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Research Article

Alleviating Students' Naive Theory on Newton's Laws of Motion through Problem Optimization and Scaffolding Discussion

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The purpose of this study is to find out what types of problems and scaffolding should be set in problem-based learning to alleviate students' naive theories. This study employed a sample of three classes with a problem-based learning process using three variations of problems and scaffolding. The findings suggested that there were significant differences among the three groups of students. The highest reduction in students' naive theories occurred in classes that used open problems equipped with discussion scaffolding. Based on the interpretation of the video results of student discussions and the average posttest class using open problems equipped with discussion scaffolding, students' naive theories were mostly reduced. Problems in problem-based learning are open-ended, which encourage students to use their naive theories to solve problems. With the scaffolding that has been designed, students' character grows as scientists. Based on the interview results, the class that used closed problems equipped with scaffolding tended to use their notes while in high school, which he was not clear about, except for doing exam questions. However, in a classroom that uses open problems equipped with discussion scaffolding and in classes that use open problems without discussion scaffolding, it is stated that students like to solve problems in their real lives. Thus, open problems in problem-based learning are the key to successful learning, whereas discussion scaffolding strengthens the implementation of these open problems.

1. Introduction

Newton's laws of motion are the central idea in mechanics and form the conceptual foundation of nearly all other physics topics [1, 2]. However, research in physics education revealed many students' naive theory or misconception even after the instruction of Newton's laws. By naive theory, we mean a belief or knowledge that students develop from their interaction with nature without sufficient abstraction. Students' naive theory is usually only true in a very specific context, but student tends to use it in a wider context. As a result, students' naive theory is often contradicted with scientific knowledge. Because the naive theory was built from a long-time effort and consistent with experiences (according to the student), the theory tends to be difficult to change and will interfere with the scientific knowledge being studied. Therefore, remediating students' naive theory needs to be a concern in physics instruction. It needs to note that students' naive theory has been given several terms in literature, including preconception, alternative conception, naive belief, or misconception [3]. In this paper, we use the term naive theory, but acknowledge others that have a preference for other terms.

An example of students' naive theory related to Newton's first law is that any object's natural state of motion is at rest [4], not including moving with constant velocity as stated by the first law. The theory is constructed based on daily experiences that if an object is initially at rest, it remains at rest, and if it is in moving first, it always slows down and gets rest again [5]. Students with this theory will develop another naive theory such as "no object moves continuously at a constant speed without a constant force pushing it [5]," and “if we want to move an object, we need to puss it with a constant force [4–6].”

An example of a students’ naive theory regarding Newton’s second law is that a constant force produces a constant velocity [7–10], not a constant acceleration. This belief is constructed based on student experiences with moving objects, which show that a constant force is needed to keep any object moving at a constant speed. For example, to keep a car moving at a higher constant speed on the highway, the driver must push the gas pedal harder than that for a lower speed, but with a relatively constant pushing [11]. Most students with this naive theory do not believe that all falling objects have the same acceleration [9, 11].

An example of students’ naive theory related to Newton’s third law is that the forces exerted by two interacting objects do not always equal in magnitude, but depend on other factors, such as mass, speed, and state of motion of the objects [12]. For example, if the two interacting objects have different masses, the more massive object must exert more force than the less massive one [8, 13]; if the two interacting objects have different speeds then the object with higher speed will exert greater force [8, 14, 15]; when one object pushes another object, the pushing object must exert more force than the object being pushed [16]. Students with this naive theory will argue that, in the war-tug game, the winner must be the more powerful person [17].

Most research on students’ naive theory of Newton’s laws of motion is more focused on the identification and/or understanding of the existence of the naive theory. Studies on how to remediate or change student naive theory into more scientific theory still less attention. This paper is intended to fill the gap, namely, trying to overcome the naive theory by applying problem-based learning (PBL), which is one of the learning approaches that are currently widely applied in science education [18–20].

The most crucial aspect of the PBL is the problem that students need to solve. The problem should be open, ill-structured, complex, real-world problem and could serve the basis for developing knowledge and problem-solving skills [18, 21–25]. Another important aspect of the PBL is scaffolding to help the student solve the problem meaningfully [26–35]. By providing the appropriate problems and scaffolding, the students’ naïve theory on Newton’s law theory might be restructured to become more coherent-scientific theory. The purpose of the study is to find out how much alleviating students’ naive theory on Newton’s laws of motion through problem optimization and scaffolding discussion.

In an effort to find out the combination of problems and scaffolding in PBL, three models were tested. The first group studied Newton’s law with PBL, using open problems equipped with scaffolding (Y_1). The second group studied Newton’s law with PBL, using open problems without scaffolding (Y_2). The third group studied Newton’s law with PBL, using closed problems equipped with scaffolding (Y_3). The best model describes its effectiveness in alleviating the students’ naive theory on Newton’s laws.

2. Method

2.1. Research Design. This research procedure was conducted using a mixed-methods concurrent triangulation design. Quantitative and qualitative methods are used together and are balanced [36–39]. To find out the best strategy, quantitative data analysis was needed while to explore students’ naive theory, qualitative data analysis was needed. Mixed methods can contribute new insights about the wide range of topics, populations, settings, and contexts of interest to the field. Further, researchers can continue to expand the kinds of integrated knowledge that is sought using mixed methods [40]. The quantitative method was used to determine the difference in the average understanding of concepts between students taught with PBL using open problems equipped with scaffolding, PBL using open problems without scaffolding, and PBL using closed problems equipped with scaffolding followed by *t*-test to see differences between classes. The qualitative method was used to analyze the reasons for each answer and to analyze the results of interviews, to get students’ epistemic games. The results of the quantitative and qualitative methods are used together and in a balanced manner to determine the percentage of degradation of Newton’s law of naive theory by application of three PBL models and percentage of Newton’s law of naive theory that survives in students’ brain construction after three PBL models are applied. This study was conducted on a group of students using six experimental classes without a control class. This stage was a qualitative integrated quantitative study divided into three groups of students. The first group studied Newton’s law with PBL, using open problems equipped with scaffolding (Y_1). The second group studied Newton’s law with PBL, using open problems without scaffolding (Y_2). The third group studied Newton’s law with PBL, using closed problems equipped with scaffolding (Y_3). In the early stages of the research, students were given a pretest in the form of a force concept inventory (FCI) [41] 30 items that have been validated and have been field-tested. This was used to determine how much the students’ initial naive theory of Newton’s law material before receiving treatment. At this stage, interviews were conducted to confirm the students naive theory. The second stage is learning implementation. During learning, students were treated with PBL, which is equipped with computer-based scaffolding in Newton’s law of learning. During learning, students were given problems that were solved in groups on student worksheets to determine their understanding, after which they were discussed together. In the third stage, students were given FCI questions as a posttest in the form of multiple-choice questions and interviews.

The quantitative and qualitative data were then reanalyzed using meta-analysis so that the data groups could be grouped, differentiated, and searched for correlation relationships between one data and other data so that the data can be categorized as data groups that strengthen, weaken, or contradict each other [42, 43]. The interview instrument was arranged based on the results of the cross-tabulation tests. Interviews were directed at exploring the students’ mindsets regarding the answers they chose. This interview stage was used to analyze why students are still in their naive theory or to ensure that students' naive theory has turned into a correct theory.

2.2. Instruments and Data Analysis. The treatment instrument used in this study was the semester lesson plan for basic physics courses. The quantitative and qualitative measurement instruments used in this research were the FCI [41] and interview guidelines. During the discussion process, the observer was equipped with an interview instrument with scaffolding status. Thus, the nature of the instrument is open, meaning that it can change depending on the student's discussion situation. The scaffolding applied to help students erode their naive theory is composite scaffolding. Both quantitative and qualitative data were collected in this study. The data were collected through observations, tests, and interviews.

