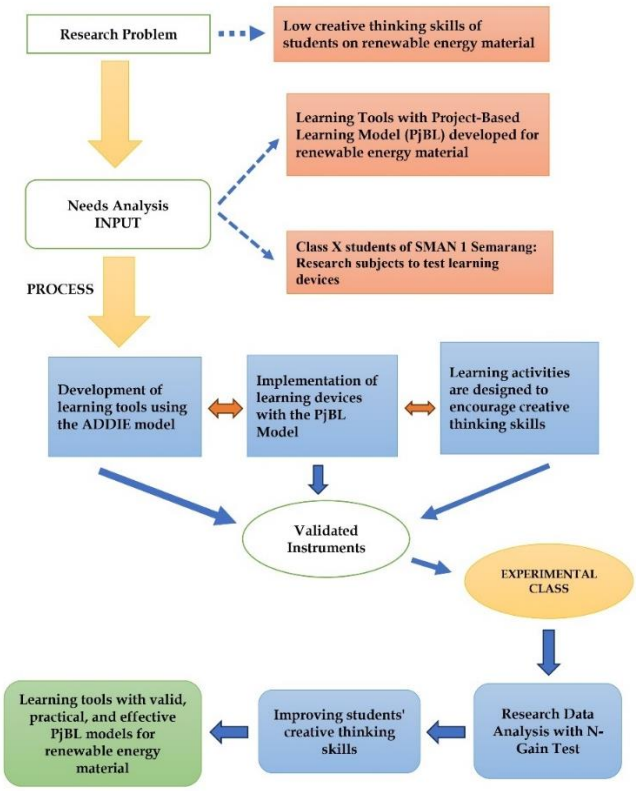

Figure 1. Research flowchart

Result and Discussion

Feasibility Test Results

The learning devices developed in this study consist of Learning Objective Analysis (*Analisis Tujuan Pembelajaran, ATP*), Teaching Modules, Student Worksheets (*Lembar Kerja Peserta Didik, LKPD*), and Creative Thinking Skills Questions. The summary of the results of the learning device validation test can be seen in the table 5.

Based on Table 5, it is known that all learning devices developed in this study are classified into the high category in the aspects of teaching modules and creative thinking skills questions, while the very high category is in the ATP and LKPD aspects. If referring to the average percentage, a value of 79% is obtained with a high category. So it can be concluded that the learning devices developed in this study can certainly be used and applied in supporting the physics learning process on renewable energy material in the classroom. With the existence of learning devices that have gone through this validation process, it certainly increases the opportunity to achieve the learning objectives that are planned by researchers and teachers at the beginning of learning (Azis & Asih, 2022).

Table 5. Summary of Results of the Learning Device Feasibility Test

Assessment Aspects	Percentage	Category
ATP	80%	Very high
Teaching Modules	76%	High
LKPD	82%	Very high
Creative Thinking Skills Questions	79%	High
Average	79%	High

It is very important for teachers to prepare learning tools before carrying out the learning process in class (Wati, 2020). This is supported by the statement put forward by Anggraeni et al. (2022) that learning devices are an important guide for a teacher or educator in implementing good learning in class, laboratory, or outside the classroom. Referring to various previous studies regarding the importance of an instrument must be valid, of course, to minimize errors in data obtained during field research (Pugu et al., 2024). Of course, by anticipating this, it is able to provide research results that are in accordance with the initial objectives of the research. Therefore, in order to create good and proper learning tools, expert validation needs to be carried out (Zahroh & Sudira, 2014).

Practicality Test Results

The practicality level of this teacher can be one of the references that illustrates that the product in the form of learning devices can be used in the teaching and learning process at school. The process of assessing the level of practicality in this study consists of four aspects of Learning Objective Analysis (*Analisis Tujuan Pembelajaran, ATP*), Teaching Modules, Student Worksheets (*Lembar Kerja Peserta Didik, LKPD*), and Creative Thinking Skills Questions. The results of the product practicality test in this study can be seen in the table 6.

Based on Table 6, it is known that the practicality of the product developed by the researcher is generally included in the very practical category, where this is supported by the average assessment results carried out by physics subject teachers with a percentage value of 83%. Based on all aspects of the product that have been

assessed, it can be seen that the research instrument in the form of a teaching module obtained the smallest percentage compared to other products, namely with a value of 78%. Of course, this is an evaluation by the researcher in order to maximize the development process again in the future related to several devices that may still be revised and developed.

Table 6. Results of the Practicality Test of Learning Devices

Assessment Aspects	Percentage	Category
ATP	82%	Very Practical
Teaching Modules	78%	Practical
LKPD	85%	Very Practical
Creative Thinking Skills Questions	87%	Very Practical
Average	83%	Very Practical

If a learning device can be used anywhere and anytime without time and circumstances, then the learning device can be considered practical (Diani, 2015). In addition, the learning material is very easy to use by teachers and students during the learning process at school.