The three groups were tested for differences using the ANOVA statistics [44]. From the results of the ANOVA statistics, the variables Ho and Ha were obtained. Ho: there is no difference in the average understanding of concepts among students who are taught PBL with open problems equipped with scaffolding, PBL with open problems without scaffolding, and PBL with closed problems equipped with scaffolding. Ha: there is a difference in the average understanding of concepts among students who are taught PBL with open problems equipped with scaffolding, PBL with open problems without scaffolding, and PBL with closed problems equipped with scaffolding.

The criteria for accepting or rejecting Ho are as follows:

(1) Ho is rejected, if Sig. < 0.05
(2) Ho is accepted, if Sig. > 0.05

Each Newton's law was represented by one question, and the answer shift was analyzed and evaluated to obtain recommendations related to applied learning.

The qualitative data obtained in this study were simplified. Data reduction was carried out by the researchers so that the data analyzed were truly accurate and relevant. The results of the qualitative data analysis were interpreted in detail in the form of students' naive conceptions of Newton's law material. From the results of the analysis of quantitative data obtained from the pretest and posttest analyses of students, several questions were taken from questions that had been considered to be indicators of students' naive conceptions and separated into one question each for Newton's first law, Newton's second law, and Newton's third law. All data were feasible and approved by the ethics committee with a certificate number: KEPK/046/ STIKes-HPZH/ VI/ 2021.

3. Results and Discussion

3.1. Results. This research procedure was conducted using concurrent mixed methods. A summary of the results of the hypothesis testing for the difference between the three experimental classes is presented in Table 1. Based on the results of the testing, the hypothesis obtained a significance of 0.000 < 0.05, or Ho was rejected. This shows that there is a difference in the average understanding of concepts among students who are taught PBL with open problems equipped with scaffolding, PBL with open problems without scaffolding, and PBL with closed problems equipped with scaffolding.

Table 1: Summary of hypothesis testing results for concept understanding.

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	20,555.211	2	10,277.606	147.650	0.000
Within groups	13,295.128	191	69.608		
Total	33,850.340	193			

The statistical results of the *t*-test, which is a further test of the hypothesis testing of the difference between the three experimental classes with the *F*-test at significant ANOVA, are presented in Table 2. Based on the data in Table 2, there was no significant difference in the pretest scores between Y_1 and Y_3, Y_2 and Y_3, and Y_1 and Y_2, so it can be concluded that the initial abilities of the three observation classes were the same. Thus, the posttest data are the main data to be analyzed in the next stage.

Further hypothesis testing with *t*-test statistics on the posttest data is presented in Table 3. Based on Table 3, the mean of $Y_1 = 75.3$ and $Y_3 = 50.0$ are the largest and smallest posttest scores obtained by students, respectively. It can be concluded that students' understanding of concepts will increase if they receive material through PBL with a mixture of open problems and scaffolding.

3.1.1. Elimination of Conceptual Errors Related to Conceptual Errors in Newton's First Law. Further analysis related to the degradation of students' conceptual errors toward understanding Newton's first law was conducted in the process of testing the effectiveness of students' pre- and post-test answer options for all learning methods with the case example of "Two metal balls of the same size but one weighing twice the weight of the other, rolling off the table horizontally at the same speed." The distribution of the answer options is presented in Table 4.

Based on Table 4, it appears that students are challenged to jack up their understanding of the error that "the heavier ball hits the floor about half the horizontal distance from the table base than the lighter ball." Likewise, the misconception is that "a lighter ball hits the floor about half the horizontal distance from the table mat than a heavier ball." The heavier ball hits the floor closer to the bottom of the table than the lighter ball, but not necessarily half the horizontal distance. It is challenging for students to avoid the misconception that heavier objects must hit the floor closer. There were still 20 students (37.0%) who did not understand that when an object was released from the table, in the horizontal direction, the object was relatively unaffected by a force, so that the object would return to its natural state, namely, moving at a constant speed. In the vertical direction, both objects have the same gravitational field strength of about 9.8 N/kg

Table 2: Results of advanced hypothesis testing with t-test statistics pretest data.

Class	Average	Sig.	Conclusion
$Y_1 - Y_3$	$Y_1 = 29.7$ $Y_3 = 28.6$	0.376	There is no significant difference between students' understanding of concepts taught by PBL with open problems equipped with scaffolding and understanding of students' concepts taught by PBL with closed problems equipped with scaffolding.
$Y_2 - Y_3$	$Y_2 = 29.3$ $Y_3 = 28.6$	0.684	There is no significant difference between the understanding of students' concepts taught by PBL with open problems without scaffolding and understanding of students' concepts taught by PBL with closed problems equipped with scaffolding.
$Y_1 - Y_2$	$Y_1 = 29.7$ $Y_2 = 29.3$	0.744	There is no significant difference between students' understanding of concepts taught with PBL with open problems equipped with scaffolding on understanding concepts of students taught with PBL with open problems without scaffolding.

Table 3: Results of advanced hypothesis testing with t-test statistics posttest data.

Class	Average	Sig.	Conclusion
$Y_1 - Y_3$	$Y_1 = 75.3$ $Y_3 = 50.0$	0.000	There is a significant difference between students' understanding of concepts taught by PBL with open problems equipped with scaffolding and understanding of students' concepts taught by PBL with closed problems equipped with scaffolding. Based on the mean score, students' conceptual understanding taught with PBL with open problems equipped with scaffolding was higher than the conceptual understanding of students taught with PBL with closed problems equipped with scaffolding.
$Y_2 - Y_3$	$Y_2 = 65.2$ $Y_3 = 50.0$	0.000	There is a significant difference between students' understanding of concepts taught by PBL with open problems without scaffolding and understanding of students' concepts taught by PBL with closed problems equipped with scaffolding. Based on the mean score, students' conceptual understanding taught with PBL with open problems without scaffolding was higher than students taught with PBL with closed problems equipped with scaffolding.
$Y_1 - Y_2$	$Y_1 = 75.3$ $Y_2 = 65.2$	0.000	There is a significant difference between students' understanding of concepts taught with PBL with open problems equipped with scaffolding and understanding of students' concepts taught with PBL with open problems without scaffolding. Based on the mean score, students' understanding of concepts taught with PBL with open problems equipped with scaffolding was higher than students taught with PBL with open problems without scaffolding.

Table 4: Distribution of pretest–posttest answer options for question number 2 class Y_3.

			Posttest							
			A*	B	C	D	E	X	A**	Total
			63.0%	13.0%	9.3%	7.4%	5.6%	1.9%	0.0%	
Pretest	A*	27.8%	14				1			15
	B	11.1%	1	5						6
	C	16.7%	5		4					9
	D	14.8%	4			4				8
	E	18.5%	7	1			2			10
	X	7.4%	2	1				1		4
	A**	3.7%	1		1					2
Total			34	7	5	4	3	1	0	54

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

or have the same acceleration of $9.8\,\mathrm{m/s^2}$. Because the two objects have a constant velocity in the horizontal direction and the same acceleration in the vertical direction, "both balls strike the floor at approximately the same horizontal distance from the base of the table." Sixteen students answered correctly during the pretest, with one student who did not have the right reason, and only 34 people answered correctly during the posttest (63.0%). Thirty students defended their original opinions, although 14 students defended the correct concept. The PBL learning model with closed problems accompanied by scaffolding was not only able to change the wrong understanding of 20 students

Table 5: Results of the interview of question number 2 to support wrong students' answers in postest.

Researcher	You are 20, there are 16 students whose answers are still wrong from pretest to posttest, there are 3 whose answers change but are still wrong, and there is 1 student who during the pretest answered correctly, but during the posttest answered wrong. I first asked the 16 students. Why do you stick with your wrong choices? Meanwhile, you have received PBL lessons.
Student 1	I'm a bit confused to apply the learning outcomes to case number 2, sir
Student 2	Looks like I didn't get the results or knowledge to solve problem number 2 sir
Student 3	I feel that the problems discussed in the lesson are easier than question number 2, sir
Student 4	Before being discussed in the next lesson, I can work on the problems shown
Other students	Like that sir
Researcher	Isn't it during the discussion that you are directed or guided by the lecturer? The guide or direction is to make it easier for you to get a way to solve problem number 2 and others?
Student 5	Right sir. I also feel that direction. Even that direction is in line with the learning stages, I no longer need it because I have mastered it
Student 6	The directions really built my line of thought, so that I was able to solve complex problems
Student 7	I also don't know sir, even though the directions are very good, but I still can't solve this number 2 problem
Student 8	I feel that the direction makes the problems raised at the beginning of the lesson very easy for me to solve
Student 9	As if there was an imbalance between the problems at the beginning of learning and his direction, Mr.
Student 10	Sorry sir, why should such a simple matter be given such detailed instructions
Student 11	when learning it seems very easy to follow the lesson, but once given the question number 2 I was not able to recall the knowledge that I gained during the lesson
Student 12	More precisely, maybe there is no knowledge of learning outcomes to solve problem number 2, sir
Other students	nodding
Researcher	Try it, Danu, just agreed. Why can't you answer correctly question number 2?
Student 13	I'm also confused sir. At that time, my seniors assessed my involvement in learning. My score is 4, sir. Maybe I'm stupid sir
Student 14	In my opinion, the lesson is not that bad, sir. I think it's good. The proof, there is another number that I can answer correctly
Student 5	I agree, Rara Pak, even if I don't get a lesson like that, I don't necessarily get a score of 43, because my score at the pre-test was 27
Researcher	You've tried Student 13, maybe it's his learning that needs to be evaluated. Come on Student 13, don't despair, keep the spirit. Don't worry about Ardi, it's only one component of the assessment. There are still 4 assessment components that your score is good. Ok, if you are Sari, I see that you have changed your choice but why are you still wrong? When the pre-test answered E, i.e., "the lighter ball hit the floor much closer to the bottom of the table than the heavier ball, but not necessarily half the horizontal distance" when the post-test changed to B, i.e., "the heavier ball hit the floor about half the horizontal distance from the base table than a lighter ball." His mindset is reversed. What is it?
Student 15	One of the problems used during learning at that time was the questions in the serway book. I just read about it, sir. The question is about gravity. The greater the gravity, the greater the acceleration. The gravity is the weight of the object, sir. Well, from that problem I was directed to answer question number 2. O, this means that the heavy object fell first
Student 16	I also think like that sir, why do I keep answering B both during pre-test and post-test
Researcher	If you are Student 17. Why did you answer correctly during the pre-test and then when the post-test turned into an incorrect answer E, namely "the lighter ball hits the floor much closer to the bottom of the table than the heavier ball, but not necessarily half the horizontal distance"
Student 17	If I knew my initial answer A was correct, then I wouldn't change it, sir
Researcher	Well, why did it change, Student 17? Think about what it's like to post-test
Student 17	At that time there was a problem at the beginning of the lesson in the form of a question about two boxes having different weights being pushed with the same force. What is the ratio of the time it takes to cover the same distance. The results of the discussion, light objects have a greater acceleration than heavier objects. Light objects reach their destination earlier than heavy objects. I applied that experience to question number 2, the result was E, sir
Researcher	Well, thank you, you have answered with enthusiasm

(37.0%) but also able to change the understanding of three students. Although it still led to incorrect understanding, it also changed the correct understanding of one student to the wrong understanding. Thus, 20 (34.0%) students still experienced naive theory.

Twenty students who were still experiencing naive theory were interviewed with the results in Table 5.

Based on the interview above, the scaffolding built by the lecturer does not seem to have any further impact because the questions are not complex or only have a single correct

Table 6: Distribution of pretest–posttest answer options for question number 2 class Y_2.

			Posttest							
			A* 73.3%	B 8.3%	C 5.0%	D 10.0%	E 3.3%	X 0.0%	A** 0.0%	Total
Pretest	A*	23.3%	10	3		1				14
	B	21.7%	11	1	1					13
	C	13.3%	7			1				8
	D	23.3%	8	1		3	2			14
	E	11.7%	6			1				7
	X	3.3%			2					2
	A**	3.3%	2							2
Total			44	5	3	6	2	0	0	60

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

answer [20, 45]. Scaffolding is useful if the problems involved in learning are complex or unstructured [19, 20, 46, 47]. Students stated that the problem at the beginning of learning did not provide knowledge on how to solve Problem 2. This means that the problem is not able to build the right mindset to solve Problem 2. A good problem is that it can provoke a high-level mindset [48]. PBL is learning that is supported by unstructured and open problems and is equipped with scaffolding at every stage of discussion [19, 26]. If problems at the beginning of PBL are not open or unstructured, PBL will not build students' higher-order thinking skills [49]. The skill to analyze a problem is a higher-order thinking skill [50]. If higher-order thinking skills are not developed, students will not be able to analyze new problems [51].

There is a question "Two metal balls of the same size but one weighing twice the weight of the other roll off a horizontal table at the same speed." In this situation, based on Table 6, it appears that the student is still difficult to jack up his misconception that "the heavier ball hits the floor about half the horizontal distance from the table mat than the lighter ball hits the floor." Likewise, the misconception of "a heavier ball hitting the floor is closer to the bottom of the table than a lighter ball, but not necessarily half the horizontal distance." It is very difficult for students to eliminate the misconception that heavier objects must hit the floor closer. Sixteen students (26.7%) still did not understand that when an object is released from the table, in a horizontal direction, the object is relatively unaffected by a force, so the object will return to its natural state, namely, moving at a constant speed. In the vertical direction, both objects have the same gravitational field strength of about 9.8 N/kg or the same acceleration of $9.8\ m/s^2$. Because the two objects have a constant velocity in the horizontal direction and the same acceleration in the vertical direction, "both balls strike the floor at approximately the same horizontal distance from the base of the table." Sixteen students answered correctly during the pretest, with two students who did not have the right reason, and only 44 answered correctly during the posttest (73.3%). Fourteen students defended their original opinions while 10 students defended the correct concept. The PBL model with open problems without scaffolding was not only able to change the wrong understanding of 34 students (56.7%) but also able to change the understanding of eight students. Although it still led to incorrect understanding, it also changed the correct understanding of four students to incorrect understanding. Thus, 16 (26.7%) students still experienced naive theories.

Sixteen students who were still experiencing naive theory were interviewed, with the following conclusions. Students feel that the problems that arise at the beginning of learning are difficult. The problems found are everyday problems that can be approached from all sides, producing different correct answers; however, the student worksheets given are very difficult to fill. Students conclude that the problem is difficult because that is an open problem that must be discussed in PBL [18–20]. From PBL elements of small-group learning [52], solution to problem [53], active learning [54], see the problem in context [55, 56], tutoring [57], write reflection [53], and use technology [58], students are stuck for a long time in the elements of small-group learning and problem solving. This occurred because the student worksheets provided was not accompanied by written scaffolding in the form of procedural and conceptual. In PBL, there are open or complex problems and directions are required to discuss these problems [19, 26, 59]. High-level thinking skills are required to solve open and unstructured problems [60, 61]. Meanwhile, students must have Vygotsky's zone of proximal development (ZPD) [62, 63]. If the problem is in the highest range in the student ZPD, then help is required to solve the problem [47]. Because the PBL problem is open, the problem will be in the highest area of student ZPD. As it requires a level of thinking in the top area of the student's ZPD, there must be scaffolding. Thus, it is natural for the results of the interviews to show that students find it difficult to solve problems. The process of solving a problem is needed to instill a student's mindset. The student's mindset was used to solve Problem 2. Based on the data in Table 6 and the results of the interviews, it can be concluded that PBL will be less successful if the problem is open and not accompanied by scaffolding in the discussion process [19, 20].