Effectiveness Test Results

Creative thinking skills data is used to describe the abilities of participants after following the learning process using Learning Devices with the Project-Based Learning Model (PjBL). Creative thinking skills observed in this study consist of four indicators, namely fluency, flexibility, originality, and elaboration. The data was obtained from the results of giving questions totaling 5 descriptive questions. The results of students' creative thinking skills can be seen in the following table.

Table 7. Results of the N-gain Test of Creative Thinking Skills of Experimental Class Students

Test	Creative Thinking Skills Indicators			
	1	2	3	4
Pre Test	54.00	48.00	50.00	53.00
Post Test	84.00	78.00	75.00	76.00
N-gain	0.65	0.69	0.50	0.49
Category	Currently	Currently	Currently	Currently

Table 8. Results of the N-gain Test of Creative Thinking Skills of Control Class Students

Test	Creative Thinking Skills Indicators			
	1	2	3	4
Pre Test	50.00	52.00	48.00	56.00
Post Test	74.00	71.00	68.00	72.00
N-gain	0.48	0.39	0.38	0.36
Category	Currently	Currently	Currently	Currently

Information
Indicator 1 : Fluency
Indicator 2 : Flexibility
Indicator 3 : Originality
Indicator 4 : Elaboration

The following is a comparative diagram of the increase in the results of students' creative thinking skills tests after using learning devices with the project-based learning (PjBL) model on renewable energy material as follows.

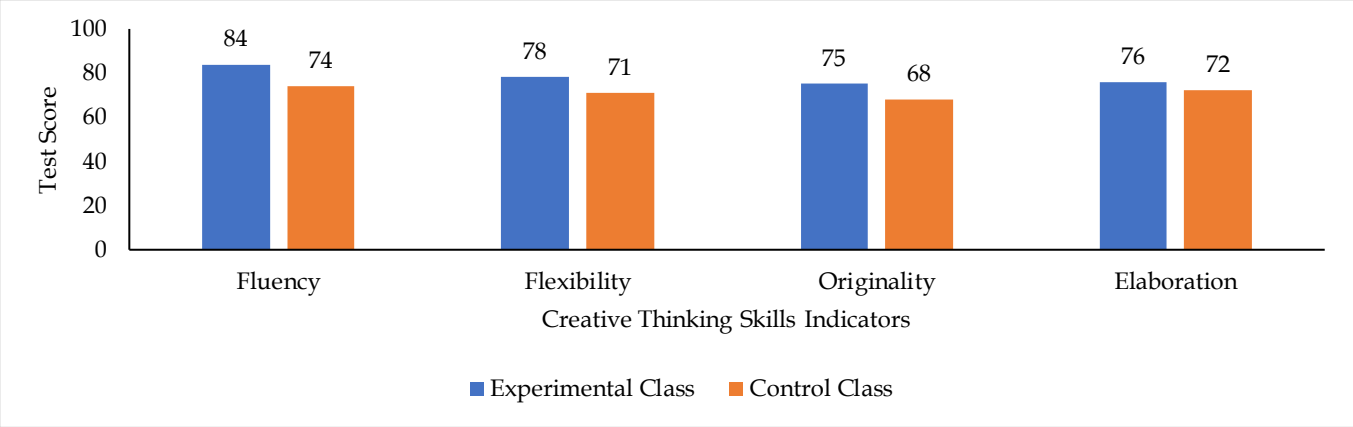

Figure 2. Comparison of final scores of students' creative thinking skills on renewable energy material

Based on Figure 2, it can be seen that the final test results in the experimental class gave higher scores in all indicators of creative thinking skills compared to the class taught with conventional learning. Based on these data, it is known that the fluency indicator is the indicator with the highest score in both classes, while the elaboration indicator is the indicator with the lowest post-test score. This indicates that the elaboration indicator still has a certain level of difficulty for students. Elaboration is the ability to develop an idea by adding details or enriching the idea (Rosita & Muflihah, 2024).

Elaboration shows the level of depth and richness of a person's ideas in solving problems. So this indicator is one of the highest indicators that must be achieved in

improving students' creative thinking skills. To accustom students to having good elaboration skills, learning should often facilitate students to solve a problem so that indirectly students are required to be able to find various alternative solutions in solving problems (Arisanti et al., 2017). Project-based learning has various learning stages that facilitate students to learn independently and develop various opinions related to the topic of the material being studied (Jalil & Shobrun, 2023; Munawaroh & Christijanti, 2013).