There is a question "Two metal balls of the same size but one weighing twice the weight of the other roll off a horizontal table at the same speed." In this situation, based on Table 7, it appears that there are still students who cannot be jacked up their misconception that "the heavier ball hits the floor about half the horizontal distance from the table

Table 7: Distribution of pretest–posttest answer options for question number 2 class Y_1.

			Posttest							
			A*	B	C	D	E	X	A**	Total
			87.5%	3.8%	2.5%	3.8%	2.5%	0.0%	0.0%	
Pretest	A*	16.3%	12			1				13
	B	16.3%	12		1					13
	C	17.5%	12	2						14
	D	16.3%	10		1					13
	E	13.8%	8	1		2				11
	X	3.8%	3							3
	A**	16.3%	13							13
Total			70	3	2	3	2	0	0	80

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

mat than the lighter ball hits the floor." Likewise, the misconception of "a heavier ball hitting the floor is closer to the bottom of the table than a lighter ball, but not necessarily half the horizontal distance." Some students still find it difficult to lift their misconceptions that heavier objects must hit the floor closer. There were still 10 students (12.50%) who did not understand that when an object was released from the table, in the horizontal direction, the object was relatively unaffected by a force, so that the object would return to its natural state, namely, moving at a constant speed. In the vertical direction, both objects are in the same gravitational field strength of about 9.8 N/kg or have the same acceleration of 9.8 m/s^2. Because the two objects have a constant velocity in the horizontal direction and the same acceleration in the vertical direction, "both balls strike the floor at approximately the same horizontal distance from the base of the table." There were 26 students who answered correctly during the pretest, 13 students who did not have the right reason and 70 answered correctly during the posttest (87.50%). Twelve students defended their original opinions, and all of them defended the correct concept. The PBL model with open problems accompanied by scaffolding was not only able to change the wrong understanding of 58 students (72.5%) but also able to change the understanding of four (5.00%) students, even though it still led to incorrect understanding and changed the correct understanding of one (1.25%) students lead to wrong understanding. There are no students who change their understanding, even though it still leads to an incorrect understanding. Thus, 10 (12.5%) students still experienced naive theory.

Of the 58 students who were able to change their incorrect understanding, 12 students changed their choice from incorrect answer option B to correct answer option A, 12 students changed their choice from incorrect answer option C to correct answer option A, 10 students changed their choice from wrong answer option B to correct answer option A, 8 students changed their choice from the wrong answer option D to the correct answer option A, 3 students did not answer and then changed their answer to the correct answer option A, and 13 students chose the correct answer option A, but did not give a reason or the reason was wrong, but when posttest still chose A by giving the correct reason. On average, 12 students who at the pretest chose the wrong answer option B had the reason that heavier objects will fall first than lighter objects depending on the ratio of their weight because the Coulomb force of heavier objects is greater than lighter objects. Twelve students were interviewed based on the results in Table 8.

Based on the interviews above, prior to the implementation of the lesson, their mindset was based on their daily experiences and mistakes in applying the knowledge they had previously acquired. Problem-solving strategies (epistemic games) are known as physical mechanism games. Students also use their knowledge of Newton's second law, but it is applied without regard to context, so that it becomes wrong. One of the parts of epistemic games that found by students is recursive plug-and-chug [64, 65]. Based on the above interview, the students stated that the change in mindset so that they chose the correct answer option, namely A, was caused by the direction they were discussing and the existence of open problems. Open problems lead students to build a mindset based on context [46] and foster the active role of students in stimulating curiosity [66]. In addition, the students also stated that their fluency in building a mindset was based on good scaffolding. Good scaffolding will help students overcome conceptual, metacognitive, and strategic challenges [67, 68].

There were 12 students who changed their choice from the wrong answer option C to the correct answer option A. On average, 12 students who during the pretest chose the wrong answer option C had the reason "the lighter object will fall first than the heavier object depending on the weight ratio, because if an object is subjected to the same force, then an object with a small mass will have a greater acceleration than an object with a large mass." Based on the interviews, 12 students were interviewed and the following results were obtained. The students used their daily experiences. If they push a light table, they will reach their destination quickly, whereas if they are heavier, they will take longer to reach their destination. If it weighs twice, the heavier object will reach its destination twice as long. Students use a physical mechanism game problem-solving strategy [65, 69, 70]. Students also use Newton's second law to analyze the problem. If the force is the same, the mass is inversely proportional to the acceleration. If the mass is large, then the

Table 8: Results of the interview of question number 2 to support wrong students' answers in pretest.

Researcher	At the time of the pretest you chose the answer option B with the average reason "heavier objects will fall first than lighter objects depending on the ratio of their weight, because the Coulomb force of heavier objects is greater than lighter objects." Is there any background why you give such reasons?
Student 18	Both objects leave the table with the same speed, while the effects of different forces cause different accelerations, so that the heavier object falls faster than the light object
Student 19	Yes sir, and because it weighs two times, the acceleration is also two times, so it's two times faster
Student 20	When I used to study Newton's Laws in high school, the force was proportional to the acceleration, sir. If the force is two times, the acceleration is also two times
Student 21	Since the acceleration is two times, the heavy object takes half the time for the light object
Student 22	Since the time is half, the horizontal distance is half
Student 23	Ditto with your friends, sir, but what I use as a basis is my experience, if an iron object for example, even though it's the same size as wood, the iron falls first
Student 24	Same with friends sir, the basis I use Newton's second law which states that the force is proportional to the acceleration. It's poop style, sir. So if the weight is two times, then the acceleration is also two times
Student 25 et al.	Ditto sir
Researcher	Ok, that's a good reason too. Fine, but after learning, you all change your answer to choose the correct answer option A. Please tell me in as much detail as possible, why did you change the answer option from B to A?
Student 18	The lesson begins by showing a video related to force proportional to acceleration. Next there is a video about the difference in the time of falling from iron and wood. That leads us to think that your answer is correct. After that, complex problems are presented and allow us to answer differently but still be correct if the assumptions are different
Student 21	At that time it was given the problem "there is a slip of mica plate on a very slippery surface." At that time there was a table with small holes, and air was blown from the holes, so that the plates seemed to float on the table without friction
Student 19	I believe the table is frictionless because when I touch the plate the slightest bit is already moving
Student 20	I continue Gunawan sir. The plate is moved to the right, then the problem is, if I push this plate up, how will the plate travel
Student 23	After that we discussed and tried to answer the problem by experiment
Student 22	During the discussion, we received assistance that was directed so that we answered the problem and did not lead to other goals
Student 25	After these discussions and experiments, I got the concept that, if there is no force, then the object will return to its original state, namely moving in a straight line
Student 24	In addition, I also get the fact that on the surface of the earth, and from the same height, then we are not talking about gravity, but talking about gravitational fields. Because the gravitational field strength of objects at the same height, then the acceleration of gravity is the same, finally we came to the conclusion, related to problem number 2 earlier, in the horizontal direction there is no force which means that both objects have the same GLB with the same speed, towards the bottom are the same at the same acceleration due to gravity, finally, the objects fall the same distance from the table
Student 26	At the end of the lesson, a video is also shown, although the objects are different, for example cotton and iron, if the room is vacuumed, the cotton and iron fall at the same time
Student 27	With us we also contract our cognition, with the fact that the 2 objects fall together at the same distance
Student 28	You've tried at first we didn't believe in Phet, but we were able to design if air friction is dominant, then the two objects fall at different distances, but if gradually the air friction force is reduced, the place where they fall horizontally becomes more equal, and when friction is made zero, So the place where the two objects fall is the same
Student 29 and others	Ditto sir
Researcher	Ok, now you Student 29, what happened during that learning
Student 29	First, I feel that I can understand the flow of thought that should be like during the discussion, secondly, the problems provided by you are able to build a mindset, so that it can be applied to other cases
Student 30	As before, sir, we are starting to be able to organize our discussion so that we come to the concept that, not the gravitational force, which is a problem variable, but the strength of the gravitational field, which we often call the acceleration of gravity
Student 26	We were able to follow your direction during the discussion until we were able to analyze the problem properly, and at that time I imagined that if later I had a problem, we used that pattern, and didn't need to be directed by anyone
Student 23	I agree with Student 22 Sir, the problem chosen will determine our success in changing our mindset. The problem is complex, it can be approached in different ways but produces different answers that are equally correct, but all of them still build our mindset, that in the case of question number 2, the first determining variable is the presence of One-Dimensional Motion with Constant velocity in the horizontal direction, and the acceleration the same gravity in the vertical direction
Researcher	Ok, you have answered well. If later the score of this course is on the border of less than 1 or two points, then I will without hesitation add it so that you get a higher grade score. Thank you

acceleration is small. Students start with physics equations and then develop conceptual stories known as mathematic to meaning mapping strategies [65]. However, their understanding was applied in a recursive plug-and-chug method to Problem 2 [71]. A ball that has twice the mass/weight will take twice as long to reach the ground because its acceleration is half that of a lighter ball. Based on the interviews, students were greatly assisted with scaffolding during discussions and open problems in student learning. Not only was it helped by scaffolding but also scaffolding awakened the mindset. When there are complex problems, students can use the scaffolding they created. Students no longer need direction or scaffolding during discussions because they have mastered the mindset that was carried out during the first discussion. Thus, because students no longer need direction in the next discussion, the direction given by the lecturer during the discussion is scaffolding [72, 73]. Open problems can shape students' mindsets, so they are not recursive plug-and-chugs but are always analyzed according to the context of the problem. Open problems in PBL can build a mindset to analyze complex everyday events [18, 60, 74].

There were 10 students who changed their choice from the wrong answer option D to the correct answer option A. On average, 10 students who during the pretest chose the wrong answer option D had the reason "the heavier ball hits the floor faster than the lighter ball, but because it has the same shape, the friction is the same; therefore, it does not have to be half the horizontal distance." Based on the interviews, 10 students were interviewed, and the following results were obtained: students apply their experiences in their daily lives. When the rubber and iron balls have the same volume, but the weight of the iron is two times, it turns out that the iron, which is heavier than the rubber, falls first, but the time difference is not too long. Students use a physical mechanism game problem-solving strategy [65, 69, 70]. Students also use Newton's second law to analyze the problem. The students also answered the free-body diagrams for each object. There is a downward gravitational force, an upward frictional force, and an upward Archimedes force. Students use pictorial analysis to solve strategies [65, 75]. From the simulation of the numbers entered, it turns out that the accelerations do not double each other. They forget that the objects are in a gravitational field. The equation used is the equation for the acceleration of gravity or the strength of a gravitational field with the same magnitude. Their understanding was applied in a recursive plug-and-chug method to Problem 2 [71]. Based on the interview, from the interview, there were five students who said "woo, that's the procedure for the discussion, then I don't need help anymore, I can do it." The comments stated that students began to absorb the direction of the lecturer as a pattern of learning and subsequently no longer needed the direction of the lecturer. Thus, because students no longer need direction in the next discussion, the direction given by the lecturer during the discussion is scaffolding [72, 73]. Open problems are able to bridge the students' thinking flow, so that the problem-solving strategy is not recursive plug-and-chug but always analyzed according to the context of the problem. Open problems in PBL can build a mindset to analyze complex everyday events [18, 60, 74].

There were eight students who changed their choice from the wrong answer option E to the correct answer option A. On average, eight students who during the pretest chose the wrong answer option E had the reason "the lighter ball hits the floor much faster to the bottom of the table than the heavier ball, but because the accelerations are different, it doesn't have to be half the horizontal distance." Based on the interviews, interviews were conducted with these eight students obtained the same results as the discussion above. Students initially used a physical mechanism game and recursive plug-and-chug problem-solving strategies. They also created a free-body diagram of an object subjected to the same force but with different masses, demonstrating a pictorial analysis problem-solving strategy [65, 75]. From the free-body diagram, students illustrated that a small mass would have a large acceleration. However, because there is still friction and Archimedes' force, the time it takes to fall from a smaller object is less than half the time it takes to fall from a larger object. Recursive plug-and-chug applies such student understanding to Problem 2 [71]. Students ignore the context; if they are in a gravitational field, then everything must obey the acceleration of gravity around $9.8\ m/s^2$. Based on the interviews, the students also went through a process similar to that of a student who originally answered D. In essence, the change in the answer to correct answer A was due to the scaffolding of discussions and open problems in PBL.

Four students were still wrong, even though the answer options chosen during the pretest and posttest were different. Based on the interviews with these four students, in general, there must be some who do not follow one of the stages of learning. The identified themes related to PBL elements are small group learning [52], solution to problem [53], active learning [54], see the problem in context [55, 56], tutoring [57], writing a reflection [64], and using technology [58]. One student did not participate in the discussion during the small-group learning stage. One student did not participate in the discussion during the problem-solving stage. One student did not participate in the discussion while seeing the problem in context. One student did not participate in the discussion during the reflection-writing stage. PBL is cyclical learning; therefore, each step must be followed. Not following one of the PBL stages has an impact on different interpretations of real symptoms. Every discussion is always accompanied by oral scaffolding to guide students in achieving their goals. If you do not participate in one of the discussion stages, the PBL cycle will be interrupted, and students will have difficulty solving complex problems [19].

There was one student who answered correctly for the correct reason when the posttest answered incorrectly (D). After the interview, it turned out that during the pretest, the student cheated on his friend, and during the lesson, he did not participate in two discussions, namely, writing reflection and seeing the problem in context.

The percentages of the three learning models in changing students' naive theories and the percentage of naive theories

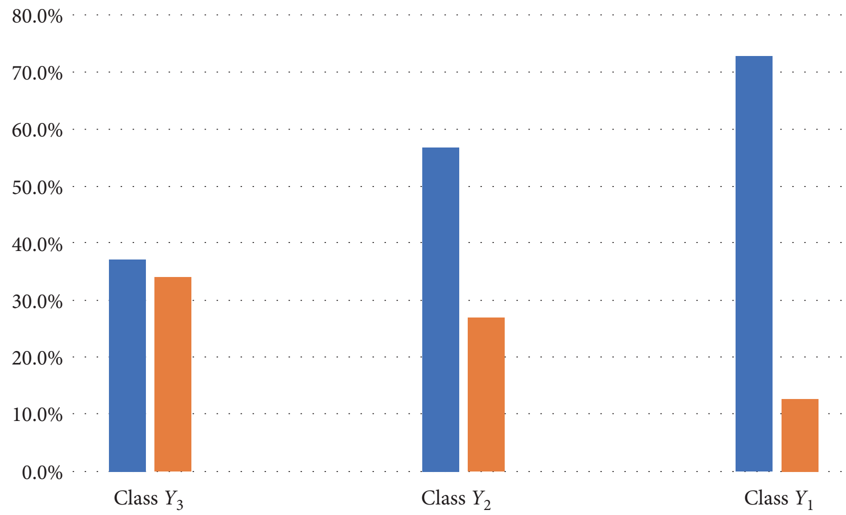

Figure 1: Percentage of degradation of Newton's first law of naive theory by application of three PBL models and percentage of Newton's first law naive theory still surviving in students' brain construction after three PBL models are applied.

Table 9: Distribution of pretest–posttest answer options for question number 26 class Y_3.