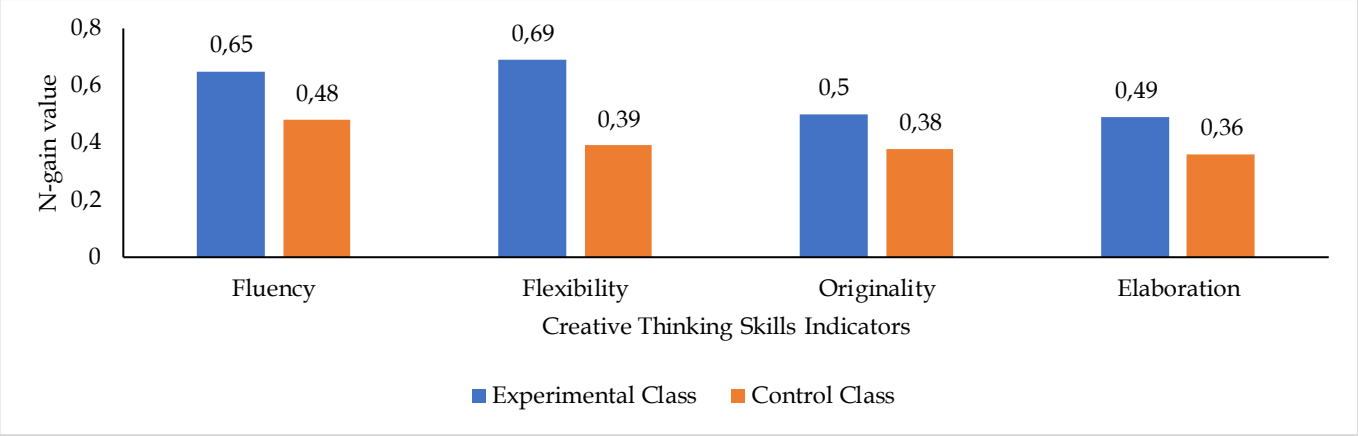

Figure 3. Comparison of n-gain values of creative thinking skills on renewable energy material

If referring to the improvement of students' creative thinking skills in the learning process of renewable energy material, it can be observed by looking at the results of the N-gain analysis in both treatment classes. The N-Gain test is a method commonly used to measure the effectiveness of learning or intervention in improving student learning outcomes (Sukarelawan et al., 2024). This method provides a strong basis for evaluating the extent to which a learning program has contributed to students' understanding and provides teachers with in-depth insight into the effectiveness of a particular curriculum or teaching method (Taali et al., 2024). The results can quantitatively describe the extent to which students have mastered the subject matter being taught.

Based on Figure 3, it can be seen that the increase in students' creative thinking skills in the experimental class taught with the project-based learning model learning device gave a higher value compared to students taught with the conventional learning model. This difference certainly indicates that the project-based learning model provides a greater opportunity to improve each indicator of students' creative thinking skills. This increase can occur, of course, because the learning steps contained in the project-based learning model are able to maximize every potential in students. By getting students used to learning independently through projects, students are required to be more skilled in analyzing and seeking information related to problems through a good literacy process. Cultivating creative thinking skills is very important in the world of education, because with creative thinking skills, students will be able to make the right decisions in a problem (Umamah & Andi, 2019).

Project-based learning models provide students with experience in learning and practicing organizing projects, providing learning experiences that involve students in a complex way and are designed to develop in the real world, making the learning atmosphere fun (Hikmah & Agustin, 2018). The project-based learning model emphasizes maximum student activity to search for and find (Miftah et al., 2024). In other words, students act as learning subjects. So that the project-based learning model is not only limited to listening activities but also directly involved in expressing and doing activities (Putri & Zulyusri, 2022). This is in contrast to the conventional learning model, where students act as learning objects, meaning that student activities are limited to listening and receiving information provided by the teacher, without being developed and studied in detail by the students.

Learning activities that apply creative thinking skills can produce something new, either in the form of ideas or real work (Suryanto et al., 2021). This can also apply 21st-century skills, namely learning and innovation (Sukmawijaya et al., 2019). So this skill is very suitable if developed using student-centered learning models, and one of them that has been proven to be successful is by using a project-based learning model (Artama et al., 2023).

Learning is considered enjoyable when it captures the interest of the students. Conversely, if the learning experience is not enjoyable, the classroom atmosphere becomes dull, and the delivery of the material is tedious, which can diminish students' motivation to learn (Makkonen et al., 2021). Thus, it is essential to possess both critical and creative thinking abilities during the cognitive process. The use of Project-based Learning

(PjBL) in physics education has a marked effect on the critical thinking abilities of students (Hikmah et al., 2023). Implementing PjBL in the study of physics allows students to engage more actively in their education and enhances their critical thinking, leading to improved cognitive skills (Khoiri et al., 2023; Nisah et al., 2024). Besides fostering critical thinking, PjBL in physics instruction also enhances students' creative thinking skills. These creative thinking abilities assist students in addressing the challenges they encounter in their physics studies (Wulandari et al., 2024; Zulyusri et al., 2023).

Conclusion

The product in the form of learning devices with a project-based learning (PjBL) model on the renewable energy material was successfully developed using the ADDIE development model consisting of objective analysis instruments (*analisis tujuan pembelajaran*, ATP), teaching modules, student worksheets (*lembar kerja siswa didik,* LKPD), and creative thinking skills questions. The results of the validation of the learning devices with an average percentage value of 79% (high). The results of the physics teacher's response regarding the practicality of the learning devices obtained a percentage of 83% (very practical). The results of the effectiveness test using the N-gain test showed that there was an increase in students' creative thinking skills on the renewable energy material taught using the project-based learning (PjBL) model learning device.

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Conflicts of Interest
The authors declare no conflict of interest.

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