			Posttest							
			A 9.3%	B 7.4%	C 14.8%	D 14.8%	E* 51.9%	X 1.9%	E** 0.0%	Total
Pretest	A	24.1%	5			1	7			13
	B	14.8%		4			4			8
	C	20.4%			8		3			11
	D	9.3%				5				5
	E*	20.4%					11			11
	X	5.6%				2		1		3
	E**	5.6%					3			3
Total			5	4	8	8	28	1	0	54

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

that still persist in constructing students' brains after applying the three learning models in each classroom are presented in Figure 1.

Based on Figure 1, there is an increase in the percentage of naive theory degradation and a decrease in the percentage of naive theory that still persists in the brain construction of Newton's first law students by the application of three PBL models in grades Y_3 to Y_2 and Y_1. Thus, the PBL model with open problems accompanied by scaffolding (Y_1) is the most effective PBL model in degrading the naive theory of Newton's first law and the smallest number of students who still hold on to naive theory [19].

3.1.2. Elimination of Conceptual Errors Related to Conceptual Errors in Newton's Second Law. Further analysis related to the degradation of students' misconceptions toward understanding Newton's second law, a process of testing the effectiveness of the student's pretest–posttest answer options for all learning methods was carried out with the case example "If the woman in the previous question doubled the constant horizontal force she exerted on the box to push it on the floor. Same horizontal line, the box then moves." Previous question "A woman exerts a constant horizontal force on a large box. As a result, the box moves across the horizontal floor at a constant speed 'v_o'." The distribution of answer options is presented in Table 9.

Based on Table 9, it appears that students are very difficult to jack up their understanding of the error that "for a while with a constant speed and greater than the speed of 'v_o' in the previous question, after that the speed continues to increase." Likewise, the misconception of "at a constant speed that doubles the speed of 'v_o' in the previous question." And "for a while at an ever-increasing speed, after that at a constant speed." It is very difficult for students to push up their misconceptions that an object that is given more force will produce a constant velocity that is higher. There are still 26 students (48.2%) who did not understand that when an object was subjected to a greater force, the acceleration was greater while the velocity continued to increase. Because the object's acceleration increases, it is "at a continuously increasing speed." There were 14 students who answered correctly during the pretest, with three students who did not have the right

Table 10: Distribution of pretest–posttest answer options for question number 26 class Y_2.

			Posttest							
			A 1.7%	B 16.7%	C 10.0%	D 18.3%	E* 53.3%	X 0.0%	E** 0.0%	Total
	A	6.7%		1			3			4
	B	15.0%	1	2	4		2			9
	C	36.7%		6	1	7	8			22
Pretest	D	15.0%			1	3	5			9
	E*	18.3%				1	10			11
	X	1.7%					1			1
	E**	6.7%		1			3			4
Total			1	10	6	11	32	0	0	60

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

Table 11: Distribution of pretest–posttest answer options for question number 26 class Y_1.

			Posttest							
			A 5.0%	B 13.8%	C 11.3%	D 1.3%	E* 68.8%	X 0.0%	E** 0.0%	Total
	A	20.0%		6			10			16
	B	18.8%	3		2		10			15
	C	22.5%		2		1	15			18
Pretest	D	23.8%		3	7		9			19
	E*	11.3%					9			9
	X	1.3%	1							1
	E**	2.5%					2			2
Total			4	11	9	1	55	0	0	80

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

reason, and only 28 people answered correctly during the posttest (51.9%). There were 34 students who defended their original opinions, although 11 students defended the correct concept. The PBL model with closed problems accompanied by scaffolding was not only able to change the wrong understanding of 17 students (31.5%) but also able to change the understanding of 17 students even though it still led to wrong understanding, and no student changed the correct understanding into wrong understanding. Thus, 26 (48.2%) students still experienced naive theories.

There is a question "If the woman in the previous question doubled the constant horizontal force she exerted on the box to push it on the same horizontal floor, the box then moves." Previous question "A woman exerts a constant horizontal force on a large box. As a result, the box moves across the horizontal floor at a constant speed 'v_o'." Based on Table 10, it appears that students still find it difficult to jack up their understanding that "with a constant speed greater than the speed 'v_o' in the previous question, but not necessarily twice as large." Likewise, the wrong understanding of "for a while at an ever-increasing speed, after that at a constant speed." It is very difficult for students to push up their misconceptions that an object that is given more force will produce a constant velocity that is higher. There were 28 students (46.7%) who did not understand that when an object was subjected to a greater force, the acceleration was greater while the velocity increased. Because the acceleration of the object changes to a large, then "with a speed that continues to increase continuously." Fourteen students answered correctly during the pretest, with three students who did not have the right reason, and only 32 students answered correctly during the posttest (53.3%). Sixteen students defended their original opinions, although 10 students defended the correct concept. The PBL model with open problems without scaffolding was not only able to change the wrong understanding of 22 students (36.7%) but also change the understanding of 19 students even though it still led to wrong understanding, and changed one student's correct understanding to wrong understanding. Thus, 28 (46.7%) students still experienced naive theories.

There is a question "If the woman in the previous question doubled the constant horizontal force she exerted on the box to push it on the same horizontal floor, the box then moves." Previous question "A woman exerts a constant horizontal force on a large box. As a result, the box moves across the horizontal floor at a constant speed 'v_o'." Based on Table 11, it appears that students have changed their understanding, but the direction of change is still toward wrong understanding, namely, "with a constant speed that is greater than the speed of 'v_o' in the previous question, but not necessarily twice as large." Likewise, toward a wrong understanding, namely, "for a while with a constant speed and greater than the speed of 'v_o' in the previous question, after that the speed continues to increase." There are still students who find it difficult to jack up their misconceptions that

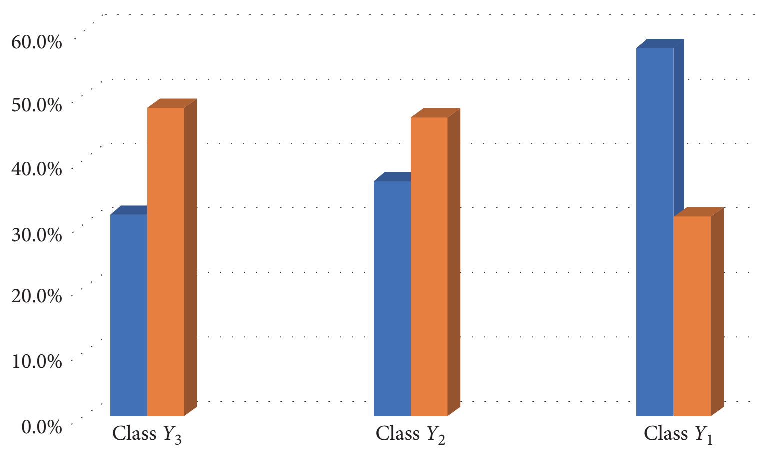

Figure 2: Percentage of degradation of Newton's second law of naive theory by application of three PBL models and percentage of Newton's second law naive theory still surviving in students' brain construction after three PBL models are applied.

Table 12: Distribution of pretest–posttest answer options for question number 28 class Y_3.

			Posttest							
			A 18.5%	B 18.5%	C 5.6%	D 5.6%	E* 51.9%	X 0.0%	E** 0.0%	Total
Pretest	A	29.6%	10				6			16
	B	24.1%		10			3			13
	C	9.3%			3		2			5
	D	9.3%				3	2			5
	E*	22.2%					12			12
	X	0.0%								0
	E**	5.6%					3			3
Total			10	10	3	3	28	0	0	54

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

objects that are given more force will produce a more constant velocity. There are still 25 students (31.3%) who did not understand that when an object was subjected to a greater force, the acceleration was greater while the velocity continued to increase. Because the acceleration of the object changes to a large, then "with a speed that continues to increase continuously." Eleven students answered correctly during the pretest, with two students who did not have the right reason, and 55 people (68.8%) answered correctly during the posttest. Nine students defended their original opinions, and all defended the correct concept. The PBL model with open problems accompanied by scaffolding was not only able to change the wrong understanding of 46 students (57.5%) but also change the understanding of 16 students even though it still led to wrong understanding, and no student changed the correct understanding into wrong understanding. Thus, 25 (31.3%) students still experienced naive theories.

The percentages of the three learning models in changing students' naive theories and the percentage of naive theories that still persist in constructing students' brains after applying the three learning models in each classroom are presented in Figure 2.

Based on Figure 2, there is an increase in the percentage of naive theory degradation and a decrease in the percentage of naive theory that still persists in the brain construction of Newton's second law students by the application of the three PBL models in grades Y_3 to Y_2 and Y_1. Thus, the PBL model with open problems and scaffolding (Y_1) is the best PBL model for degrading the naive theory of Newton's second law and the smallest number of students who still hold on to the naive theory [19].

3.1.3. Elimination of Conceptual Errors Related to Conceptual Errors in Newton's Third Law. There is a question "In the picture on the right, student 'a' has a mass of 95 kg and student 'b' has a mass of 77 kg. They sat in identical office chairs, facing each other. Student 'a' places his bare feet on student 'b's' knees, as shown. Student 'a' then suddenly pushed out with his feet, causing both chairs to move." Based on Table 12, it appears that students find it very difficult to jack up their understanding; the error is that "no student uses one style against another." Likewise, the wrong understanding of "student 'a' gives force to student 'b,' but 'b' does not give any force to 'a'." It is very difficult for students to understand that taking the initiative and having a large mass will

Table 13: Distribution of pretest–posttest answer options for question number 28 class Y_2.

			Posttest							
			A	B	C	D	E*	X	E**	Total
			3.3%	13.3%	13.3%	13.3%	56.7%	0.0%	0.0%	
Pretest	A	18.3%		5	1		5			11
	B	15.0%				1	8			9
	C	26.7%	1	2	1	4	8			16
	D	10.0%	1	1	3		1			6
	E*	16.7%			2	2	6			10
	X	10.0%				1	5			6
	E**	3.3%			1		1			2
Total			2	8	8	8	34	0	0	60

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

give them a larger force. There were still 26 students (48.2%) who did not understand that when two objects interact, the interaction force must be equal in magnitude and opposite in direction. When two objects interact, the interaction forces must be equal in magnitude and opposite in direction, so "each student applies the same amount of force to the other student." Fifteen students answered correctly during the pretest, with three students who did not have the right reason, and only 28 people answered correctly during the posttest (51.9%). There were 38 students who defended their original opinions, although 12 students defended the correct concept. The PBL model with closed problems accompanied by scaffolding was not only able to change the wrong understanding of 16 students (29.6%) but also change the understanding of 13 students even though it still led to wrong understanding, and no student changed the correct understanding into wrong understanding. Thus, 26 (45.2%) students still experienced naive theories.

There is a question "In the picture on the right, student 'a' has a mass of 95 kg and student 'b' has a mass of 77 kg. They sat in identical office chairs, facing each other. Student 'a' places his bare feet on student 'b's' knees, as shown. Student 'a' then suddenly pushed out with his feet, causing both chairs to move." Based on Table 13, it appears that there are still students who find it difficult to jack up their understanding, the error is that "every student uses one style against another, but student 'b' gives a bigger style." There were still 26 students (43.3%) who did not understand, and when two objects interacted, the interaction force had to be equal in magnitude and opposite in direction. When two objects interact, the interaction forces must be equal in magnitude and opposite in direction, so "each student uses the same amount of force on the other student." Twelve students answered correctly during the pretest, two students did not have the right reason, and only 34 answered correctly during the posttest (56.7%). Seven students defended their original opinions, although six students defended the correct concept. The PBL model with open problems without scaffolding was not only able to change the wrong understanding of 28 students (46.7%) but also change the understanding of 22 students. Although it still led to incorrect understanding also changed the correct understanding of four students to incorrect understanding. Thus, 26 (43.3%) students still experienced naive theories.

There is a question "In the picture on the right, student 'a' has a mass of 95 kg and student 'b' has a mass of 77 kg. They sat in identical office chairs, facing each other. Student 'a' places his bare feet on student 'b's' knees, as shown. Student 'a' then suddenly pushed out with his feet, causing both chairs to move." Based on Table 13, it appears that there are still students who find it difficult to improve their understanding. The error is that "every student uses one style against another, but student 'b' gives a greater force." And "every student uses one force against the other, but student 'a' gives the greater force." There were still 29 students (36.3%) who did not understand, and when two objects interacted, the interaction force had to be equal in magnitude and opposite in direction. When two objects interact, the interaction forces must be equal in magnitude and opposite in direction, so "each student applies the same amount of force to the other student." Fourteen students answered correctly during the pretest, with three students who did not have the right reason, and 51 answered correctly during the posttest (63.8%). Twelve students defended their original opinions, although 10 students defended the correct concept. The PBL model with open problems accompanied by scaffolding was not only able to change the wrong understanding of 41 students (51.3%) but also change the understanding of 27 students. Although it still led to incorrect understanding, it also changed one student's correct understanding to wrong understanding. Thus, 29 (36.3%) students still experienced naive theories.

The percentages of the three learning models in changing students' naive theories and the percentage of naive theories that still persists in constructing students' brains after applying the three learning models in each classroom are presented in Figure 3.

Based on Figure 3, there is an increase in the percentage of naive theory degradation and a decrease in the percentage of naive theory that still persists in the brain construction of Newton's second law students by the application of the three PBL models in grades Y_3 to Y_2 and Y_1. Thus, the PBL model with open problems accompanied by scaffolding (Y_1) is the best PBL model for degrading the naive theory of Newton's

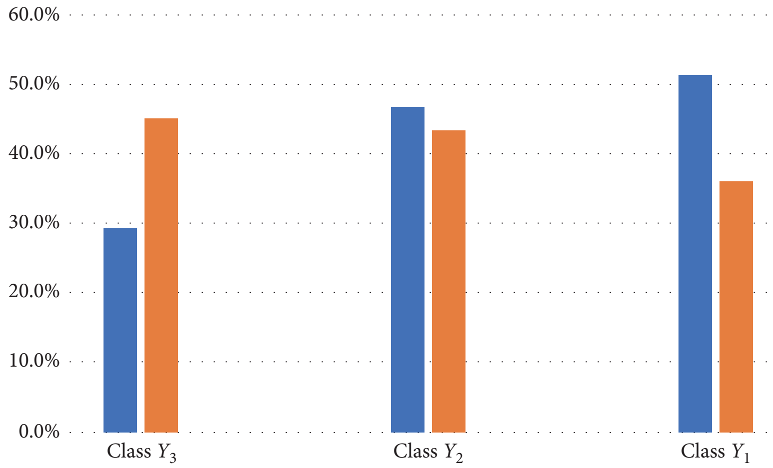

Figure 3: Percentage of degradation of Newton's third law of naive theory by application of three PBL models and percentage of Newton's third law naive theory still surviving in students' brain construction after three PBL models are applied.

Table 14: Distribution of pretest–posttest answer options for question number 28 class Y_1.

			Posttest							
			A 3.8%	B 13.8%	C 10.0%	D 8.8%	E* 63.8%	X 0.0%	E** 0.0%	Total
	A	21.3%		5	2	2	8			17
	B	15.0%	2		4		6			12
	C	20.0%		1	1	2	12			16
Pretest	D	23.8%	1	3	1	1	13			19
	E*	13.8%				1	10			11
	X	2.5%		2						2
	E**	3.8%				1	2			3
Total			3	11	8	7	51	0	0	80

*Correct answer. X students do not answer. **Students choose the correct option but without the right reason. A, B, C, D, and E is the choice.

third law and the smallest number of students who still hold on to naive theory [19].

3.2. Discussion

3.2.1. Meta-Analysis of Quantitative Data with Qualitative. Tables 4, 9, and 12 show the distribution of pre- and post-test answer options from class Y_3, taught using the PBL model with closed problems accompanied by scaffolding. The interesting aspect that can be seen from the impact of this learning is the persistence of students' understanding of concepts before and after learning. Is it a false conception or a correct conception? This is because the problems used in PBL are closed [76, 77]. The nature of closed problems is that there is only one correct answer [48, 78]. Problems arise in textbooks that have one correct answer. This causes students to memorize how to solve these problems. Although computer-based scaffolding, a mixture of procedural scaffolding and conceptual scaffolding, has been provided, the effect is not significant in changing students' understanding of concepts. Scaffolding will have a big impact if problems that provoke higher thinking skills are presented [79, 80]. If the problems presented do not require high-thinking skills, then the existence of scaffolding is not optimal because without scaffolding, they are conditioned to memorize the old way of solving problems. This is also supported by qualitative data in the form of their reasons when answering the pretest and posttest questions, as well as the results of the interviews. During the pretest, the students provided the same rationale/reason as during the posttest. Based on the interviews before learning, the students also provided the same rationale as after learning.

Slightly different conditions occurred in class Y_2, related to changes in students' concept understanding. The characteristics listed in Tables 6, 10, and 13 show the same attenuation of answers at the pretest and posttest. The characteristic that is informed by the data from the table is that the same answers were depleted during the pretest and posttest. The answer from the relative pretest was not the same as that in the posttest. This is because the problems in learning are already open. The hallmark of an open problem is that it has no single correct answer. For example, related to Newton's first law, given the problem "If we want to make a stationary car move continuously in a straight line at a constant speed, we have to push it or pull it constantly. If the car is already moving, then we stop pushing or pulling, the car slows down, and one day, the car stops

Table 15: Findings of PBL stages with open problems with scaffolding.

Stage	Description of activities
Identification of problems	The teacher gives an open problem which is the result of class observations. The results of class observations can be obtained from the problems in the article. Students write down observations, analyze phenomena, formulate problems, and hypotheses. Students work in small groups of up to four people and make videos. During the discussion process, the teacher provides oral scaffolding. Students open the moodle which has been accompanied by written scaffolding in procedural and conceptual form.
Hypothesis proving	Students determine variables, design experiments, conduct experiments, and discuss results. When conducting experiments, the teacher provides procedural scaffolds and provides conceptual scaffolds in the form of expert to novice scaffolds, and makes a video of the process of proving this hypothesis.
Presentation of results	Students present the results ranging from observing phenomena and suggesting hypotheses to experiments. Presentations are made in each group by taking turns with their friends. During one presentation, others must ask at least one question. Students make a video of the presentation of the results.
Deepen material	Students deepen their understanding of the material that has been studied by working on questions from the questions in the article.

again. In reality, an object will not move in a straight line at a constant speed if no continuous force acts on the object. This statement was incorrect. Using experiments, prove that the statement is false and analyze why it happens in everyday life." Students can be creative in solving problems [19, 81]. What happens is that there are students who solve problems through experiments with reference to $F = 0$, thus proving the truth that if the car is pushed, then there is a frictional force equal to the thrust such that $F = 0$ and the car moves in a straight line. There are also those who solve the problem using a direct experiment where the frictional force is zero; thus, when an object is pushed, the acceleration remains constant but the speed continues to increase continuously. When the thrust is released, the acceleration is zero and the object moves at a constant speed. Because it also triggers different thinking, students tend to use new thinking patterns [18, 82]. However, because it is not accompanied by scaffolding, students' thinking patterns tend to be undirected, so there are still many students whose answers are different from the pretest, but are still wrong [83]. Open problems in PBL tend to free students to be creative in solving problems [19]. If it is not accompanied by scaffolding, then the creation becomes wild [84], and many lead students to new naive conceptions.

In line with the condition of class Y_2, the characteristics of changes in the understanding of concepts in class Y_1, as shown in Tables 7, 11, and 14, indicate that there is a degradation of the same answers when students answer the pretest and posttest questions. The answer from the relative pretest was not the same as that in the posttest. This is because the problems in learning are already open. The hallmark of an open problem is that it has no single correct answer. As it also triggers different thoughts, students tend to use new patterns of thinking when working on posttest questions. The use of scaffolding causes students' mindsets to tend to be focused [85, 86], so there are not many students whose answers are different from the pretest, but are still wrong. Open problems in PBL tend to free students to be creative in problem solving. Accompanied by scaffolding, the creation is not wild, so only a few lead students to new naive conceptions.

Based on the pre- and post-test scores of each student, each student was obtained. The average N_{gain} class was obtained by evening out of N_{gain} students in each class. Based on the N_{gain} data, the average N_{gains} for classes Y_3, class Y_2 is 0.50, and Y_1 are 0.30, 0.50, and 0.65, respectively. These data prove that the PBL model using open problems with scaffolding is the most effective in eradicating naive theory.

3.2.2. New Findings Related to Learning Model for Naive Theory Degradation Newton's Laws. Based on Table 15, the first stage of PBL, namely, "Identification of Problems," must use open problems, and during discussions, it is necessary to provide written scaffolding in procedural and conceptual form to the student worksheet, and during discussions, oral scaffolding is given. In the second stage, "Proofing Hypotheses" when conducting experiments, procedural scaffolds, and conceptual scaffolds are given in the form of an expert to a novice scaffold.

The crucial findings of this research are related to the problem base, application of scaffolding, and discussion patterns. The basis of the PBL problem in this research is an open problem, whereas other studies are closed [21–25] and mixed problems, but according to the curriculum [87–92]. Open problems allow students to use different ways of solving but produce the same correct solution. Open problems are characterized by unstructured problems. Closed problems are characterized by structured problems. Scaffolding in this study is procedural and conceptual scaffolding contained in student worksheets, whereas other researchers apply scaffolding incidentally [47, 87, 89–94]. As discussed in this paper, each answer option is based on students' epistemic games while other studies are based on data reported in the previous works [47, 87–90, 92, 94–98].

The main finding in this study is students' alleviated naive theory through PBL accompanied by open problems or students' daily problems and supported by scaffolding. As the implication, physics education should do PBL. The problems presented are problems experienced by students in daily life, which are the foundation of students in defending their naive theory. Because, meaningful learning is learning that is closely related to the daily events of students. Teachers must know the relevance of the material to be studied with students' daily problems that are relevant to the material. These problems must be experienced by students in everyday life. Thus, teachers must be very familiar with the daily life of their students. Teachers must design PBL by using problems experienced by students in everyday life. For example, when teaching Newton's third law, the teacher must present a problem related to the impact of students pushing their friends. To strengthen this learning, scaffolding is needed as an effort to ease the complexities that arise in the PBL. Scaffolding must be packaged procedurally and conceptually so as to return the concept of Newton's laws to students to their central idea. Procedural and conceptual scaffolding is effective and efficient when computer-assisted. Thus, the learning scenarios created by the teacher must be computer-assisted.

4. Conclusion

The most effective PBL model for eradicating naive theories related to Newton's laws is PBL, which uses open problems accompanied by scaffolding. In its application, it is recommended that teachers complete this lesson with Moodle's knowledge. With open problems, students were invited to think about solving everyday problems with the right mindset. This activity guarantees that students use the concepts of scientists to solve their daily problems. Scaffolding stimulates procedural and conceptual abilities for every time-solving problem. Thus, open problems and scaffolding in PBL will ensure that students always use the correct theory to solve their daily problems. Future learning based on Science, Technology, Engineeing, and Mathematics will be effortless using PBL with open problems accompanied by scaffolding.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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